THE PHYSICS OF LIVING CELLS

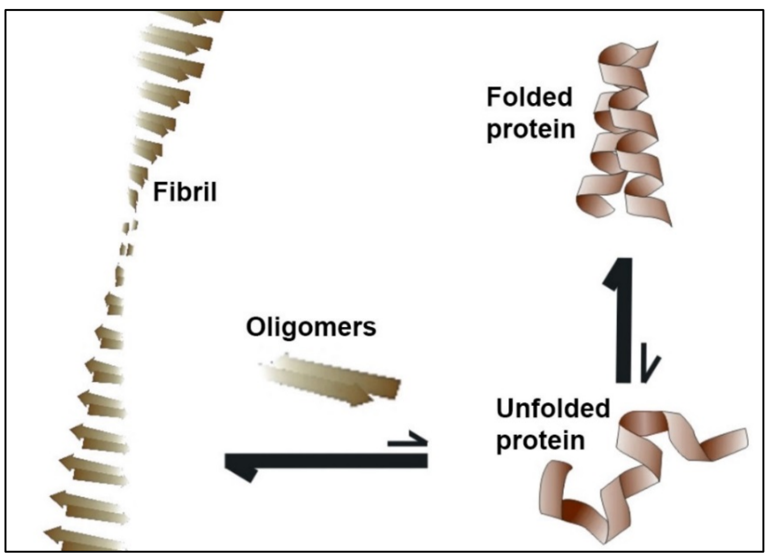
A team-taught OLLI course featuring faculty from the National Science Foundation Physics Frontiers Center for the Physics of Living Cells (CPLC)

January 27, 2016: Martin Gruebele

James R. Eiszner Endowed Chair in Chemistry, Professor of Physics

WHEN THE GOOD GUYS GO BAD: PROTEINS IN THE HUMAN CELL

Abstract: Our bodies continually make proteins that are distributed throughout the body: high-density lipoproteins in your blood, insulin to regulate sugar uptake, alpha synuclein in your neurons so they can form memories. But it's a two-way street: proteins are synthesized and folded, but proteins also become unmade and misfolded all the time, and when they do, bad things can happen. For example, alpha synuclein interacts with nerve cell membranes and aggregates, causing illnesses such as Parkinson's. With age, the equilibrium between making and unmaking shifts in favor of the latter, as our bodies' various defense mechanisms against their own bad proteins lose efficiency. Much remains unknown about the mechanisms involved, but I will talk a little about the various proteins, and what happens in cells when things go wrong. Questions during the talk are welcome.



Short Reading:
http://www.sciencedaily.com/releases/2015/11/151112123926.htm

Websites: http://www.chemistry.illinois.edu/faculty/Martin_Gruebele.html

http://www.scs.illinois.edu/mgweb/

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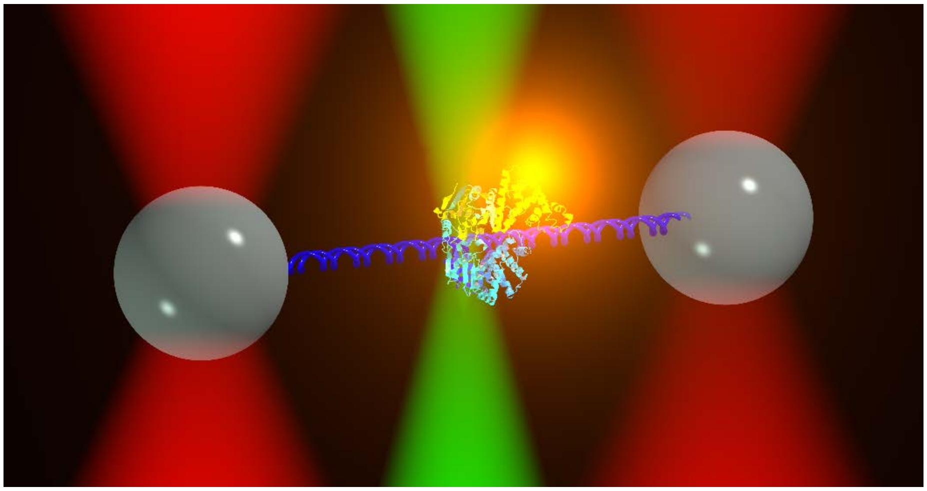
February 3, 2016: YANN CHEMLA

Associate Professor of Physics and Biophysics

NATURE'S NANO-MACHINES

Abstract: The cell is the smallest unit of life. Through many decades of research, scientists have come to view the living cell as a kind of "factory", wherein specialized machinery carries out essential tasks at specific times and places. These molecular machines behave as minuscule, nanometer-size engines. They perform tasks as diverse as maintaining the cell's DNA, transporting cargo around the cell, and moving the cells themselves. In the last twenty years the emerging new field of "single-molecule biophysics" has revolutionized our understanding of these machines. Using tools from the physical sciences, researchers are now able to study molecular machines



one at a time in unprecedented detail. In this talk, I will discuss the state of the art in this field, what new insights have merged, and how these studies relate to human health and disease.

Short Reading: http://physics.illinois.edu/news/story.asp?id=10946

Websites: https://physics.illinois.edu/people/profile.asp?ychemla

http://research.physics.illinois.edu/chemlalab/

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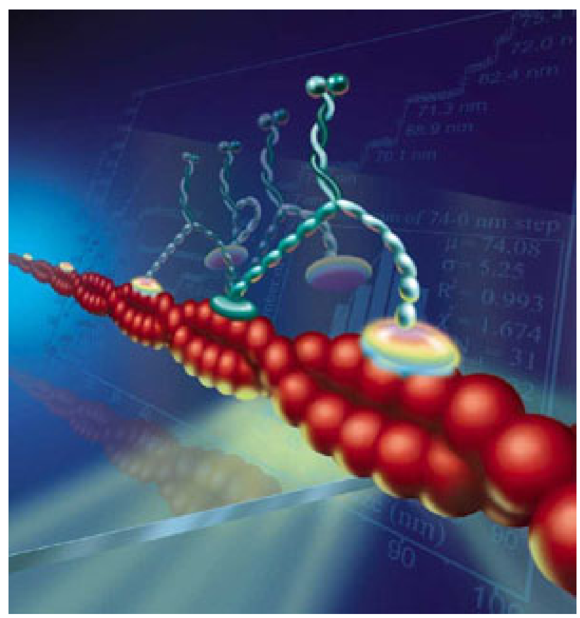
FEBRUARY 17, 2016   PAUL SELVIN

Professor of Physics

HOW FIONA, SHREK'S GIRLFRIEND, LIGHTS UP YOUR LIFE. AND WHY SHE ALMOST WON THE NOBEL PRIZE.

ABSTRACT: Cells are like little cities, with cars and trucks moving proteins around on roadways. Sometimes the traffic is heavy, sometimes light. Sometimes the trucks hit a roadblock, causing detours and even turn-a-rounds. Other times the trucks break down, causing significant problems. Inside of a cell, these "trucks" are called molecular motors. But how do these molecular motors move? Do they roll along or walk along, much as a human walks. Borrowing from Hollywood movies, we invented a technique, called FIONA, (the wife of Shrek) which enables us to shine light on the molecular motors and tease apart how they move. It turns out they take tiny steps, only 1/1000 of a hair's width! But these little motors do a big job: without them, essential ingredients would take a thousand years instead of a few days to reach their destination. This however wasn't all that FIONA could do. A cousin of hers won a Nobel prize two years ago. Come hear all about it!



Short Reading: http://www.tifr.res.in/~roop/NaturesNanotech.htm
Websites: http://physics.illinois.edu/people/profile.asp?selvin
http://people.physics.illinois.edu/Selvin/PRS/PRS.html

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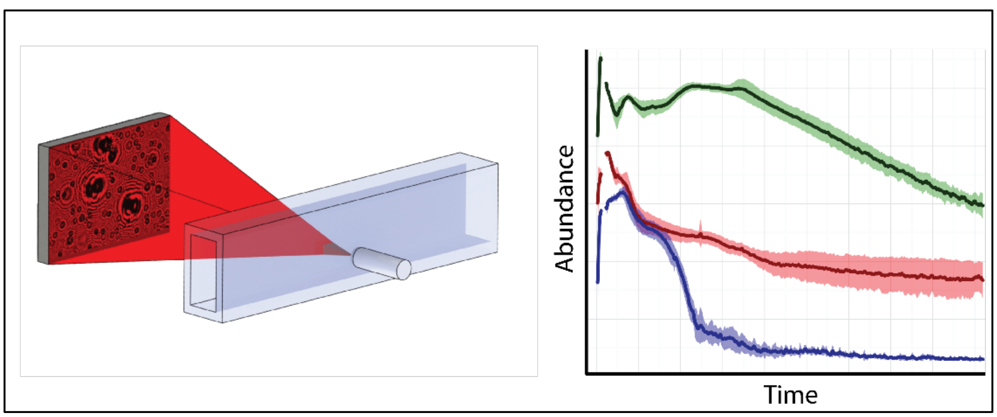
MARCH 3, 2016 SEPPE KUEHN

Research Assistant Professor of Physics

PLAYING THE TAPE TWICE: IS ECOLOGY REPRODUCIBLE?

ABSTRACT: What would happen if you could "re-run" the ecological and evolutionary history of the earth? Would the same biological rules that govern life today still be in effect? More importantly, if you could re-run the tape many times - would each round be entirely different or would there be simple rules or laws that described the outcomes you observed? This question has been considered by biologists (and physicists interested in biology) for many decades. Clearly, running such an experiment is not possible! However, we can ask the same question on a smaller scale over shorter durations. What would happen if you could create many identical ecosystems (replicates) and let them "run" for long periods of time? Would the changes in the number of each species (abundances) be very reproducible from replicate to replicate? Or - would the outcome be idiosyncratic? My collaborators and I performed precisely this type of experiment with microbial communities. I will present our results and explore the idea that there might be simple laws governing how ecosystems change in time.



Short Reading: (Physics viewpoint) http://physics.aps.org/articles/v8/101

Websites: http://www.kuehnlab.org/

https://physics.illinois.edu/people/profile.asp?seppe

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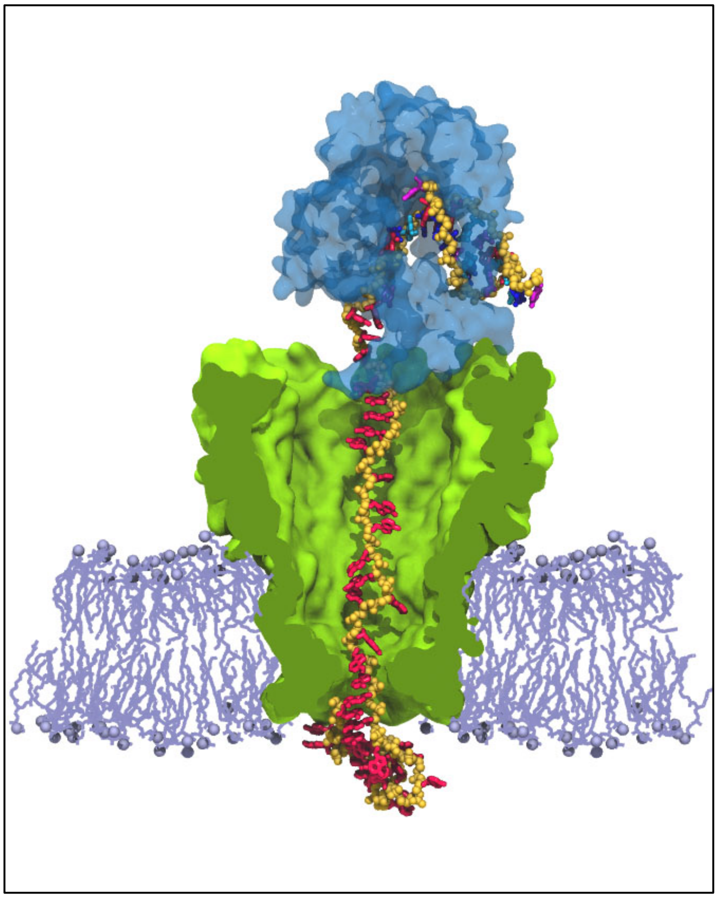
March 9, 2016: ALEK AKSIMENTIEV

Associate Professor of Physics

CLOSE ENCOUNTERS WITH DNA

Abstract: After water and oxygen, DNA is, very likely, the most famous molecule of life known to men. This is not surprising, as the eye-catching double helix of DNA carries instructions to manufacture and assemble all the components of a living organism. The wealth of information encoded in DNA often overshadows its unusual physical properties, for example, the possibility of effective attraction between same-charge DNA molecules. Furthermore, the methods used to determine the informational content of DNA—its nucleotide sequence—until now relied on biological processes. In this lecture, I will describe our recent efforts to characterize the physical properties of DNA and demonstrate how these properties can be exploited in a physics-based technology of DNA sequencing.



Short Reading: http://www.economist.com/node/18304268

Websites: https://physics.illinois.edu/people/profile.asp?aksiment

http://bionano.physics.illinois.edu/

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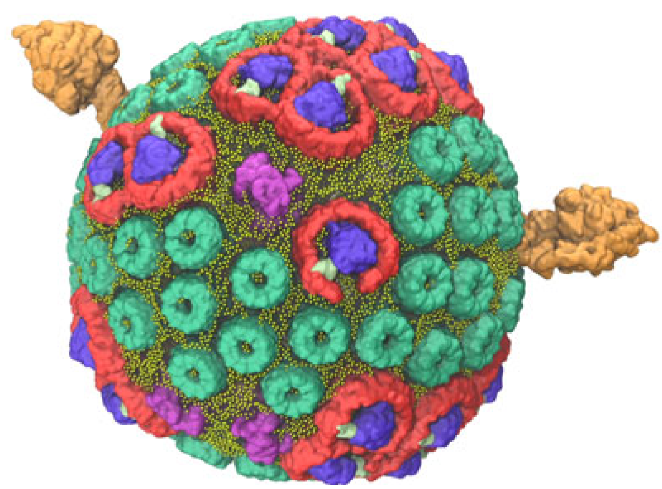
March 16, 2016 KLAUS SCHULTEN

Professor of Physics, CPLC Co-Director

The Physics and Chemistry of Photosynthesis

Abstract: Living systems, down to their smallest, truly living components — cells — are made up of a huge number of molecules. Resolving a cell molecule-by-molecule, namely at the level of chemistry and physics, is a long-held dream, as this feat would link the life sciences with the physical sciences at the most basic level. Can such a highly resolving microscope ever be realized? The answer is yes, however, this microscope takes the form of a computer. Such computational microscope has been developed, programmed to build on biological data, as well as on chemical and physical knowledge. The first instance of a molecule-by-molecule view shows a key part of a photosynthetic bacterium, namely the photosynthetic chomatophore of the so-called purple bacterium *Rhodobacter sphaeroides*. The chromatophore is about 100 nm in size and, in volume, is about a hundredth of the bacterial cell. The view of the chromatophore is amazing and beautiful. One sees a clockwork of physical and chemical processes: light absorption producing optically excited chlorophyll molecules; chlorophyll excitation spreading through the entire chromatophore, inducing electron and proton transfer at certain centers; electrons being moved around by different charge carriers; protons being pumped into the chromatophores until the protons' pressure becomes high enough that they mechanically drive synthesis of molecules of ATP, a fuel that provides energy for most cellular activities.



Short Readings/Links: For more information visit:
https://www.olcf.ornl.gov/2015/07/29/researchers-build-bacterias-photosynthetic-engine/
http://tcbg.illinois.edu/2014/05/07/photosynthesis-movie-released/

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FEBRUARY 10, 2016   NIGEL GOLDENFELD

Professor of Physics

WHAT CAN THEORETICAL PHYSICS TELL US ABOUT THE ORIGIN AND EVOLUTION OF EARLY LIFE?

Abstract: Life on Earth is wonderfully diverse, with a multitude of life forms, structures and evolutionary mechanisms. However, there are two aspects of life that are universal --- shared by all known organisms. These are the genetic code, which governs how DNA is converted into the proteins making up your body, and the unexpected left-handedness of the amino acids in your body. One would expect that your amino acids were a mixture of left and right-handed molecules, but none are right handed! In this talk, I describe how these universal aspects of biology can be understood as arising from evolution, but generalised to an era where genes, species and individuality had not yet emerged. Lastly, I will describe experimental work, conducted in collaboration with Tom Kuhlman, that probes the mechanisms of evolution at the molecular level, in real time, in living cells. These experiments complement the theoretical work, and can test some of the fundamental assumptions of the theory of evolution.

Short Readings/Links:
http://guava.physics.uiuc.edu/news/articles/Mark%20Buchanan%20article%20about%20HGT%20in%20New%20Scientist%201-26-2010.pdf

Websites: http://guava.physics.uiuc.edu/~nigel/

http://guava.physics.uiuc.edu/

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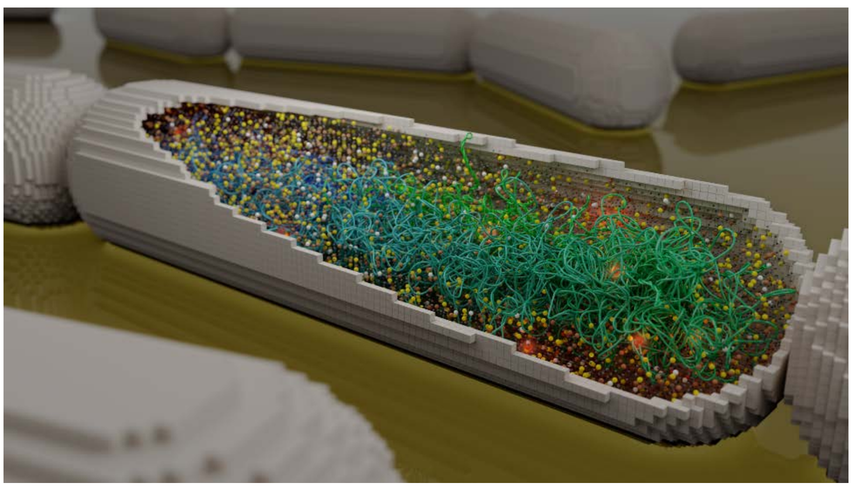
ZAIDA LUTHEY-SCHULTEN

Lycan Professor of Chemistry and Physics

FEBRUARY 24, 2016

THE PHYSICS OF CELLULAR METABOLISM

ABSTRACT: Bacteria such as the E. coli adapt their metabolism—what they use as fuel and how they break it down—according to what resources they have available. Just like human muscle cells, bacteria prefer to burn glucose in the presence of oxygen, but they can also release some of the energy stored in glucose through a form of metabolism that does not require oxygen. This metabolic pathway produces a chemical byproduct, acetate, that still contains some unharvested chemical energy. I will show in this lecture how life in a bacterial colony will depend on location. Cells at the bottom, lacking oxygen, would break down glucose into acetate. Cells at the top would take up that acetate and use their access to oxygen to complete its breakdown, extracting the remaining available energy from the original glucose substrate. Cells in the outermost ring, with access to both glucose and oxygen, exhibit the fastest growth. We call this emergent cooperativity metabolic reprogramming, and the energetic competition involved in it reveals new insight into the behavior of yeast and human stem cells.



Short Reading: https://cplc.illinois.edu/news/whole_story.asp?id=11262

Websites: http://www.chemistry.illinois.edu/faculty/Zaida_Luthey_Schulten.html