BP 29: PhD Focus session: Theory of stochastic processes with applications in biology (joint session SOE/BP/DY/AKjDPG)

Session initiated and organized by Rosalba Garcia Millan, Johannes Pausch and Ignacio Bordeu Weldt (Imperial College, UK), in cooperation with divisions DY, BP, SOE and the jDPG.

Time: Thursday 15:00–18:45 Location: H17

Invited Talk BP 29.1 Thu 15:00 H17

Ecosystem stability and altruistic advantage — •Nick Jones — Imperial College Mathematics, London, UK

In this talk I consider why many, empirically observed, directed networks might contain a lack of feedback loops. An answer might be network growth mechanisms that favour clear trophic levels and which generate assymetries between the in degrees and out degrees of nodes. This is a partial answer to May's (Complexity-Stability) Paradox. Finally I will outline an, ageing relevant, concrete biological example of spatial demographic stochasticity where altruists can dominate a system even when actively selected against.

BP 29.2 Thu 15:45 H17

Thermodynamics of steady-state switching — •Jacob Cook[1,2] and Robert G. Endres[1,2] — [1]Department of Life Sciences, Imperial College, London, UK — [2]Centre for Integrative Systems Biology and Bioinformatics, Imperial College, London, UK

Entropy production is a hallmark of nonequilibrium processes in stochastic thermodynamics. Multistable nonequilibrium systems are abundant outcomes of nonlinear dynamics with feedback yet relatively little is known about what determines the stability of the steady states and their switching rates in terms of entropy and entropy production. Here, we will link the fluctuation theorem for the entropy production along trajectories and the large-deviation approach of minimum-action-path theory to elucidate the thermodynamics of steady-state switching. Interestingly, we find that the entropy production at steady state plays no explicit role, but the entropy production along switching trajectories is key. Alternative stabilising and destabilising mechanisms such as steady-state entropy and diffusive noise are also investigated.

BP 29.3 Thu 16:00 H17

Dynamical phase transition in assemblies of chemotactic cells — •Charlie Duclut — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

We consider a large number of chemotactic cells that diffuse, die, divide and interact at long range via the release of chemicals. We investigate the dynamics at long time and focus on the phase transition that occurs between a dilute and a dense phase using a renormalization group analysis. If we consider only interactions that conserve the particles number, exact scaling exponents can even be obtained; this analysis predicts in particular a superdiffusive behaviour of the cells close to the phase transition.

Invited Talk BP 29.4 Thu 16:15 H17

Topological Hindrance and Jamming Transitions in Multi-Species Transport — •Erwin Frey — Arnold-Sommerfeld-Center for Theoretical Physics, Ludwig-Maximilians-Universität München, München, Germany

Motivated by recent experimental studies that have addressed the stepping behavior of kinesins, we investigate a lattice gas model for simultaneous transport of two species of active particles on a microtubule. The species are distinguished by their different gaits: While the first species moves straight ahead, the second follows a helical path. We show that the collective properties of such systems critically differ from those of one-species transport as described by generalised totally asymmetric exclusion processes. This is most evident in a jamming transition far below full occupation, as well as in nonequilibrium pattern formation. The altered behavior arises because - unlike the case in single-species transport - any given position may be targeted by two particles from different directions at the same time. However, a particle can leave a given position only in one direction. This simple change in connectivity significantly amplifies the impact of steric interactions and thus becomes a key determinant of mixed species transport. We computationally characterize this type of hindrance and develop a comprehensive stochastic theory for collective two-species transport along a cylinder. Our observations show high robustness against model extensions that account for additional biomolecular features which suggests relevance also in a biological context.

15 min. break

Invited Talk BP 29.5 Thu 17:00 H17

Seeing and believing at super-resolution — •Susan Cox — Randall Centre for Cell and Molecular Biophysics, King's College London

Super-resolution microscopy is a powerful tool for imaging structures at a lengthscale of tens of nm, but its utility for live cell imaging is limited by the time it takes to acquire the data needed for an image. For localisation microscopy the acquisition time can be cut by more than two orders of magnitude by using advanced algorithms which can analyse dense data, trading off acquisition and processing time. Information can be traded for resolution: for example, the whole dataset can by modelled as arising from blinking and bleaching fluorophores (Bayesian analysis of Blinking and Bleaching), although at a high computational cost. However, all these approaches will come with a risk of artefacts, which can mean that the image does not resemble the underlying sample. We have recently developed Harr Wavelet Kernel Analysis, a multi-timescale prefiltering technique which enables high density imaging without artefacts. The results of benchmarking with other techniques reveal that at high activation densities many analysis approaches may achieve high apparent precision (very sharp images), but poor accuracy (the images don't look like the sample). I will discuss the relationship between precision, accuracy and information content in super-resolution microscopy images.

BP 29.6 Thu 17:45 H17

Filament flexibility enhances power transduction of F-actin bundles — •Alessia Perilli[1], Carlo Pierleoni[2], Giovanni Ciccotti[1], and Jena-Paul Ryckaert[3] — [1]Dept. of Physics, Sapienza University of Rome, Italy — [2]Dept. of Physical and Chemical Sciences, University of L'Aquila, Italy — [3]Dept. of Physics, Free University of Brussels, Belgium

In different biophysical cellular processes, semiflexible biofilaments like Factin and F-tubulin are known to exploit chemical free energy, associated to their growth by polymerization, to perform mechanical work against an external load. In vitro experiments have recently been set up to measure the force-velocity relationship of an actin bundle or to equilibrate the bundle polymerizing force by an optical trap restoring force. Theoretical interpretation is usually based on multi filament brownian ratchet models assuming perfectly rigid filaments (Mogilner-Oster). In this talk, we will exploit statistical mechanics tools and a coarse grained stochastic dynamic approach based on the discrete Wormlike Chain (WLC) model, to study the influence of filament flexibility on the non-equilibrium velocity-load relationship for a bundle of parallel un-crosslinked actin filaments pressing against a mobile wall. Using a realistic value of the actin persistence length, we show that flexibility enhances the power developed by the polymerizing force against the load in a way which increases with the length of the bundle, as long as the pushing filaments remain in the nonescaping regime.

Topical Talk BP 29.7 Thu 18:00 H17

Reconstructing the topographic landscape of epithelial-mesenchymal plasticity — •Francesc Font-Clos, Stefano Zapperi, and Caterina A. M. La Porta — Center for Complexity and Biosystems, University of Milan, Italy

We construct a topographic map underlying epithelial-mesenchymal plasticity by combining numerical simulations, statistical physics methods and analysis of bulk and single-cell gene expression data. The map reveals a multitude of metastable hybrid phenotypic states, separating stable epithelial and mesenchymal states, and is reminiscent of the free energy measured in glassy materials and disordered solids.

Topography of epithelial-mesenchymal plasticity, Francesc Font-Clos, Stefano Zapperi, Caterina A. M. La Porta, Proceedings of the National Academy of Sciences Jun 2018, 115 (23) 5902-5907; DOI:

10.1073/pnas.1722609115

BP 29.8 Thu 18:30 H17

Beating cancer 'escape room': let's use mathematical modelling to unlock cells! — •Núria Folguera-Blasco — The Francis Crick Institute, London, UK

The inherent capacity of differentiated cells to switch their phenotype in vivo in response to damage stimuli might have a pivotal role in ageing and cancer. However, how the mechanisms of phenotype reprogramming are established remains poorly understood. In order to elucidate such mechanisms, we present a stochastic model of combined epigenetic regulation (ER)-gene regulatory network (GRN) to study the plastic phenotypic behaviours driven by ER heterogeneity. Our analysis of the coupled system reveals the existence of pluripotent stem-like and differentiated steady-states. Crucially, ER heterogeneity is responsible for conferring abnormal robustness to pluripotent stem-like states, which cause the locking of the cells in a stem cell-like state prone to cancer development. By analysing the ER heterogeneity, we formulate epigenetic heterogeneity-based strategies capable of unlocking and facilitating the transit from differentiation-refractory (pluripotent stem-like) to differentiation-primed epistates. Our results suggest that epigenetic heterogeneity regulates the mechanisms and kinetics of phenotypic robustness of cell fate reprogramming. The occurrence of tunable switches capable of modifying the nature of cell fate reprogramming from pathological to physiological might pave the way for new therapeutic strategies to regulate reparative reprogramming in ageing and cancer.