INTRODUCTION

Biological physics at large facilities: from molecule to cell

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While walking by a spectrometer at a neutron scattering facility, I overheard the following conversation between two scientists preparing to run an experiment.

‘I have autoclaved the cells,’ said the physicist.
‘What? Are you mad?’ exclaimed the biologist.

The anecdote illustrates more than a trivial misunderstanding between colleagues of different backgrounds. Different scientific disciplines do use different languages. The experiment had been designed to characterize molecular dynamics in HeLa cells. It had been impressed upon the physicist that it was very important to work under sterile conditions, to avoid bacterial contamination. And, therefore, he had autoclaved the spectrometer sample holders, which he called ‘cells’.

Problems in biology have preoccupied physicists for centuries. Newton was fascinated by animal electricity. In the final paragraph of Principia, he reflects admirably that ‘... all sensation is excited, and the members of animal bodies move at the command of the will, namely, by the vibrations of this Spirit, mutually propagated along the solid filaments of the nerves, from the outer organs of sense to the brain, and from the brain into the muscles. But these are things that can neither be explained in few words, nor are we furnished with that sufficiency of experiments which is required to an accurate determination and demonstration of the laws by which this electric and elastic Spirit operates’.

Since the birth of modern molecular biology and its huge expansion, physics and biology have collaborated intensively to address specific issues. Interestingly, in spite of the development of wide interfacial research areas, the two disciplines maintain not only their different languages but also their specificities in the way they each approach a problem. The interfacial area of biological physics deals mainly with the physical methods and the study of the physical properties of biological systems; it is well anchored in physics departments. This is perhaps in contrast to biophysics, which often has its own departments, and mainly applies physical methods to address biological questions. Relatively easy-to-handle model systems are usually used in biological physics, the main effort going into the instrumentation, methodology and physical analysis. Sample preparations in biophysics, on the other hand, can be extremely sophisticated, involving heavy biochemistry and cell biology. Having made these simplistic, but I hope, useful generalizations, I must warn the reader that they are just that, generalizations that do not hold true and fast in all cases.

Large facilities, such as user-oriented synchrotrons and neutron sources, are, by their very nature, major interdisciplinary crossroads. They have been particularly effective in bringing together physicists, chemists and biologists to stimulate major breakthroughs. The impact of using physics methods in the study of biological systems has grown rapidly with unique opportunities offered by new instrumentation and methodologies at large facilities worldwide. In September 2008, a workshop in Biological Physics was organized in Grenoble by the European Synchrotron Radiation Facility and the Institut Laue Langevin. It succeeded in its original aim of bringing together members of the biology and physics communities for a discussion on the state-of-the-art and future perspectives of physics instrumentation and methods for the study of biological structures and dynamics at neutron sources and synchrotron radiation (SR) facilities. An integrated approach is essential to understand the physics of biological processes. The results of the discussions, however, reached well beyond the simplistic model of ‘a biologist with a problem meets a physicist with a method’. The workshop also provided the opportunity for confrontation between different conceptual approaches to the problems posed by the complexity of biological systems: for example, that of the soft matter physics community, on the one hand, and that of biophysicists, biochemists and cell biologists, on the other.

The articles in this themed issue were invited from the presentations given at the workshop. This issue is not a complete review of biological physics at large facilities, as each contribution is not necessarily a complete review of its field. Rather, papers were selected to illustrate the variety of instrumental and

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Methodological approaches being developed and the increasing complexity of the systems that are being open to study. In the context of encouraging a common interdisciplinary language, there is a paper by Lakey (2009) aimed at biologists, on neutron-scattering techniques. The limitations of high-resolution protein crystallography due not only to cell dimension, but also to crystal size and quality, are being pushed back. A paper by Yonath (2009) describes the amazing results from SR crystallography on the ribosome, the vast macromolecular complex that is the protein factory in all cells. Cherezov et al. (2009) describe SR applications in the examination of sub 10 micron size membrane protein crystals, and, at the other extreme, we have a paper by Oksanen et al. (2009) on large crystal growth for high precision neutron crystallography to characterize protonation states. Three papers by Jasnin et al. (2009) describe SR techniques to help understand protein growth for high precision neutron crystallography to elucidate the protonation states. Three papers by Jasnin et al. (2009) describe SR applications in the examination of sub 10 micron size membrane protein crystals, and, at the other extreme, we have a paper by Oksanen et al. (2009) on large crystal growth for high precision neutron crystallography to characterize protonation states. Three papers by Jasnin et al. (2009), Ortore et al. (2009) and Paciaroni et al. (2009) discuss the measurement of molecular dynamics in vitro and in vivo by neutron spectroscopy. Kaulich et al. (2009) and Ortega et al. (2009) report on major developments in cell imaging by various SR-based techniques. The soft-matter physics characterization by SR and neutron reflectometry of model membrane lipid systems and their interactions are described in two papers by Zhao et al. (2009) and Schneck et al. (2009). Human antibody and complement proteins participate in cascade molecular interactions that form a vital part of the immune system. A paper by Perkins et al. (2009) describes how the structures of these proteins were modelled from small angle X-ray and neutron scattering to provide novel biological insights.

References


