# DY 63: Statistical Physics of Biological Systems II (joint session BP/DY)

Time: Thursday 15:00–17:15 Location: H 2013

DY 63.1 Thu 15:00 H 2013

**Do Predator attacks tune a collective of interacting agents to criticality and why?** — •Pascal Klamser[1,2] and Pawel Romanczuk[1,2] — [1]Institute for Theoretical Biology, Department of Biology, Humboldt-Universität zu Berlin — [2]Bernstein Center for Computational Neuroscience, Humboldt-Universität zu Berlin

Based on theoretical considerations it is hypothesized that biological systems self-tune to criticality [1]. Motivated by this, we investigate the collective behavior of self-propelled agents at the phase transition from an ordered (parallel moving agents = *school*) to a disordered movement (*swarm*) and their reaction to a predator. Systematic numerical simulations show that at the phase transition the performance of the predator decreases. However, this decrease is not only caused by a better response of individuals to the predator, but also by complex spatial structures of the collective at the transition. This finding emphasizes the need of explicitly considering spatial models to describe biological systems, e.g. fish swarms. Beside different interaction-networks (voronoi, k-nearest neighbor, visual-field) an evolutionary algorithm was used to check for the relevance of the results.

[1] Mora, T. and Bialek, W. J Stat Phys (2011) 144: 268.

DY 63.2 Thu 15:15 H 2013

**Intermittent collective behavior in small groups of gregarious animals** — •Luis A. Gómez[1], Richard Bon[2], and Fernando Peruani[1] — [1]Laboratoire J. A. Dieudonné, Université Côte d'Azur, Nice, France — [2]Centre de Recherches sur la Cognition Animale, Université Paul Sabatier, Toulouse, France

Collective behavior of small groups of gregarious animals is our subject of interest. Experiments with small groups of merino sheep showed interesting features like periodicity of moving and resting phases, synchronization of these phases at the individual level, collective stick–slip dynamics and cohesivity of the group around the center of mass. We show some experimental evidence obtained from the tracking of individual sheep that suggests that the no motion phase of the individuals is qualitatively different to the motion phase. In particular, we discover that a refractory period can be associated to the no motion phase. We propose the introduction of a 3-state model in order to describe the experimental observations for several group sizes (2, 3, 4 and 8 individuals) and study the temporal evolution. Although the model is proposed at the individual level, repercussions at the collective level emerge.

DY 63.3 Thu 15:30 H 2013

**How a well-adapting immune system remembers** — •Andreas Mayer[1], Vijay Balasubramanian[2], Thierry Mora[3], and Aleksandra Walczak[3] — [1]Princeton University, Princeton, USA — [2]University of Pennsylvania, Philadelphia, USA — [3]Ecole normale superieure, Paris, France

The adaptive immune system uses its past experience of pathogens to prepare for future infections. How much can the adaptive immune system learn about the statistics of changing pathogenic environments given its sampling of the antigenic universe? And how should it best adapt its repertoire of lymphocyte receptor specificities based on its experience? Here, to answer these questions we propose a view of adaptive immunity as a dynamic Bayesian machinery that predicts optimal repertoires based on past pathogen encounters and knowledge about typical pathogen dynamics. Two key experimentally observed characteristics of adaptive immunity emerge naturally from this model: (1) a negative correlation between fold change of protection upon a challenge and preexisting immune levels and (2) differential regulation of memory and naive cells. We argue that to explain the benefits of immune memory, antigenic environments need to be highly sparse. We derive experimentally testable predictions about the diversity of the memory repertoire over time in such sparse antigenic environments. The Bayesian perspective on immunological memory provides a unifying conceptual framework for a number of features of adaptive immunity and suggests further experiments.

DY 63.4 Thu 15:45 H 2013

**Asymmetric Link detection via a generalized ESABO approach** — •Jens Christian Claussen — Computational Systems Biology, Jacobs University Bremen, Germany

Mutualisms in biological populations are widespread from bacteria to mammals. Mutualistic interactions can be positive (synergistic) or negative. Often even in microbial data the number of available samples is marginally sufficient to allow for detection of interactions, especially for the low-abundance species that may carry important information in clinical context. The recently introduced ESABO method (PloS Comp Biol 13: e1005361 (2017)) utilizes an information-theoretic approach to evaluate binarized abundances and was demonstrated to detect interaction links that were not apparent in the classical correlation analyses. ESABO provides high (resp. low) scores if joint occurence is higher (resp. lower that in surrogate data. As so far, ESABO concludes on negative interactions when co-occurrence is lower than expected. However, this can be due to asymmetric (unidirectional parasitic) interaction in any of two directions, or due to symmetric interactions. Here we generalize the ESABO method to analyze co-abundance data resolving for asymmetry between the interactions.

DY 63.5 Thu 16:00 H 2013

**Modelling the Emergence of Robustness and Evolvability in Genotype-Phenotype Maps** — •Marcel Weiss[1,2] and Sebastian E. Ahnert[1,2] — [1]Theory of Condensed Matter Group, Cavendish Laboratory, University of Cambridge, UK — [2]Sainsbury Laboratory, University of Cambridge, UK

Genotype-Phenotype (GP) maps play an important role in evolution and their properties fundamentally affect the outcome of evolutionary processes. A striking property found in several GP maps, such as that of RNA secondary structure, is the positive correlation between the robustness and evolvability of phenotypes, meaning that a phenotype can be strongly robust against mutations and at the same time evolvable to a diverse range of alternative phenotypes. By introducing two analytically tractable GP map models that follow the principles of real biological GP maps, we study the characteristics that cause this positive correlation between phenotype robustness and evolvability. We find that it only emerges if mutations can have non-local effects on sequence constraints, highlighting that these effects are likely to be an important feature of many biological GP maps.

**Invited Talk** DY 63.6 Thu 16:15 H 2013

**Out-of-equilibrium response of soft and biological matter to forces and deformation** — •Claus Heussinger — Institut für theoretische Physik, Universität Göttingen

In the talk I will give a few examples from our research concerning the complex dynamical response of soft and biological materials to perturbations via forces or deformation. The systems we study are, in general, far from thermal equilibrium. Phenomena will range from the emergence of flow instabilities (shear-banding, rheo-chaos) in complex fluids, over the visco-elasto-plastic behavior of biological cells and their sub-cellular components, to the fluid-to-solid jamming transition in a-thermal granular particles. The goal is to define suitable model systems where the relevant physical mechanisms can be identified and understood. To this end we use different simulation tools going hand in hand with analytical modeling and, whenever possible, experimental verification.

DY 63.7 Thu 16:45 H 2013

**Mechanical tuning of synaptic patterns enhances immune discrimination** — •Milos Knezevic[1,2] and Shenshen Wang[1] — [1]Department of Physics and Astronomy, University of California Los Angeles, Los Angeles, CA 90095, USA — [2]Institut fur Theoretische Physik, Technische Universitat Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

An immunological synapse is an adhesive intercellular junction that forms between B cells and antigen-presenting cells (APCs) during recognition. This dynamic surface contact is patterned with complementary receptors and ligands on the apposing membranes, thus specifically regulating directed information transfer. Via synapses, B cells use mechanical pulling forces to extract antigen (Ag) from APCs for subsequent processing and presentation. Recent experiments show that, depending on the stage in its life cycle, a B cell exhibits distinct synaptic patterns accompanied with different strength and timing of force usage, which appears to lead to varied stringency of affinity discrimination. Using a minimal model of membrane adhesion, we study how the observed synaptic architectures can originate from normal mechanical forces coupled to lateral organization of mobile receptors, and show how this coupling might affect the efficiency and selectivity of Ag acquisition. We conclude that cytoskeletal forces could play an important role in tuning the synaptic patterns, which in turn enlarges the dynamic range of immune recognition with enhanced discrimination.

DY 63.8 Thu 17:00 H 2013

**Specialisation and plasticity in interacting biological populations** — Solenn Patalano[1], •Adolfo Alsina[2], Steffen Rulands[2], and Wolf Reik[1] — [1]Babraham Institute, Cambridge, UK — [2]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

The structure and dynamics of biological systems are tightly regulated on multiple scales, from transcriptional and epigenetic regulation to population level feedback. While many biological systems are surprisingly robust against environmental fluctuations they, simultaneously, exhibit a remarkable plasticity in response to changes in their environment. Using the social wasp Polistes as an example we combine experimental and theoretical methods to study how a primitive society simultaneously achieves phenotypic specialisation and a remarkable degree of plasticity. After perturbing the society by queen removal, we experimentally follow the relaxation dynamics into the social steady state across scales, from social and behavioural measurements to physiological measurements and detailed molecular characterisations of single wasps. We develop a theoretical framework that explains the emergence of the social structure of Polistes as a result of opposing dynamics on the molecular and the population scales. We show that such dynamics provide a general principle of how both specialization and plasticity can be achieved in biological systems. As well as elucidating mechanisms of epigenetic plasticity in wasps and other biological systems this study shows that the multiscale dynamics in primitive social insects provide a laboratory for non-equilibrium physics.