

Contributed Talks

Gareth Alexander

University of Pennsylvania

Hydrodynamic Interactions of Linked-Sphere Swimmers

I will describe our recent work on the hydrodynamics of linked sphere swimmers, with emphasis on some general results that can be obtained from kinematic reversibility

Thomas Angelini

Harvard University

Multi-cellular Substrate Deformation Guides Collective Migration

Wound healing, embryonic dorsal closure, and tumor cell invasion all involve collective motion and spatial correlations in cellular migration patterns. Although many of the cell types involved in these processes are mechano-sensitive, it is not known how a large collection of cells can work together to deform their surroundings, nor whether such interactions affect migration. Here, we will show that MDCK epithelial cells can impose long-distance, multi-cellular deformation patterns on their substrate, and that the resulting deformations guide collective cell motion.

Meredith Betterton

University of Colorado

Theory of Filament Depolymerization by Motor Proteins

Active biological materials in the cytoskeleton are made up of filaments and cross-linkers. In cells, multiple proteins alter the length of the filaments. Our work is a theoretical description of filament shortening by motor proteins, inspired by kinesin-8 motors which move with directional bias on microtubules and also promote microtubule shortening. The theory describes crowding and collective effects in the motor motion as well as the coupled dynamics of motors and the shortening microtubules. The model quantitatively reproduces the key features of in vitro experimental data, particularly the length-vs-time traces for stabilized MTs in the presence of purified kinesin 8, including length-dependent depolymerization. We have also determined the parameter regime in which the rate of MT depolymerization is length dependent: length-dependent depolymerization occurs only when MTs are sufficiently short; this crossover is sensitive to the bulk motor concentration.

Itai Cohen

Cornell University

Soft Squishy Tissue. The Depth dependent Mechanical Properties of Articular Cartilage

Articular cartilage is a highly complex and heterogeneous material in its structure, composition and mechanical behavior. Understanding these spatial variations is a critical step in designing replacement tissue and developing methods to diagnose and treat tissue affected by damage or disease. In this talk I will show that confocal microscopy in conjunction with particle image velocimetry (PIV) techniques can be used to determine the depth dependence of the shear mechanical properties of articular cartilage. I will show that the shear modulus of this tissue varies by up to two orders of magnitude over its depth, with the least stiff region located about 200 microns from the surface. We find that this region stiffens with shear strain and weakens under compressive strain. I will describe a physical model that account for this behavior by taking into account the local buckling of collagen fibers in this region. Finally, I will report on the frequency dependence of the local modulus and speculate on the functionality that this distribution of material properties gives the tissue

Luca Giomi

Syracuse University

Hydrodynamics and Rheology of Active Polar Films

I will discuss the dynamical and rheological properties of active polar liquid crystalline films. Like active nematic films, active polar films undergo a dynamical transition to spontaneously flowing steady-states. Spontaneous flow in polar fluids is, however, always accompanied by strong concentration inhomogeneities or “banding” not seen in nematics. In addition, a spectacular property unique to polar active films is their ability to generate spontaneously oscillating and banded flows even at low activity. The oscillatory flows become increasingly complicated for strong polarity.

Vishwesh Guttal

Princeton University

Evolution of Collective Behavior in Animal Groups

Organisms ranging from bacteria to humans can collectively perform complex coordinated tasks which no single individual may be able to do on their own. A fundamental question in biology is to understand how evolution can favor such remarkable behaviors which benefit the group as a whole when the natural selection is acting at the level of individuals who act in their own interest. Specifically, in this project, we try to understand selection pressures that lead to the evolution of social behavior and leadership in the context of mass migration that occurs in a variety of organisms. We find evolutionary stable strategies using techniques such as frequency dependent selection and adaptive dynamics on spatially explicit computational models of swarming

Evgeniy Khain

Oakland University

Invasive Patterns of Malignant Brain Tumors

We study the in vitro growth dynamics of malignant brain tumors. A growing tumor consists of a dense proliferating zone and an outer less dense invasive region. Experiments with two different types of cells show qualitatively different behavior: one cell line invades in a spherically symmetric manner, while another gives rise to branches and forms clusters in the invasive region. We reproduced the experimentally observed patterns using both a continuum approach (reaction-diffusion equations) and stochastic discrete (agent-based) modeling. We also showed that above a critical value of cell-cell adhesion large clusters grow from a homogeneous suspension of cells, while below the threshold the system remains homogeneous. The predictions of the model have been verified in a new experiment in which we followed the clustering dynamics of tumor cells on a surface.

Simone Koehler

Technische Universitaet Muenchen

Out-of-equilibrium in vitro Actin Networks

Cells have to adapt their local mechanical and structural properties in order to fulfill their physiological tasks. While already purely crosslinked networks can show clear out-of-equilibrium properties, the activities of molecular motors ensure the local adaptability of the cytoskeleton. Therefore, we study the effect of molecular motors in crosslinked networks. Dramatic structural dynamics as well as macroscopic mechanical properties are determined and discussed. It appears that a sensitive balance of time scales for unbinding of crosslinkers and motor activity are the clue for the understanding of such complex active networks.

Oleg Lavrentovich

Kent State LCI

Electrically Driven Dynamics of Small Particles in Liquid Crystals

Solid particles immersed in the liquid crystal bulk create director distortions. Elastic repulsion from the bounding walls are strong as compared to gravity forces and keep the particles levitating in the bulk. The electric field applied to the cell causes propulsion of the particles; the mechanisms of propulsion are based on dielectric anisotropy and back-flow effect, as well as Quincke rotation phenomenon

Lisa Manning

Princeton University

A Model for Surface Tension in Cell Aggregates

The mechanical properties of embryonic tissues likely play an important role in cell movements and pattern formation during embryogenesis, and these properties can be measured using a variety of techniques including tissue surface tensiometry (TST). Different types of tissues have different surface tensions, which can be used to predict cell sorting behavior in aggregates. We develop a “broken bond” model for surface tension in ordered 2D and 3D cell aggregates, and generalize this model to random aggregates of varying size. The model accounts for adhesive contacts, bulk elasticity, and cortical elasticity, and suggests that measured surface energies result from a combination of packing topology and these forces. This model can be used to interpret data from tissue surface tension experiments and extract information about time-varying adhesive contacts.

Simon Norrelykke

Princeton University

Foraging Strategies for Starving and Feeding Amoeba

Do individual cells have a search strategy when their target is outside their range of detection? Does this strategy change when a high density of targets is encountered? To answer these questions, we observed single, well-isolated cells of the social amoeba *Dictyostelium* as they forage for bacteria. Time-lapse movies of this predator-prey system were recorded and analyzed. By varying the concentration of the food source over several orders of magnitude the dynamics of the amoebae as they responded to their environment could be studied.

Fernando Peruani

CEA and Institute of Complex Systems Paris

Self-propelled Particles with Nematic Interactions: From Simple Agent-based Models to Experiments with Rod-Shaped Bacteria

Self-propelled, polar particle with polar, “ferromagnetic” interactions as well as apolar particles with apolar, “nematic” interactions have been studied extensively within recent years. Here, we address a third case that mixes properties of these systems: self-propelled, polar particles with apolar, nematic interactions. First, we study collective phenomena in a simple two-dimensional stochastic system of self-propelled particles (SPP) interacting locally through an apolar, nematic alignment mechanism [1]. Extensive simulations show that there are four qualitatively different regions of spatial organization. At high noise intensity, disordered spatially homogeneous distributions are found, while at low noise intensity long-range nematic order is found. For intermediate noises and large enough system size, the system segregates into macroscopic areas of high and low density. The high density areas take the form of bands that can take on stable straight

shapes or can be dynamically changing depending on the size of the system, band width and noise intensity. A second more detailed model consist of self-propelled rods interacting through volume-exclusions in two dimensions. Herein, non-equilibrium clustering is observed in simulations and rationalized with a mean-field theory [2].

A suitable experimental realization of self-propelled particles with nematic interactions are gliding rod-shaped bacteria on a substrate. Such bacteria - as other microorganisms - exhibit a transition to multicellularity which starts with the onset of clustering and aggregation. We have studied the combined effects of active, adventurous motion and anisotropic cell shape in assemblies of a mutant strain of myxobacteria that exhibit neither social motility nor so-called C-signalling. We observe a transition to clustering and collective motion, that is presumably caused by simple physical volume-exclusion interactions only. Our results show that in gliding bacteria, the combination of anisotropic cell shape and active motion, leads to a primitive effective alignment mechanism. The transition to clustering is correctly predicted by the hard-rod model in [2] and verified by comparison of cluster-size statistics predicted by the model with corresponding statistics taken from experimental data.

Reference:

[1] F. Peruani, A. Deutsch, and M. Bär, Eur. Phys. J. ? Special Topics 157, 111 (2008).

[2] F. Peruani, A. Deutsch, and M. Bär, Phys. Rev. E 74, 030904(R) (2006).

Co-workers: M. Bär (PTB), F. Ginelli, H. Chate (CEA), A. Deutsch, J. Starruss (TU Dresden), V. Jakovljevic, L. Sogaard-Andersen (MPI Marburg)

Patrick Underhill

RPI

Velocity and Stress correlations in Suspensions of Swimming Microorganisms: Theory and Simulation

Large collections of swimming microorganisms are able to produce collective motions on a scale much larger than the scale of a single organism. In particular, the collective behavior leads to velocities larger than that of an isolated organism, fluid structures larger than the size of an organism, enhanced transport in the fluid, and enhanced stress fluctuations which produce altered rheological properties. We show theoretically how these phenomena are linked to the interactions between the organisms and compare the predictions with the results from computer simulations. In this way we can understand how the behavior scales with concentration, the importance of the method of swimming used, the influence of run-and-tumble like motions of the organisms, and how the interactions can lead to large-scale fluid structures. In periodic geometries, the large-scale fluid structures lead to simulation results that depend on the simulation box size. This result is in stark contrast with results from confined systems. The additional length scale (screening length) introduced by the confinement seems to prevent these large-scale structures from forming.

Torsten Wollert

Syracuse University

F-Actin Dynamics in Human Skin Cells Directs Velocity of Cell Migration

In multicellular organisms, directional cell migration is required for normal physiological processes, such as embryogenesis, immune responses and wound healing, as well as for disease processes such as tumor formation and metastasis. Cell migration is an actin-mediated process that occurs in 4-steps: (a) a coordinated cycle of leading edge protrusion in the direction of migration, (b) substrate adhesion of the protrusion, (c) generation of tension on new adhesions to advance the cell body, and (d) de-adhesion of the trailing cell rear. Remodeling of the actin cytoskeleton initiated by a member of the Rho GTPase signaling pathway occur at each step of the migration cycle. We used long-term live cell imaging of human skin cells (OKF6/TERT-2), co-cultured with *Candida albicans* to mimic an infection, to determine which members of the Rho signaling pathway were elicited by this pathogen and when they were activated. Computational motion analysis was used to quantify cell migration. Over a 6-hr period, we observed the sequential activation of members of the Rho signaling pathway that caused the actin cytoskeleton to form stress fibers at 3 hrs followed by formation of lamellipodia at 6 hrs resulting in an increase in cell migration. Soluble virulence factors secreted by *C. albicans* are thought to be responsible for activation of the Rho signaling pathway.

Clare Yu

UC Irvine

The Transportation System Inside a Living Cell

A living cell has an infrastructure much like that of a city. We will describe the transportation system that consists of roads (filaments) and molecular motors (proteins) that haul cargo along these roads. We will give an example showing how pigment cells regulate this transport.