Thursday Minisymposium

Organisers: Grieneisen & Spill

Erwin Frey

Ludwig-Maximilians University Munich
"Self-organization principles of intracellular pattern formation"
Dynamic patterning of specific proteins is essential for the spatiotemporal regulation of many important intracellular processes in procaryotes, eucaryotes, and multicellular organisms. The emergence of patterns generated by interactions of diffusing proteins is a paradigmatic example for self-organization. We will discuss quantitative models for intracellular Min protein patterns in E. coli, Cdc42 polarization in S. cerevisiae, and the bipolar PAR protein patterns found in C. elegans. By analyzing the molecular processes driving these systems we will show how to derive a theoretical perspective on general principles underlying self-organized pattern formation of proteins in cells.

Veronica Grieneisen

Cardiff University
"Self-organization through the mesoscale, lessons from plant patterning and adaptive responses"
This core ability of a cell to polarize in isolation from others then leads to the collective emergence of tissue polarity, which will be dependent on the mode of cell-cell interaction. In plants, such tissue polarity will allow for information flow over large distances, be it to guide development or to interface the environment, such as in plant-nutrient uptake. We will show how for such organism-level coordination of signals, sub-cellular components turn out to be extremely important. Also, we will discuss temporal-spatial dynamical constraints operating on such polarized tissues which are likely to have a evolutionary-developmental role in the systems we encounter in nature.

Stan Maree

Cardiff University
"Intracellular patterning coupled to cell shape can lead to sensitization of signal detection"
A lot of animal and plant cell polarity can be understood by simple biochemical processes. Exploring their dynamics shows that simple circuits are able to generate a plethora of diverse cellular patterns. Firstly, I will discuss how we can explore the potential for break-of-symmetry within cells. I will then explore, how through modelling we can better understand the feedbacks between these patterns and biophysical triggers that cause cell shape changes. Finally, I will show how polarity formation can also be used as an integrator for sensing external cues, and discuss how alterations of this could cause tissue-level disruption. To extend these insights directly to experimental data, I will then show how our modelling framework can also be used for segmentation of imaging data, showing examples that range from complex epithelia to organoids.

Padmini Rangamani

University of California at San Diego
"Stability analysis of a bulk-surface model for membrane-protein clustering"
Protein aggregation on the plasma membrane (PM) is of critical importance on many cellular processes such as cell adhesion, endocytosis, fibrillar conformation, and vesicle transport. Lateral diffusion of protein aggregates or clusters on the surface of the PM plays an important role in governing their heterogeneous surface distribution. However, the stability behavior of the surface distribution of protein aggregates remains poorly understood. Therefore, understanding the spatial patterns that can emerge on the PM uniquely through protein-protein interaction and diffusion is an important step towards a more complete description of the mechanisms behind protein clustering on the cell surface. In this work, we investigate the pattern formation of a reaction-diffusion model that describes the dynamics of a system of ligand-receptor complexes. The purely diffusive ligand in the cytosol can bind receptors in the PM and the resultant ligand-receptor complexes not only diffuse laterally but can also form clusters resulting in different oligomers. From a methodological viewpoint, we provide theoretical estimates for diffusion-driven instabilities of the protein aggregates based on the Turing mechanism. We also obtain the distribution of the size of the protein aggregates and their spatial locations depending on both initial conditions and kinetic parameters using computational methods. Our results suggest that spatial heterogeneity emerges only when the cluster diffusion rates decay as a function of cluster size.