NATO ASI & SUSSP 59 : EDINBURGH, SCOTLAND, UK

29th March - 8th April 2004

SOFT CONDENSED MATTER PHYSICS IN MOLECULAR AND CELL BIOLOGY

The purpose of the ASI/SUSSP was to bring together some of the principal scientists responsible for furthering the frontiers of the application of soft matter physics to the understanding of biological systems. Once together the scientists presented their work to junior researchers including myself over a ten day period.

Biology is 'living soft matter' – biological surfactants (lipids) make up the membranes, while proteins and DNA are biological polymers. Brownian motion has a dominant role – diffusion on structures with reduced spatial dimensionality (2-dimensional on membranes and 1-dimensional on various filamentous structures such a microtubules) play a crucial role in transport and other processes, while diffusion in a very-high-dimensional free-energy landscape underlies protein folding. The new insights into soft matter gained by physicists over the last few decades can therefore be expected to have significant impact on the understanding of biological systems, from single biomolecules through to cells and (perhaps) beyond. In particular, the increasing attention paid by soft condensed matter physicists to *non-equilibrium* phenomena and *dynamics* are crucial to the interaction between the two fields.

The lecturers at the ASI were

D. Andelman (Tel Aviv)
D. Bensimon (Paris)
S. U. Egelhaaf (Edinburgh)
R. Elber (Cornell)
D. Frenkel (Amsterdam)
J. F. Joanny (Paris)
M. Kozlov (Tel Aviv)
F. C. Mackintosh (Amsterdam)
T. C. B. McLeish (Leeds)
P. D. Olmsted (Leeds)
R. Podgornik (Ljubljana)
W. Poon (Edinburgh)
M. Rief (Munich)
C. F. Schmidt (Amsterdam)
C. A. M. Seidel (MPI, Goettingen)
P. B. Warren (Unilever)

The school started with an introductory lecture from Wilson Poon titled "Coarse graining in biology - *History, uses and limitations"*. This included case studies on lysozyme and amyloids showing the application of coarse graining.

Each lecturer presented three lectures on their specific areas:

Frenkel (Colloids)

Frenkel gave an introduction to colloids and bio-colloids, and then talked about diffusion in cells and forces between colloids. Other topics were colloid dynamics, the continuity of the gaseous and liquid states. Entropy was discussed in the context of entropic (hard-sphere) crystals, micelle formation, lyotropic liquid crystals and entropic cooperativity with ssDNA-coated colloids was used as an example.

Warren (Polymers)

Warren talked about polymer physics, structure in solutions, dynamics, phase behaviour, kinetics and rheology. Areas such as single chain properties and equilibrium structure (random walks, excluded volume) were covered. Multi-chain properties including phase behaviour free energy [Flory-Huggins], phase behaviour and osmotic pressure in polyelectrolytes were presented. For dynamics single chain Rouse, Zimm models, many chains, entanglements and reptation were addressed.

Olmsted (Amphiphiles)

Amphiphilic and lipid structures in the cell were discussed along with self assembly (micelles/membranes and beyond). The constituents of lipid bilayers were presented and the basics of membrane mechanics/elasticity explained. Membrane fluctuations, shapes and morphologies of membranes were covered. Finally Olmsted talked about proteins/inclusions in membranes and dynamics.

Andelman (Electrostatics)

Electrostatics in soft and biological systems was introduced covering ionic solutions and electrolyses (d=0), charged polymers, polyelectrolytes (d=1), charged surfaces, interfaces and membranes (d=2), charged colloids, proteins and micelles (d=3). The lectures then covered the Poisson-Boltzmann Equation, Debye-Huckel length and Bjerrum length. Andelman then moved on to free energy and pressure finishing with the persistence length.

Kozlov (Membranes)

Kozlov presented how biophysics applies to membranes. The elasticity of biological (Lipid) membranes was the introductory topic. Kozlov then moved on to talk about membranes as universal biological wrappers. The latter lectures were on membrane deformations in biology and biological processes involving membrane fusion.

Bensimon (DNA)

Bensimon spoke on Protein/DNAinteractions at the single molecule level. He then spoke about manipulations by a magnetic trap and monitoring a single helicase. The concluding aspects of the lecture series were studies of Single Topoisomerases, DNA supercoiling and single molecule uncoiling by topoisomerases

Podgornik (Electrostatics)

Podgornik spoke on the topic of the faces of electrostatics, weak-coupling electrostatics, strong-coupling electrostatics, DNA equation of state in low and high salt. The lecture series then looked at electrostatics and conformational fluctuations, elasticity, DNA persistence length, DNA stretching modulus. Podgornik ending the lecture series with talks on polyelectrolyte bridging, interactions between nucleosomal core particles.

Seidel (Fluorescence)

Seidel spoke about Single molecule Fluorescence spectroscopy in solution, and then on the principles of single-molecule fluorescence detection. Finally Seidel spoke about multiparameter fluorescence detection and analysis of molecular structure and dynamics by multiparameter-fluorescence spectroscopy.

Elber (Proteins)

This lecture series presented by Elber was on the topic of applied protein folding (learning theory) and the need for a search strategy (bioinformatics). Further topics covered were evolutionary capacity of protein structures (statistical mechanics), analyzing the space of possible protein sequences on a global level. Finally constraints on protein evolution imposed by thermodynamic stability and testing for evidence of evolutionary pathways between known protein folds was presented.

McLeish (Barrier Crossing)

McLeish presented one lecture on thermal barrier crossing in biological physics. The lecture presented topics such as the binding rates of proteins, currents. Further to this the Einstein relation, the general 1-d diffusive ("Kramers") case was discussed concluding with pre-exponential factors and intermediates and higher dimensions.

A book will be published on the proceedings of the course. If you have any questions please contact myself Ajay Tharakan on 01234222945 or on e-mail at Ajay.Tharakan@Unilever.com