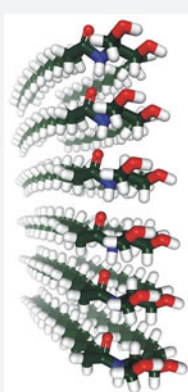




Biophysics



Biophysics—applying the theoretical, computational, and experimental methods of physics to biological systems—is at the leading edge of a revolution in biology. Applying the hallmarks of physics—simplified, quantitative, and predictive models—to biology, however, is extremely challenging due to the complex nature of biological processes. Yet, great progress has been made in understanding biological machinery in such areas as protein folding, ion channels and molecular motors. The ultimate goal of this work is nothing less than a revolution in biology, in which whole biological systems may be analyzed quantitatively.

Biophysics at UMD is a strong, highly interdisciplinary research effort involving faculty from Physics, Chemistry, Biology, and Engineering. The research area has grown significantly over the past 5 years and since summer 2008 includes a cross disciplinary graduate student training program, the Biophysics Graduate Program, directed by Professor Dave Thirumalai.

Biophysics research at UMD includes world leaders in key areas of quantitative modeling for complex processes such as statistical physics and nonlinear dynamics...UMD fosters a relationship with the National Institutes of Health (NIH) to work on the most relevant biological problems with the best biological tools and world's leading researchers. Four of the new Biophysics projects started by the physics faculty are highlighted below.

Arthur La Porta is measuring the reaction of biological molecules when they are perturbed to understand how the enzymes move along substrates or undergo conformational changes to gain an understanding of how these processes are related to regulated processes in living tissue.

Arpita Uphadhyaya is developing techniques to understand the mechanics of the process of cell spreading and movement by measuring both the physical properties and studying the statistical and continuum mechanics at the theoretical level.

Rajarshi Roy, in collaboration with the National Institutes of Health, is developing fundamental analytical structures to determine how neurons connect, the networks the neurons form, and how stimuli alter the connections and the network.

Wolfgang Losert, Edward Ott, and Michelle Girvan, in collaboration with the National Cancer Institute (NCI), are pioneering new methods to study collective processes of genes to identify specific communities of genes that are involved in producing particular cancers.

Maryland Biophysics Program

<http://marylandbiophysics.umd.edu/>

Pulling and Twisting Single Molecules

Single Molecule Biophysics is the study of the behavior of large protein or protein-nucleic acid biological molecules that are individually perturbed and measured. The ability to apply force and torque to a biological molecule and measure nanometer displacements allows scientists to study critical biological processes with unrivaled precision. For instance, many enzymes must move along their substrate or undergo conformational changes as they perform their functions. Optical trapping experiments allow researchers to directly detect and perturb these dynamics.

In Arthur La Porta's lab, one biological system being studied is transcription, in which an RNA polymer is synthesized with sequence copied from double stranded genomic DNA. The enzyme which performs this function, RNA polymerase, moves along the DNA template, dwelling at each nucleotide long enough to catalyze the ligation of the corresponding nucleotide to the nascent RNA polymer. Using an optical trap La Porta watches this process in real time to discover the extent to which the enzymatic activity of RNA polymerase is determined by the sequence being transcribed or by force and torsional strain on the DNA template. The expression of a protein in a biological organism depends on the corresponding gene being transcribed, and the experiments being performed and envisioned will allow researchers to better understand how this process is regulated in living organisms.

Arthur La Porta alaporta@umd.edu

<http://www2.physics.umd.edu/%7Ealaporta/LaPorta.html>



Cell Motility

Cell adhesion and migration is essential for embryonic development, wound healing, and proper functioning of the immune system. When cell cohesion and migration are impaired, the invasive behavior of cells leads to cancer metastasis. Cell movement is achieved through adhesion bonds, protrusion of the membrane at the leading edge of the cell, and retraction of the rear of the cell facilitated by the contraction of the actin myosin networks. These are clusters of adhesion molecules and cytoskeletal components which act as mechano-sensory sites allowing a cell to sense and generate forces required for movement and change in shape.

Arpita Upadhyaya is developing an understanding of the mechanics of the process of cell spreading and movement through a combination of techniques such as high resolution fluorescence imaging of GFP-tagged proteins in live cells, high-speed imaging, micro-fabrication to perturb the cell substrate interface, and optical trapping to measure forces exerted by the cytoskeleton and membrane. At a theoretical level, statistical mechanics and continuum mechanics approaches are used to model these phenomena. Biophysical models of cell adhesion and migration add a physical dimension in embryonic development, wound healing, and proper functioning of the immune system.

Arpita Upadhyaya arpitau@umd.edu <http://www2.physics.umd.edu/%7Earpitau/>

Neuronal Avalanches

Rajarshi Roy is working collaboratively with the Section on Critical Brain Dynamics, NIH, to determine how signals are propagated in tissue samples. As part of this question Roy is looking at how neurons are connected in the brain and how the neurons function as a network. He collects data with microelectrode arrays which measure the electrical activity of the sample and allow the tissue sample to be stimulated. Drugs are introduced into the system, and the signals in the system are measured to determine how the drugs alter the network connections. An understanding of the changes that occur in these networks as stimuli are applied will lead to a better understanding of the mechanisms operating in Parkinson's disease, epilepsy, and other seizure conditions. This knowledge will, in turn, help researchers to discover how to create positive change in these networks.

Rajarshi Roy rroy@umd.edu

Collective Dynamics in Biology

Many cancers involve misregulation of a large number of genes, so the complex interplay of all genes needs to be understood in designing targeted interventions of multiple cell processes. A key challenge is to assess what combinations of cell processes and associated genes are most important for a specific cancer.

Edward Ott, Michelle Girvan, and Wolfgang Losert, working collaboratively with the NCI, are investigating the dynamics of biological process at the system level to characterize collective dynamics and emergent properties of cell systems. They are carrying out modeling work on gene networks of cancer cells and studying characteristics of gene expressions particular to different types of lymphoma cancers to learn how to identify the important ensembles of genes for each cancer type. Ott and Girvan have pioneered new methods to detect communities in networks, to find important links or nodes, and to analyze the dynamics of networks. They are applying these novel tools to one of the most pressing problems in cancer research: pinpointing the links and nodes for potential cancer treatment.

Wolfgang Losert wlosert@umd.edu <http://www.ireap.umd.edu/~wlosert>
Edward Ott edott@umd.edu
Michell Girvan girvan@umd.edu

