Cavendish Laboratory

13. Biological and Soft Systems Research Sector

http://www.bss.phy.cam.ac.uk

What is Biological Physics?

Traditionally physics and biology are considered to be two different subjects. Physics stands for the study of Newtonian mechanics, optics, electricity and magnetism, or simply the mathematical description of the motion and action of macroscopic objects. Biology on the other hand is the science describing how life is build up of complex molecules such as DNA or proteins that make part of cells constituting our body. However, many famous physicists who are known for their achievements in 'hard condensed matter' and nuclear physics (like Erwin Schrödinger or Niels Bohr), and also natural scientists such as Darwin have contributed profoundly to our understanding of life. Some have done fundamental experimental work in areas such as molecular structure and dynamics, photosynthesis, or cell membranes. Others have applied their mathematical skills to develop theories for neural networks, electron transfer and phenomena such as the heart's rhythm. Others have found that their skill as instrumentalists can change medicine, through such advances as computed tomography and magnetic resonance imaging. All have experienced the excitement of working in this rich and interdisciplinary field.

DNA – a carrier of life and versatile building material for new applications.

The double helix of DNA was discovered here in the Cavendish by Watson and Crick. It is one of the greatest discoveries of the 20th century, and led to the understanding we have of genes and how they work. But how are genes actually controlled? Is DNA always a double helix? And how does it all fit inside every human cell - there's 2 metres of it in every single cell?

But DNA can be used for much more than just biology - we can make new materials out of it, and make complicated three-dimensional shapes - a kind of DNA origami. We can use it to make tiny motors, and boxes that open and shut with a key. And maybe we can make computers out of it as well ... a true biological computer.

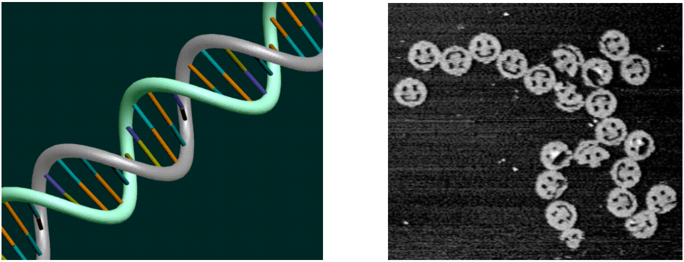

Figure 1: DNA origami of viruses made by Paul W.K. Rothemund from a harmless virus-DNA. He "pinched" it into shape with "staples" made from of much shorter DNA strands (ref.: P.W.K. Rohemund, Nature, Vol 440|16 March 2006|doi:10.1038/nature04586).

Stretching cells with light: Early cancer diagnosis

Just like mammals have a solid skeleton to keep the shape of the body and give it rigidity cells also have a skeleton – the cytoskeleton. This is make of specialized proteins that form long semi-flexible polymers giving cells their shape and mechanical strength. Physicists have found that when cells are exposed to two opposing laser beams a cell can be trapped by the optical pressure. This pressure can stretch the cell by varying amounts depending on its elasticity. In recent years researchers at the Cavendish have shown that cells of the same type become much softer (more deformable) when they are cancerous. Hence they developed a diagnostic tool from this to discriminate healthy from cancerous cells.

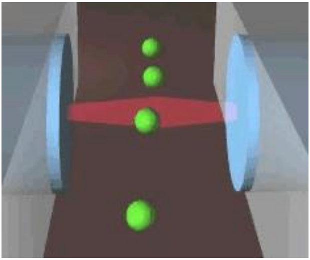

Figure 2: Schematic of an optical stretcher. In a flow chamber, cells in suspension can be trapped by two opposing laser beams of low intensity, emanating from optical fibers. Increasing the intensity of the laser light augments the forces at the surface of the cell, leading to measurable deformation. Publication: J.Guck et al., Biophysical Journal 88:3689-3698 (2005)

Butterfly wings: Colour produced by structure

Some colors we observe in Nature are not caused by pigments but simply by micron-sized building blocks that are arranged in a very ordered fashion. Examples are opals, which are semiprecious stones made of spherical silica particles, some butterflies and beetles show colored wings that are due to sub-micron structures and not pigments.

Figure 3: The blue color of the wings of the Morpho (left) is due to the highly regular packing of its building blocks (right). (reference: Y. Zheng, X. Gao and L. Jiang, Soft Matter, 2007, DOI: 10.1039/b612667g)

Researchers in the Biological and Soft Systems sector of the Cavendish Laboratory are learning from these examples in nature in order to make new ‘photonic’ materials that could be used to develop better light-harvesting solar cells, lasers, and mirrors for electronic applications.