BP 1: Evolutionary and Population Dynamics

Time: Monday 9:30–12:00 Location: H43

Invited Talk BP 1.1 Mon 9:30 H43

Physical Aspects of Evolutionary Transitions to Multicellularity — •Raymond Goldstein — Department of Applied Mathematics and Theoretical Physics, University of Cambridge, UK

An important issue in evolutionary biology is the emergence of multicellular organisms from unicellular individuals. The accompanying differentiation from motile totipotent unicellular organisms to multicellular ones having cells specialized into reproductive (germ) and vegetative (soma) functions, such as motility, implies both costs and benefits, the analysis of which involves the physics of buoyancy, diffusion, and mixing. In this talk, I discuss recent results on this transition in a model lineage: the volvocine green algae. Particle Imaging Velocimetry of fluid flows generated by these organisms show that they exist in the regime of very large Peclet numbers, where the scaling of nutrient uptake rates with organism size is highly nontrivial. In concert with metabolic studies of deflagellated colonies, investigations of phenotypic plasticity under nutrient-deprived conditions, and theoretical studies of transport in the high-Peclet number regime, we find that flagella-generated fluid flows enhance the nutrient uptake rate per cell, and thereby provide a driving force for evolutionary transitions to multicellularity. Thus, there is a link between motility, mixing, and multicellularity.

Invited Talk BP 1.2 Mon 10:00 H43

Surfing genes: On the fate of neutral mutations in spreading populations — •Oskar Hallatschek and David Nelson — Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

Population expansions in space are common events in the demographic history of many species and have a strong impact on their genealogy. As compared to individuals in the wake, the pioneers in the wave front are usually much more successful in passing their genes on to future generations, not only because their reproduction is unhampered by limited resources but also because their offspring start out from a spatial position where they have good chances to keep up with the wave front (often by means of mere diffusion). Those pioneer genes have the chance to "surf" on the wave and the likelihood to do so will be the focus of the presentation. By means of simple experimental systems (E. Coli and Yeast), simulations and analytical considerations, we explore how the footprints of the successfully surfing genes may be used to infer past population expansions.

15 min. break.

BP 1.3 Mon 10:45 H43

A stochastic approach to group selection — •Arne Traulsen — Program for Evolutionary Dynamics, Harvard University, USA

A minimalist stochastic model of multi-level or group selection is discussed. A population is sub-divided into groups. Individuals reproduce; offspring are added to the same group. If a group reaches a certain size, it can split into two. Faster reproducing individuals lead to larger groups which split more often. It can be shown that this population structure acts as a suppressor of selection [1]. In this model, higher level selection emerges as a by-product of individual reproduction and population structure, allowing the evolution of cooperation. In a situation in which individuals interact with other members of the group in an evolutionary game which determines their fitness, one can derive a condition for the evolution of cooperation by group selection: if b/c> 1+ n/m then group selection favors cooperation [2]. The parameters B and c denote the benefit and cost of the altruistic act, while n and m denote the maximum group size and the number of groups. The model can be extended to more than two levels of selection and to include migration.

[1] A. Traulsen, A.M. Sengupta, and M.A. Nowak, J.Theor.Biol. 235, 393 (2005).

[2] A. Traulsen and M.A. Nowak, PNAS 103, 10952 (2006).

BP 1.4 Mon 11:00 H43

Stationary population distribution of quasispecies in fitness landscapes with multiple peaks — •Andrea Wolff and Joachim Krug — Universität zu Köln, Institut für theoretische Physik, Köln, Deutschland

We investigate the long time behaviour of the quasispecies model, as introduced by M. Eigen in 1971, in permutation invariant fitness landscapes. Examples include the multiplicative single peak Fujiyama landscape and a landscape with two peaks of different heights and widths. In the latter case, the competition between the two peaks leads to a first order 'selection transition' at which the population shifts discontinuously from one peak to the other. In contrast to the well-known delocalization transition occuring at the error threshold, the mutation rate at the selection transition does not scale with the sequence length N as $\mu \propto 1/N$. As a consequence, recently developed functional integral methods for estimating the largest eigenvalue of the evolution matrix in the limit $N \to \infty$ cannot be applied. Here we use direct diagonalization techniques to examine the nature of the selection transition and to find the correct scaling behaviour of the mutation rate with the sequence length.

BP 1.5 Mon 11:15 H43

Coexistence versus extinction in cyclic population models — •Tobias Reichenbach, Mauro Mobilia, and Erwin Frey — Arnold Sommerfeld Center for Theoretical Physics (ASC) and Center for NanoScience (CeNS), Department of Physics, Ludwig-Maximilians-Universität München, Theresienstrasse 37, D-80333 München

The maintenance of biodiversity under species coevolution is a central issue in modern theoretical biology. Cyclic dominance of species combined with local interactions of spatially distributed individuals has been identified experimentally as a potential mechanism, see e.g. B. Kerr, M. A. Riley, M. W. Feldman and B. J. M. Bohannan [Nature **418**, 171 (2002)]. We address these questions by studying theoretically a "rock-paper-scissors" model of three species that cyclically dominate each other. In the absence of spatial structure, fluctuations arising in finite populations are shown to have a drastic influence on the fate of the species and cause extinction. Arranging the individuals on a two-dimensional lattice and allowing only local interactions dramatically changes the situation. Spatial patterns form and ensure coexistence of all three species.

BP 1.6 Mon 11:30 H43

The Stability and Structure of Model Food Webs with Adaptive Behavior — •Satoshi Uchida and Barbara Drossel — Institut für Festkörperphysik, Technische Universität Darmstadt, Hochschulstraße 6, D-64289, Darmstadt, Germany

We present results for the stability and structure of model food webs described by population dynamics and adaptive behavioural dynamics (adaptive foraging and predator avoidance). In particular the influence of the initial network topology (randomly connected or niche model), and the type of constraints on the adaptive behavior (linear or nonlinear) are investigated. We evaluated two kinds of stability, namely the proportion of species surviving after running population dynamics, and the species deletion stability, and we measured two types of network parameters - link density and trophic level structure. We show that the initial web structure does not have a large effect on the stability of food webs, but foraging behavior has a large stabilizing effect. It leads to a positive complexity-stability relationship whenever higher "complexity"implies more potential prey per species. The observed link density after population dynamics depends strongly on the presence or absence of adaptive foraging, and on the type of constraints used. We also show that the foraging behavior preserves the initial trophic level structure for random and niche webs, while the population dynamics destroys the initial trophic structure for random webs.

BP 1.7 Mon 11:45 H43

Influence of carrying capacity on stochastic predator-prey models — •Mauro Mobilia[1], Mark Washenberger[2], and Uwe Taeuber[2] — [1]Arnold Sommerfeld Center and Center for NanoScience, Ludwig-Maximilians-Universitaet Muenchen — [2]Virginia Polytechnic Institute and State University

We study a class of stochastic lattice predator-prey systems in the presence and the absence of restrictions on the number of particles per site. In the former case, the systems are characterized by an extinction threshold. On the other hand, when there is no site restrictions, the species always coexist in two dimensions. In both cases, by pointing out similarities and differences, we carefully discuss the properties of the coexistence phases and of the correlated spatio-temporal structures which form in the course of the dynamics.

Refs: cond-mat/0606809 (accepted in J.Phys.:Condens. Matt.); Phys. Rev. E 73, 040903(R) (2006); q-bio.PE/0512039 (accepted in J.Stat.Phys.); q-bio.PE/0609039.