Poster Presentations

Session I

(I.1)

Bradly Alicea
Michigan State University

Emergent Natural Selection and the Evolution of Novel Biological Surfaces

The goal of this presentation is to stake out a territory for a unified theory of self-assembly using a complex systems and evolutionary dynamics perspective. I will make three general predictions regarding the self-assembly of biological surfaces during development and over the course of function. I will also consider the hierarchical organization of biological surfaces and how this effects their organization and dynamics. The three concepts most relevant to this emerging theory are natural selection on surfaces, polymer population dynamics, and synchronization. Besides playing a fundamental role in the self-assembly phenomenon, all of these terms are defined and put into context. This is done using specific examples from nature and simple computational systems. Finally, a series of future applications are briefly discussed.

(I.2)

Thomas Angelini
Harvard University

Matrix Production in Response to Nutrient Depletion in Bacillus Subtilis Biofilms

Encasing the cells that comprise a bacterial biofilm, the extracellular polysaccharide (EPS) matrix may serve several purposes in biofilm development and survival. One class of examples involves adhesion; the EPS can contribute to cell-cell adhesion and cell substrate adhesion. In contrast to biofilm expansion by proliferation, which produces more nutrient consumers, EPS production could be an alternative, more efficient method of biofilm expansion. The recent work of Vlamakis, et al (2008) demonstrated a transition in the rate of EPS production during biofilm growth. At early stages of development, when the biofilm is thin, a low level of matrix is expressed. At later stages, when the biofilm has thickened, EPS production is dramatically increased. This transition could be a response to nutrient depletion, as there must be a critical biofilm thickness, above which nutrients cannot diffuse into the center of the biofilm before being consumed by cells at the edge. Here we quantify biofilm size and shape during the early stages of Bacillus Subtilis biofilm growth, simultaneously monitoring matrix expression levels. We show that the critical biofilm size scales with nutrient concentration as expected by a simple nutrient depletion model.

(I.3)

Thorsten Auth
Forschungszentrum Jülich

Active Fluctuations of the red Blood Cell Membrane

Red blood cells have a complex cell membrane that consists of a lipid bilayer and a sparsely anchored cortical spectrin cytoskeleton. Even though first quantified more than 20 years ago, the fluctuations of the cell membrane are not completely understood. On the one hand static deformation experiments find that a high shear modulus is provided by the cytoskeleton, on the other hand to explain the results of some fluctuation measurements seems to require a vanishing shear modulus. Also the existence of active fluctuations for red blood cells is still under debate. Measurements of the fluctuations for different viscosities of the surrounding fluid as well as experimental fluctuation spectra suggest that the fluctuations are actively driven. The active fluctuations can be quantified phenomenologically by an effective temperature that is 2-3 times the room temperature. Shape and fluctuations of red blood cells change with the ATP concentration: the normal shape of the cell is the discocyte, if the cells are starved they assume the echinocyte shape and cells with abundant ATP become stomatocytes. We find no active fluctuations for echinocytes and the strongest active fluctuations for stomatocytes.

(I.4)

Thomas Caswell
University of Chicago

Dynamical Measurements Near the Colloidal Glass Transition

We investigate the dynamics of a dense colloidal system near the glass/jamming transition. Using particles made of N-isopropylacrylamide (NIPAM) we are able to continuously vary the volume fraction of the sample while observing the sample. Thus, a single physical system can be used for a range of volume fractions further the sample can be repeatedly melted and quenched while under observation. The sample is observed in a single plane of a three dimensional samples using confocal microscopy. Images are acquired at 20fps and processed to locate and track single particles in 2-D and time. From this data a number of dynamical measurements can be taken.

(I.5)

Henry Fu
Brown University

Theory of Swimming Filaments in Viscoelastic Fluids

Motivated by the swimming of sperm in the non-Newtonian fluids of the female mammalian reproductive tract, we examine the swimming of filaments in the nonlinear viscoelastic upper convected Maxwell model. We obtain the swimming velocity and hydrodynamic force exerted on an infinitely long cylinder with prescribed beating pattern. We use these results to examine the swimming of a simplified sliding-filament model for a sperm flagellum, in which hydrodynamic forces play a crucial role in determining beating patterns. Viscoelasticity tends to decrease the swimming speed.

(I.6)

Kahlil Howard
Syracuse University

Nature as a Scaffold: the Rational Redesign of a Protein Pore

FhuA (Ferric hydroxamate uptake protein component A) is a multifunctional outer membrane protein found in E. coli., which facilitates the uptake of Fe3+, along with phage binding, and the transportation of small peptides. By utilizing rational protein design, our group has altered the structure of FhuA, a 22-stranded beta-barrel with a lumen occluded by a 160-amino acid residue N-terminal plug, to form an large open protein nanopore with cross-sectional dimensions of 49 x 36 Å. Along with removal of the plug, a combination of systematic deletions and modifications of the extracellular loops, coupled with molecular dynamics, has enabled us to engineer protein pores with properties that do not exist in nature. Preliminary electrophysiological data has so far indicated that it is indeed possible to form engineered stable protein nanopores. We are now in the process of characterizing several such engineered nanopores with reduced current noise. The long-term goal is the use of these nanopores in single-molecule detection of double-stranded DNA.

(I.7)

Shailly H. Jariwala
Syracuse University and Syracuse Biomaterials Institute

Effect of Surface Modulus and Extracellular Matrix (ECM) Adhesion Proteins on PC12 Cell Proliferation and Neurite Outgrowth

The formation of the glial scar following spinal cord injury and the biochemical environment that it presents are major barriers to axonal regeneration post injury. Therefore it is crucial to establish axonal regeneration following a spinal cord injury (SCI). It has been established that the biochemical cues from the microenvironment govern the response of cells and their assembly into desired structures. Only lately, it has been documented that the mechanical properties of the underlying tissue also affect cell behavior and hydrogels have been used as substrates to study how neurite outgrowth is affected by varying mechanical properties of substrates [1, 2]. Extracellular matrix (ECM) plays an important role in cell migration, adhesion, and differentiation, and thus it is important to look at the role of ECM proteins in nerve regeneration[3]. Thus this study looks at the effect of ECM adhesion proteins primarily collagen, laminin and fibronectin on neurite extension. Polyacrylamide (pAAm) hydrogels are being investigated in this study as a model substrate material for looking at neurite outgrowth in vitro since they are optically clear, their mechanical properties are easily tunable and their macroporous structure allows for penetration of media to provide a physiological environment. The goal of this study is to compare neurite outgrowth of pheochromocytoma (PC12) cells on pAAm substrates of varying modulus coated with different ECM adhesion proteins.

1. Leach JB et al. J. Neural Eng. 2007 ; 4 :26-34
2. Flanagan LA et al. Dev. Neurosci. 2002 ; 13 :2411-15
3. Attiah DG et al. J. Mat. Sci : Mat. In Med. 2003 ; 14 :1005-1009

(I.8)

Yevgeniy Kalinin
Cornell University

Bacterial Chemotactic Responses in the Presence of Multiple Chemoattractant Gradients: Effects of Receptor Number Variation

Bacterial chemotaxis has long been served as a paradigm for the studies of chemosensory systems. Current research on bacterial chemotaxis, however, is mostly limited to the chemotactic responses to single chemical gradients. In natural environment, bacteria encounter numerous chemicals at the same time making it important to understand how bacteria make a decision on which chemical they should pursue first when placed in a complex chemical environment. In this work, we studied responses of swimming Escherichia coli (E. coli) bacteria to two opposing spatial concentration gradients of methyl-DL-aspatate (MeAsp) and L-serine using a combination of microfluidic device and cell tracking techniques. By varying the ratio of Tar (exogenous) and Tsr (endogenous) receptor numbers in E. coli cells, we demonstrated that E. coli bacteria switch their chemical preference as a function of the receptor number ratio. More interestingly we find that in natural environments E. coli are able to modify their chemical "tastes" by changing the number of receptors of a given kind. While this behavior is undoubtedly related to E. coli's survival strategy the exact reasons for it and its mechanisms remain to be discovered.

(I.9)

Yael Katz
Princeton University

Information Processing in Animal Groups

Coherent, collective motion exhibited by schools of fish, flocks of birds, and swarms of insects can be coordinated by repeated local interactions among individuals which themselves have limited sensing and cognitive abilities. In a conceptually similar way to coordinated animal groups, sensory systems collect information from a noisy environment and integrate this over a wide range of spatial and temporal scales to arrive at a behavioral response. Existing models of collective behavior do not reproduce many observed behaviors of real animal groups such as signal amplification, threshold responses, and the ability to change behavior on the fly, depending on environmental conditions. While in neural systems, the microscopic rules are often known, quantitative kinematic data on animal behavior is scarce and thus the rules governing individual behavior are not well described. Here we use inspiration from neuroscience to arrive at

possible local rules for individual behavior, which can lead to observed group properties. We develop numerical simulations, run on graphics processing units, to explore the relationship between these microscopic rules and the macroscopic behavior of the group. Experiments are underway to test the predictions of these models using an experimental schooling fish system.

(I.10)

Evgeniy Khain
Oakland University

Instabilities and Fluid-solid Coexistence in Dense Shear Granular Flow

In this work, we consider a dense rapid shear flow of inelastically colliding hard disks: a plane Couette flow in the absence of gravity [1, 2]. To investigate the dense flow regime, we applied both Navier-Stokes granular hydrodynamics and event-driven molecular dynamics (MD) simulations. In contrast to earlier works on dense rapid granular shear flow [3], we incorporated a recent finding that shear viscosity diverges at a lower density than the rest of constitutive relations [4]. We also proposed new interpolation formulas for constitutive relations between dilute and dense cases and justified them in MD simulations [1]. In a steady flow, the viscous heating of the granular media is balanced by energy dissipation through inelastic collisions. This balance can be achieved in different ways, resulting in either a uniform shear flow (with constant velocity gradient, density and temperature), or a flow with nonlinear velocity, density and temperature profiles. In some regions in the phase diagram, two or three different steady flow solutions are possible for the same values of parameters. We performed a linear stability analysis of the uniform shear flow. We showed that when the inelasticity of particle collision becomes large enough, the uniform shear flow gives way to a two-phase flow, where a dense "solid-like" striped cluster can coexist with (one or two) fluid layers [5]. The existence of this regime is a direct result of the viscosity divergence [1]. The entire phase diagram of parameters is computed theoretically. The results of the analysis are verified in MD simulations, and a good agreement is observed. This shows that granular hydrodynamics can successfully describe dense rapid flows, and opens a new theoretical approach to investigation of the dynamics of dense granular systems.

[1]. E. Khain, Phys. Rev. E 75, 051310 (2007).
[2]. E. Khain and B. Meerson, Phys. Rev. E 73, 061301 (2006).
[3] L. Bocquet et al, Phys. Rev. E 65, 011307 (2002); L. Bocquet, J. Errami, and T. C. Lubensky, Phys. Rev. Lett. 89, 184301 (2002); M. Alam and P. R. Nott, J. Fluid Mech 377, 99 (1998); M. Alam et al, J. Fluid. Mech. 523, 277 (2005).
[4]. R. Garcia-Rojo, S. Luding, and J. J. Brey, Phys. Rev. E 74, 061305 (2006).
[5]. E. Khain, submitted (2009).

(I.11)

Gulmammad Mammadov
Syracuse University

Active Brownian Motion of an Asymmetrical Particle

An active system is driven out of equilibrium by an internal or external energy source that can lead to self-propulsion. We have studied analytically the Brownian motion of an asymmetrical (rod-like) particle self-propelled at a fixed speed v along its long axis in two dimensions. We show that the diffusion is anisotropic at short times, but becomes isotropic at long times. In the long time regime one recovers conventional diffusion, with mean-square displacement that grows linearly with time. The diffusion coefficient is enhanced by self-propulsion, with Deff=Dv2/tR, where tR is the rotational diffusion time.

(I.12)

Narayanan Menon
University of Massachusetts Amherst

Fluctuations in Vibrated Granular Rods

Abstract Unavailable