

THE BIOLOGICAL PHYSICIST

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This is the August issue. You did not miss the June issue. Due to some technical and timing issues, I did not prepare a June issue. This issue includes the PRL/PRE highlights for both the June and August issues. In addition, we continue with our overviews of federal programs and interviews with program directors who oversee biological physics research initiatives. In this issue, Dr. Yodh describes the Center for the Physics of Living Cells at UIUC.

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National Science Foundation Physics Frontiers Centers Program

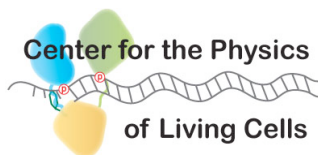


Continuing with our theme (over the course of the next few issues) to highlight program directors federal funding agencies that oversee programs directly and/or indirectly involved in biological physics research, and on-going large-scale programs sponsored by these federal programs, this issue highlights the NSF Physics Frontiers Center, the Center for the Physics of Living Cells at the University of Illinois, Urbana-Champaign.

The Center for the Physics of Living Cells University of Illinois at Urbana-Champaign

www.cplc.illinois.edu

by Jaya Yodh, PhD



The Center for the Physics of Living Cells (CPLC) at the University of Illinois at Urbana-Champaign

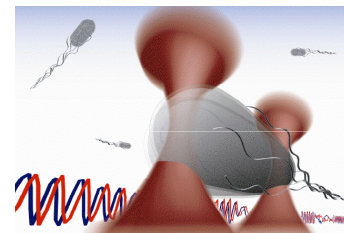
was established in 2008 as one of nine NSF Physics Frontier Centers (PFCs), and the second PFC focusing on biological

physics. Under the co-direction of [Taekjip Ha](#) and [Klaus Schulten](#), the CPLC is making transformational advances at the scientific boundary of the 'physics of living cells.' The Center's aspiration is to create an experimentally-based, dynamic portrait of the living cell at the ultimate resolution. The CPLC comprises investigators in the fields of physics, chemistry, biochemistry, microbiology, and electrical engineering and is uniquely poised to tackle the major challenges of this field by pioneering the creation of synergies between different approaches such as single-molecule and live-cell experimental techniques and biological computation and theory. To illustrate the success of this synergistic, interdisciplinary approach, we will highlight three recently published efforts from our Center.

Bacterial Treadmills to study chemotaxis. Many bacteria, such as *E. coli*, propel themselves in water using rotating helical tails called flagella. They sense chemicals in their surroundings and alter their swimming behavior in order to move toward favorable environments (and away from unfavorable ones) in a phenomenon called chemotaxis. Bacterial chemotaxis serves as a model for the way all living cells capture and

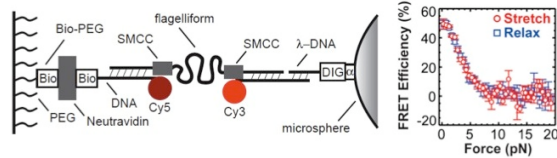
process signals from their environment, and modulate their behavior based on those signals. The laboratories of CPLC faculty, [Yann Chemla](#) and [Ido Golding](#), have recently developed a new method to study this process ([Nature Methods 6 \(11\):831-835, 2009](#)). Using optical "tweezers", or focused laser light, they immobilized individual *E. coli* cells in water without impeding their swimming motion. In essence, this generated a "bacterial treadmill" in which a cell swims but remains in place.

The cells are trapped in a microfluidic chamber, allowing introduction of chemical signals in a controlled environment and observation of how bacteria alter their swimming response. Swimming behavior is tracked by following changes in the laser light path caused by bacterial motion and imaging fluorescently labeled cells and their flagella. This technique allowed the team to follow bacterial swimming over long durations and with a resolution hitherto unachievable. New and previously unanswerable questions can be addressed now such as whether bacteria swim with preferred spatial and directional orientations.



Calibrating *In Vivo* Tension Sensors. It has become increasingly clear that the tension across proteins can control the cellular fate but until recently it had not been possible to determine the tension applied across a protein *in vivo*. The group of Martin Schwartz at University of Virginia

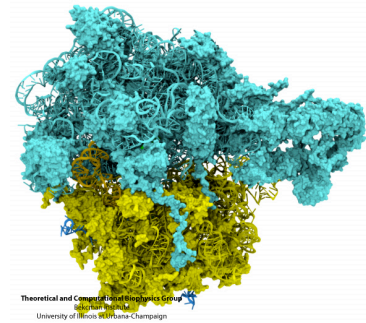
developed an *in vivo* tension sensor where a protein motif from a spider silk protein is labeled with two genetically encoded proteins of different colors at the two ends. By inserting this sensor in the middle of a protein called vinculin, they were able to show that a change in tension across the



vinculin protein can be detected as a change in fluorescence resonance energy transfer (FRET) between the two fluorescent proteins. The groups of [Taekjip Ha](#) and [Steve Sligar](#) designed a scheme to calibrate the tension sensor. By using the single molecule fluorescence-force spectroscopy instrument developed in the Ha group (Hohng et al, Science, 318, 279-283, 2007), CPLC students Michael Brenner and Ruobo Zhou built a precise mapping between the FRET efficiency and force. They found that the tension sensor is most sensitive to the force range 1-5 pN. Combined with cellular FRET imaging, the vinculin protein of a migrating cell is under about 2.5 pN of force (Grashoff et al, Nature, 466, 263-266, 2010).

Insights into the Ribosome Revealed through the Computational Microscope. The translation of genetic information into proteins is essential for life. At the core of this process lies the ribosome, a quintessential large (2.5-4.5 MDa) molecular machine responsible for translating genetic material into functional proteins. In spite of challenges presented by its sheer size and complexity, several X-ray atomic resolution structures of the ribosome have been determined (2009 Nobel Prize in Chemistry). However up until recently, these structures remained elusive for factor-bound ribosomes. Moreover, X-ray crystallography does not resolve the multitude of conformations these structures can assume, which is critical for understanding the dynamics of translation and the conformational changes undergone by the ribosome. In contrast, cryo-electron microscopy (cryo-EM) produces three-dimensional density maps of ribosomes at medium resolution and thus can capture the ribosome in different conformational states. However, these maps don't reach atomic resolution, needed to understand the function of the ribosome in detail along its functional cycle.

To solve this problem, [Klaus Schulten](#) and colleagues applied their pioneering technique, **molecular dynamics flexible fitting (MDFF)**, which morphs or flexibly fits atomic-resolution X-ray crystal structures into cryo-EM maps using molecular dynamic simulations – to obtain high-resolution structures of the *E. coli* ribosome in different functional states imaged by cryo-EM. In a collaboration with Joachim Frank of Columbia University (Gumbart et.al., (2009) Structure, 17: 1453-1464), MDFF revealed how the ribosome works with Elongation Factor EF-TU

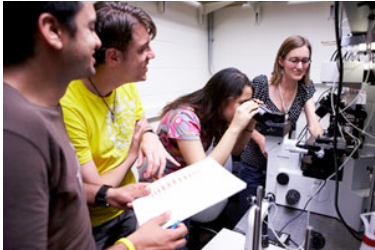


to recognize transfer RNA (tRNA). This is a critical interaction in protein synthesis since the ribosome must bind the specific tRNA that carries the correct amino acid to be incorporated into the growing polypeptide chain. Their MDFF structures revealed that upon ribosome recognition of the correct tRNA, the bound EF-TU undergoes a conformational change in which a key hydrophobic gate region swings open to allow subsequent steps in the translational elongation cycle to take place. The Schulten group has applied MDFF to resolve many other conformational states of the ribosome in combination with other interaction partners, ultimately leading to an elucidation of structural and functional dynamics of this essential machine.

Training and Outreach. Currently, the CPLC encompasses 13 faculty (Professors [Taekjip Ha](#), [Klaus Schulten](#), [Paul Selvin](#), [Yann Chemla](#), [Alek Aksimentiev](#), [Martin Gruebele](#), [Zan Luthey-Schulten](#), [Nigel Goldenfeld](#), [Karin Dahmen](#), [Steve Sligar](#), and [Carle Woese](#) from the University of Illinois, [Ido Golding](#) from Baylor College of Medicine, and [Greg Timp](#) from University of Notre Dame) as well as approximately one hundred graduate students and postdoctoral fellows. One of the key features of CPLC training is that students and postdoctoral fellows are required to work on a joint project between two laboratories/advisors, thus catalyzing new collaborative research directions and technical advances to investigate the physics of living systems.

A broader aspect of CPLC training involves participation of our students and postdoctoral

fellows as teaching assistants in the annual **Physics of Living Cells Summer School** (www.cplc.illinois.edu/summerschool/). The week-long Summer School provides hands-on, on-site training in the latest single-molecule, live-cell experimental and computational biophysical tools and is open nationwide and internationally to senior



undergraduates, graduate students, postdoctoral fellows, and researchers in chemical and life sciences, biophysics, physics and engineering. The 2009 Summer School trained 20 students in six different advanced modules focusing on single-molecule fluorescence, optical trapping, fast relaxation imaging, single event detection in living cells, and computational biophysics. This year, the 2010 Summer School has doubled in size (37 students and 11 training modules) indicative of its growing relevance to the scientific community. The unique opportunity provided by our Summer School is reflected in the following testimonial from a student in our 2009 program, “Teaming up with researchers from all over the world, I feel the excitement of exploring the molecular world of biological systems every day. Most importantly, the hands-on experience I gained from this summer school is priceless.”

The CPLC has recently established an outreach program with the Campus Middle School for Girls in Urbana, Illinois to integrate Visual Molecular Dynamics (VMD), a computational visualization tool developed by [Klaus Schulten](#), and complementary experimental labs into 7th grade science curriculum – also involving instruction by Center graduate students. The Center also sponsors new research collaborations via its Visiting Scientist Program, and actively recruits new graduate students and postdoctoral fellows through CPLC fellowship programs. If you would like more information about training and research at the CPLC, contact [Jaya Yodh](#), Director of Education and Outreach at 217-244-1155, jyodh@illinois.edu.

PRL HIGHLIGHTS

Soft Matter, Biological, &
Inter-disciplinary Physics Articles from
Physical Review Letters

2 April 2010

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**Effect of Surface Freezing on Meniscus
Relaxation in Side Chain Comb Polymers**

Shishir Prasad, Zhang Jiang, Michael Sprung, Sunil
K. Sinha, and Ali Dhinojwala
Published 30 March 2010 // 137801

**Generalized Einstein or Green-Kubo Relations
for Active Biomolecular Transport**

Udo Seifert
Published 30 March 2010 // 138101

**From Localized Orbitals to Material Properties:
Building Classical Force Fields for Nonmetallic
Condensed Matter Systems**

Benjamin Rotenberg, Mathieu Salanne, Christian
Simon, and Rodolphe Vuilleumier
Published 30 March 2010 // 138301

**Colloidal Motility and Pattern Formation under
Rectified Diffusiophoresis**

J r mie Palacci, Benjamin Ab cassis, C cile
Cottin-Bizonne, Christophe Ybert, and Lyd ric
Bocquet
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**Fruit Flies Modulate Passive Wing Pitching to
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Attila J. Bergou, Leif Ristroph, John Guckenheimer,
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**DNA Condensation at Freestanding Cationic
Lipid Bilayers**

C. Herold, P. Schwille, and E. P. Petrov
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**Macroscopic Kinetic Effect of Cell-to-Cell
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Pan-Jun Kim and Nathan D. Price
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**Nucleation of Ordered Phases in Block
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Xiuyuan Cheng, Ling Lin, Weinan E, Pingwen
Zhang, and An-Chang Shi
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Thermodynamically Stable Blue Phases

F. Castles, S. M. Morris, E. M. Terentjev, and H. J.
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**Surface Instability Driven by Dipole-Dipole
Interactions in a Granular Layer**

Daniel Lopez and Fran ois P tr lis
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**Helix-Coil Kinetics of Individual Polyadenylic
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Jianxun Lin, Anatoly Kolomeisky, and Amit Meller
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**Retinal Glial Cells Enhance Human Vision
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**Light-Harvesting Mechanism of Bacteria
Exploits a Critical Interplay between the
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Felipe Caycedo-Soler, Ferney J. Rodriguez, Luis
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M. Bottiglieri, L. de Arcangelis, C. Godano, and E. Lippiello

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Chaotic Dynamics of Red Blood Cells in a Sinusoidal Flow

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Collective Escape of Chemotactic Swimmers through Microscopic Ratchets

Guillaume Lambert, David Liao, and Robert H. Austin

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Alberto Martín-Molina, César Rodríguez-Beas, and Jordi Farauto

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Thomas E. Angelini, Edouard Hannezo, Xavier Trepât, Jeffrey J. Fredberg, and David A. Weitz

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Microdynamics and Criticality of Adaptive Regulatory Networks

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Analysis of Entanglement Length and Segmental Order Parameter in Polymer Networks

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Thomas E. Ouldridge, Ard A. Louis, and Jonathan P. K. Doye

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Synchronization and Collective Dynamics in a Carpet of Microfluidic Rotors

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Claudia Holz, Dirk Opitz, Lilo Greune, Rainer Kurre, Michael Koomey, M. Alexander Schmidt, and Berenike Maier

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Inertial Lubrication Theory

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Second Order Catalytic Quasispecies Yields Discontinuous Mean Fitness at Error Threshold

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Direct Observation of Confined Single Chain Dynamics by Neutron Scattering

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Streaming Instability in Growing Cell Populations

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Transient Shear Banding in a Simple Yield Stress Fluid

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Photoexfoliation of Graphene from Graphite: An Ab Initio Study

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Thermal Conductivity of Periclase (MgO) from First Principles

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Entropy Production of Cyclic Population Dynamics

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Fluctuation Theorem Applied to F1-ATPase

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Christopher M. Spillmann, Amit V. Kapur, Frank W. Bentrem, Jawad Naciri, and Banahalli R. Ratna
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Alexander K. Buell, Jamie R. Blundell, Christopher M. Dobson, Mark E. Welland, Eugene M. Terentjev, and Tuomas P. J. Knowles
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Ionel Popa, Prashant Sinha, Marco Finessi, Plinio Maroni, Georg Papastavrou, and Michal Borkovec

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Pressure Independence of Granular Flow through an Aperture

M. A. Aguirre, J. G. Grande, A. Calvo, L. A. Pugnaloni, and J.-C. Géminard

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Stephanie C. Weber, Andrew J. Spakowitz, and Julie A. Theriot

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Binquan Luan, Hongbo Peng, Stas Polonsky, Steve Rosnagel, Gustavo Stolovitzky, and Glenn Martyna

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L. Giomi and L. Mahadevan

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T. Guérin, J. Prost, and J.-F. Joanny

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P. Nghe, S. M. Fielding, P. Tabeling, and A. Ajdari

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Roni Parshani, Shai Carmi, and Shlomo Havlin
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Surface Alignment and Anchoring Transitions in Nematic Lyotropic Chromonic Liquid Crystal

V. G. Nazarenko, O. P. Boiko, H.-S. Park, O. M. Brodyn, M. M. Omelchenko, L. Tortora, Yu. A. Nastishin, and O. D. Lavrentovich
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Postdoctoral Position in Chaotic Advection Dynamics Northwestern University Evanston, Illinois

The group of Professor Adilson E. Motter at the Department of Physics and Astronomy, Northwestern University, has an opening for a postdoctoral position in the area of chaotic advection dynamics. The research will focus on the theoretical and computational modelling of inertial effects in the dynamics of finite-size particles transported by fluid flows, including applications to passive and active processes in physical and biological systems. Candidates with background in nonlinear dynamics and experience with computer simulations are encouraged to apply. The candidate may have a Ph.D. in physics, applied mathematics, astrophysics, mechanical engineering or a related field. Previous research experience with chaos or fluid mechanics would be a plus. The ideal candidate will also have strong analytical and writing skills and a demonstrated ability to conduct independent high-impact research.

The appointment is available immediately. Salary is competitive, depending on qualifications and experience. To apply, please e-mail curriculum vitae along with a brief statement of how your research interests are related to this position to Adilson E. Motter at motter@northwestern.edu, and arrange to have two letters of recommendation e-mailed to the same address. Applications received before November 15, 2010 will receive full consideration. For more information about The Motter Group, please go to:

<http://www.physics.northwestern.edu/people/personalpages/amotter.html>

The Department of Physics and Astronomy at Northwestern University is located in Evanston, Illinois, which is situated along the shores of Lake Michigan only 30 minutes north of downtown Chicago. Northwestern University is an Affirmative Action/Equal Opportunity Employer. Applications from women and under-represented minorities are encouraged. Hiring is contingent upon eligibility to work in the US.

Postdoctoral Position in Computational Chemistry University of Santiago de Compostela

The group of computational chemistry of the University of Santiago de Compostela (www.usc.es) offers a post-doctoral contract to investigate the adsorption of peptides onto self-assembled monolayers by molecular dynamics simulation. The work will be done under the supervision of Dr. Saulo A. Vazquez (University of Santiago de Compostela) and Dr. Emanuele Paci (University of Leeds).

Duration: one year, renewable, with flexible starting date.

Gross Salary: 32,000 Euro.

Location: Centre for Research in Biological Chemistry and Molecular Materials, University of Santiago de Compostela, Spain (<http://www.usc.es/campusvidaci/eng/centro-singular-ciqus.html>)

Qualifications: Ph.D. Degree in chemistry, biochemistry, structural biology, physics or related disciplines. Expertise in molecular dynamics simulations.

To apply please send an email and attach a CV to:

Dr. Saulo A. Vazquez (saulo.vazquez@usc.es)

Conferences, Meetings, Workshops, Summer Schools

If you would like to post an announcement for a workshop or conference in this Newsletter, send your notice (text) or a PDF document (resized to a maximum size of 7 inches x 10 inches) to the editors.

XL Winter Meeting on Statistical Physics

January 4-7, 2011

Monte Taxco Hotel

Guerrero, Mexico

The purpose of the meeting is to bring together the national community of physicists working on statistical physics and related areas, in order to exchange knowledge and results, and discuss new lines of research. We also invite a group of internationally-renowned scientists who have made fundamental contributions in their respective fields. This provides the opportunity to exchange ideas between national and foreign colleagues in a pleasant and informal environment.

The main program consists of plenary lectures given by selected invited speakers who present, in a non-technical way, the "state of the art" in their fields of study, as well as their main contributions. In addition to the plenary lectures, there will be poster sessions.

The deadline for early registration is **December 1, 2010**.

For additional information and to register, point your browser to:

<https://sites.google.com/site/wintermeetingstatphys/>

Or contact the organizing committee via the following email address:

winter.statphys@gmail.com

The 5th International Conference on Bioinformatics and Biomedical Engineering (iCBBE 2011)

Wuhan, China May 10-12, 2011

www.icbbe.org/2011

Technical Areas to be covered at this conference include:

Bioinformatics & Computational Biology:

Protein structure, function and sequence analysis
Protein interactions, docking and function
Computational proteomics
DNA and RNA structure, function and sequence analysis
Gene regulation, expression, identification and network
Structural, functional and comparative genomics
Computational evolutionary biology
Data acquisition, normalization, analysis and visualization
Algorithms, models, software, and tools in Bioinformatics
Any novel approaches to bioinformatics problem

Bioinformatics & Computational Biology:

Biomedical imaging, image processing & visualization
Bioelectrical and neural engineering
Biomaterials and biomedical optics
Methods and biology effects of NMR/CT/ECG technology
Biomedical devices, sensors, and artificial organs
Biochemical, cellular, molecular and tissue engineering
Biomedical robotics and mechanics
Rehabilitation engineering and clinical engineering
Health monitoring systems and wearable system
Bio-signal processing and analysis
Biometric and bio-measurement
Biomaterial and biomedical optics
Other topics related to biomedical engineering

Special Sessions:

Biomedical imaging
Biostatistics and biometry
The information technology in bioinformatics
Environmental pollution & public health

For more information about this conference, please contact: submit@icbbe.org

Biocomplexity XI: The Evolution of Cooperation: Paradoxes of Individuality and Collectivity

**December 3rd – 5th , 2010
Indiana University, Bloomington, Indiana, USA**

www.biocomplexity.indiana.edu/events/biocXI/

Cooperation occurs throughout the biological world, and similar mechanisms and patterns of cooperative organization appear across the hierarchies of biological structures.

Genes organize into genomes, cells into multicellular organisms, organisms into institutions and societies, and species into ecologies. Might there be important analogies between mechanisms at one such level of organization and mechanisms at a different level?

Cooperation benefits a society, while evolution selects at the level of individuals. Despite insights into the mathematics of selection in the presence of cooperation, many aspects of the development of cooperation remain mysterious in practice.

What is an individual? Is individuality discrete or continuous? Can selection act simultaneously on multiple scales? How did cells abandon reproduction to a specialized germ line? How did stable multicellularity evolve in the face of noncooperative advantages?

When does stable cooperation require enforcement? Can the fitness functions of evolutionary theory capture an individual's transfer of fitness to a collective? Are individuals the correct fundamental units of cooperative systems?

The intra-cellular cooperation of genes, molecular machines, and organelles resembles a microscopic city; does the heterogeneity of the conventional units of biology reflect an ancient cooperation predating the origin of life?

Is an ecosystem composed of individuals, or is an individual composed of ecosystems? Can the evolution of cooperation inform engineering or economic regulation?

This workshop will investigate these subtle and provocative issues, which are often ignored or misunderstood.

Talks will cover subjects ranging from cooperation inside of cells, bacterial biofilms, social insect colonies, human institutions and societies, cancer etiology and progression to the question of how single cells subsumed their fitness in favor of multi-cellular collectives.

Register by November 5, 2010

Registration is free. Please see website for more information.