Soundbytes

Suphatra Adulrattananuwat
Syracuse University
A Cell's Bioenergetic Network

Chlamydomonas reinhardtii, a unicellular green alga with two cilia for swimming and an eyespot to absorb the light, has been widely used as a model organism in biology, medicine, physics and biotechnology due to the similarity of part of its genome to the human, the diversity of mutants, and ease of handling. We have used it to study the dynamics of its control of ATP by holding a single cell with a micropipette, stimulating it with red light (~670 nm) causing photosynthetic synthesis of ATP, and by monitoring its ciliary motility with a quadrant photodetector. Due to the proportional relationship between the energy molecule (ATP) and ciliary beating frequency (BF), this method has allowed us to monitor dynamically the perturbation of a primary bioenergetic pathway. By monitoring its frequency response, we have used it to model the response system and explore the cell's own feedback control which is surprisingly effective for a biological system. It does not fail until it is driven by the rapid modulation of red light at the relatively high frequency of 20 Hz.

Shiladitya Banerjee
Syracuse University
Activity-Induced Deformation of Cross-linked Actin Networks

Cross-linked actin networks have been shown to form anisotropic phases beyond a certain density of crosslinkers. Here we adapt field theories of nematic elastomers to propose a simple phenomenological model for such a cross-linked actin gel. The effect of active crosslinkers like myosins is incorporated via a nonequilibrium contribution to the stress tensor. We show that in a thin film of such active elastomer in a quasi-one dimensional geometry one observes activity-induced rotation of the director above a critical value of the activity. Such instabilities bear resemblance to the full-wavelength Frederickz transition observed in nematic elastomers under external fields. However, here the instabilities are driven by the activity of the crosslinkers, which is controlled by the chemical energy of ATP hydrolysis. Due to coupling of the director to the elastic degrees of freedom, such spontaneous distortion of the nematic field leads to spontaneous deformation of the network.

Kelly Burke
Case Western Reserve University and Syracuse Biomaterials Institute
Liquid Crystalline Elastomers as Soft Shape Memory Networks

Main-chain liquid crystalline elastomers were prepared by hydrosilylation chemistry in which diene mesogens are polymerized with hydride terminated poly(dimethylsiloxane) and crosslinked with a tetravinyl silane. All elastomers are polydomain and show smectic-C phases. Dynamic mechanical analysis shows the networks have a glass transition and an isotropization temperature that are both caused by the mesogen, and changing the mesogenic composition has been shown to merge or separate these transitions. Because the networks are based on poly(dimethylsiloxane), they are "soft" with storage moduli less than 10 MPa at all temperatures. These smectic-C liquid crystalline networks show excellent bulk one-way shape memory fixing and recovery around the mesogen's Tg as well as reversible elongation and contraction when cooling and heating, respectively, through the clearing point. This reversible behavior takes place under little applied stress and is strongly dependent on the material's crosslink density, with the magnitude of actuation increasing and the threshold stress required for actuation decreasing as crosslink density decreases. Applications that exploit the reversible thermoresponsive properties of these networks LCEs include artificial muscles. Furthermore, the soft moduli of these networks enable reversible imprinting of microscale topographies on the elastomer's surface, where fixing and recovery of the pattern is possible due to the mesogens and is envisioned for applications as smart substrates.

Valerie Cross
Cornell University

Mechanisms of cell-cell communication within 3D collagen matrices during vascular network formation in vitro

Vasculogenesis is a dynamic process whereby large populations of individual endothelial precursor cells interact locally to build a globally connected vascular network. Motility-related cell behaviors including migration (chemotaxis, durotaxis, and haptotaxis) and extensive protrusive activity have been observed to be critical during vasculogenesis; however, the general principles guiding the morphogenesis of the primitive vascular system are poorly understood. Here, we embed human umbilical vein endothelial cells (ECs) in three dimensional (3D) type I collagen matrices to study both global network formation and local cell-cell interactions. We report that the formation of a 3D percolating network requires 1) a critical cell seeding density (corresponding to a linear cell separation of eight microns) and 2) the ability of a subset of ECs to migrate through the matrix. To investigate the local length scale of cellular interactions, we track the protrusion dynamics of isolated cells and cell pairs at various initial separations using live cell imaging. We use fluorescently labeled collagen with embedded micro beads, chemistry, and boundary conditions to show that 1) filopodial protrusions follow collagen fibers and show a bias in the direction of neighboring cells, dependent on the initial cell pair separation and 2) VE-cadherin contact, local gradients of VEGF, and MMP-dependent matrix degradation do not direct protrusion angle. Finally, we use permeable, fixed boundaries to separate mechanical and mass transport mechanisms of cell-cell communication.

Xiaofan Luo
Syracuse University
You CAN get blood from a plastic: A New Self-healing Polymer System

Here we present our development of a unique polymeric material that can "bleed" upon heating. The material is a blend of two commercially available polymers and features a special phase separated morphology in which two phases are co-continuous. Upon heating, one phase undergoes a melting phase transition with a relatively large increase in volume, while the other phase remains glassy and exhibits only minor volumetric expansion. This results in a microscopic expansive flow, or "bleeding" of the molten phase onto the surfaces, while the material shows little visible changes macroscopically. We have successfully demonstrated the applications of this material as self-healing composites and reversible adhesives. We envision broad applicability of this approach to design and make "bleeding" polymers for various applications.

Patrick Mather
Syracuse University
Color-Changing Shape Memory Polymers

We have recently developed materials that change shape and color in synchronicity. Semicrystalline networks (shape memory rubbers) of various chemical composition serve as host to an excimer-forming fluorophore whose solubility is designed to be limited to the amorphous phase of the network. Thus, heating strain-fixed crystalline networks above their melting transition leads to a simultaneous shape and color change. The effect is reversible and its dynamics aesthetically pleasing.

Mohammad Mohammad
Syracuse University
Transporting Endotoxin Polymer by ABC Transporter

The ATP-binding-cassette (ABC) transporters are protein nanomachineries associated with membranes and common to all living cells. ABC transporters utilize the energy of ATP hydrolysis to transport a variety of solutes across the membrane, for example, polysaccharides. Pseudomonas aeruginosa, a Gram-negative pathogenic bacterium, employs a bi-component ABC transporter as an active efflux of polysaccharides during the biogenesis of endotoxic lipopolysaccharides. We reconstituted the ABC transporter in various systems, including microsomes, planar lipid bilayer, and transfected N2a cell lines to obtain a mechanistic understanding of the functional properties of this nanomachinery. We employed single-channel electrical recordings to show that the transmembrane domain (TMD) of the ABC transporter features pore-forming activity. Further, our biochemical characterization of purified components sheds light on the structural assembly of this bi-component ABC transporter. Our long-term goal is to explore, detect, and characterize the polysaccharides' transport at single-protein complex resolution. The use of a broad range of reconstitution systems enables a comprehensive investigation of the ATP-dependent transport kinetics and thermodynamics of the large-size solutes from one side of the membrane to the other. These studies might contribute to drug design against Pseudomonas aeruginosa.

David Niedzwiecki
Syracuse University
Using Synthetic Nanopores as Stochastic Sensors

Biological and solid-state nanopores have been used as stochastic sensors to probe single proteins[1] and nucleic acids[2] at the single-molecule level. We have produced solid-state nanopores with a range of diameters between 2 nm and 20 nm in silicon nitride films to investigate protein-nucleic acid interactions. Solid-state nanopores hold several advantages over their biological counterparts, including greater robustness of the pore, the ability to tune the diameter of the pore, and the potential for either integration into a lab-on-a-chip platform or parallelization for high-throughput devices. The technique also has the potential to be used as a highly sensitive and selective detection device in molecular biomedical diagnosis.

Movileanu, L. Trends Biotechnol. 2009, In Press.
Branton, D. et al., Nat.Biotechnol. 2008, 26, 1146-1153.

Desmond Ong
Cornell University
Crystallization and Dislocation Dynamics of Non-spherical colloidal Particles in a 2D Confinement cell.

We are investigating the equilibrium and dynamic behavior of non-spherical colloidal particles confined in a 2D cell. Our confinement cell allows us to study the phases formed by these particles at different gap heights. We are also investigating the response of the system to external perturbations that strain the sample.

David Quint
Syracuse University
Structure at the Leading Edge

We model the cytoskeletal network at the leading edge of a crawling cell as a growing network of branched filaments where the branching angle is a parameter. We investigate collective properties of this network as a function of this angle to search for an optimal branching angle, which Nature has selected to be approximately 70 degrees. For example, simultaneously maximizing for forward growth/extension and minimizing for the time for the network to form a spanning structure sets an optimal angle, albeit a smaller one than Nature has selected.

Suntao Wang
Cornell University
Self-assembled 2D TMV Arrays on Fluid Lipid Membranes

Bionanoparticles are ideal building blocks for creating ordered two-dimensional (2D) structures. The 2D protein crystals or ordered arrays are of great scientific and technological interest. In this talk, the use of in-situ x-ray scattering techniques (XR and GISAXS) are demonstrated to monitor the formation of self-assembled, 2D ordered arrays by tobacco mosaic viruses (TMVs) on a lipid layer that was either supported by a solid substrate or formed at the liquid-vapor interface. Atomic Force Microscopy was also used to directly image the final structure to provide real space confirmation of developed structural order. The observations show that at the presence of divalent ions in the solution, TMV rods adsorbed on the fluid lipid monolayer form well ordered closely packed 2D arrays. The ordering of the 2D structures strongly depends on the charge density in the lipid monolayer. Possible models are discussed to describe the 2D structure order.

Zhenwei Yao
Syracuse University
Shape of Structured Vesicles

Large robust and tunable vesicles with internal smectic and nematic order have recently been synthesized using diblock coplymers with sidechain nematogens. We explore the role of the internal structure in controlling the shape of both metastable intermediate states and equilibrium vesicles.

Shiliyang Xu
Syracuse University
A Toy Spin Model of Jammed Solids

To investigate the vibrational modes of a jammed, or amorphous, solid, we construct a lattice spin model with both ferromagnetic and antiferromagnetic interactions. The type of interaction is determined by the geometry of the lattice, which is disordered, thus, giving rise to a spin glass. Correlations in the geometry lead to a correlated spin glass whose phase diagram we are currently investigating. We conjecture that spin waves in this model resemble the quasilocalized vibrational modes observed in jammed solids.

Clare Yu
University of California Irvine
Beating Cilia in Frog Embryos

Beating cilia are found throughout our body, e.g., in our trachea, brains, and kidneys. We use a fast camera to film cilia beating in frog embryos. We are studying how correlated cilia are within a cell and between different cells. This is related to planar cell polarity.