PHYSICS AND CHEMISTRY SHOW THEIR WORTH

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Many sectors claim to benefit the UK economy, but physics and chemistry are a rarity for actually providing evidence, according to Imperial College economist Professor Jonathan Haskell.

His previous work on the contribution of science to economic growth was widely quoted by ministers prior to the government's spending review of 2010. He was speaking at the launch, held at the House of Commons in June, of two series of case studies showing how curiosity-driven research leads to new technologies that affect our daily lives.

He joked that he's seen enough figures on contributions to the economy to account for 170% of GDP, but rarely any evidence to back up those assertions. *Physics: Transforming lives*, produced by the Institute of Physics, and the Royal Society of Chemistry's *Chemistry: We mean business* provide just that.

Examples of applications of science, on cancer treatments derived from fundamental physics and on the role of chemistry in healthcare, were discussed by physicist Professor Dewi Lewis and by University of York chemist Professor David Smith.

The event was hosted by Alok Sharma MP, who said he was pleased to see that the case studies were produced as a collaborative effort between the research councils and learned societies. "What you have provided is demonstrating the fantastic link between academia, research, industry, the economy and the marketplace," he added.

Scientists from around the UK were on hand at the event, held on the Commons' terrace, showcasing their research and its applications.

Copies of the case studies are available from the Institute of Physics and Royal Society of Chemistry websites, iop.org and rsc.org.

CANCER TREATMENT (from IOP's *Physics: Transforming lives*)

Cancer refers to a wide group of diseases in which cells divide uncontrollably, producing a tumour that seriously disrupts surrounding tissues. When cancers are particularly aggressive, these out-of-control cells can also spread to other parts of the body, causing yet more damage.

Radiotherapy involves directing high-energy radiation – such as X-rays and beams of particles, including electrons and protons – at a tumour to destroy it. The aim is to damage the DNA of the cancer cells to stop them proliferating, while ensuring that the radiation dose received by healthy tissue is small enough that it can recover. The particle accelerators that produce these high-energy beams were originally developed for the study of particle and nuclear physics.

The chances of surviving cancer are greatly enhanced by early and accurate diagnosis, and knowing its precise location and size. Here, too, physics has provided many of the most important tools. Exploring the structure of the universe on the very small scale (atomic, nuclear and particle physics) or the large scale (astronomy and cosmology) requires the development of new ways of "looking" at things that cannot be seen with the naked eye. This ability to visualise what cannot ordinarily be seen has led to the advanced imaging that underpins modern medical diagnostics.

HOW DOES RADIOTHERAPY WORK?

When a charged particle or an X-ray passes through any substance, it knocks out electrons, leaving a trail of ionisation. When it passes through the body, this ionisation can break one or both of the strands of DNA. If the damage is small, the cell's natural repair mechanisms can fix it. But a complex double-strand break – in which there are multiple breaks close together in each helix – is too difficult, leaving the cell unable to reproduce successfully. By carefully designing the treatment plan to accumulate a high radiation dose in the tumour, while keeping the dose to normal tissue low enough for repair mechanisms to work, the tumour can be destroyed.

IMPACT

One in three people will get cancer at some point in their lives. The chance of getting cancer increases with age, with about two-thirds of cancers occurring in people over the age of 65. In 2010, there were around 157,250 deaths from cancer in the UK. Although cancer survival rates have doubled in the past 40 years, the number of sufferers increases each year because of advances in diagnosis and an ageing population.

More than half of cancer patients will receive radiotherapy as part of their treatment, and radiotherapy contributes about 40% to the successful treatment of cancer. Half of the world's 20,000 particle accelerators are in use in hospitals, and each can treat between 4500 and 6500 patients per year.

Increasingly, patients are being treated with more advanced radiotherapy treatments, such as proton-beam and gamma-ray therapies. In 2012 approximately 70,000 patients worldwide received proton beam therapy, but it is estimated that 137,000 patients per year could benefit from the treatment in the US alone. Worldwide there are around 150 Gamma Knife units, which have collectively treated around 500,000 patients with brain tumours.

The Department of Health recently announced a £250m investment to build two proton-beam therapy centres in the UK by 2017. It is estimated that more than 1500 patients per year would benefit from the establishment of a new National Proton Beam Therapy Service in the UK. Today there are 43 proton and carbon-ion centres worldwide, and 23 more are planned or under construction. The UK is a key supplier of component parts for these modern accelerators.

Early detection of cancer, for example through physics-based imaging techniques, greatly increases the chances of successful treatment.

Better diagnosis and shorter waiting times also mean that people living with the disease can have an enhanced quality of life. In addition to the human costs of the disease, cancer also exacts huge economic costs. The direct healthcare expenditure on cancer in the UK is £5.6bn a year. There are also additional costs through time off work, the impact on family and friends of continuing care, and the loss of productivity due to premature death.

FUTURE

Work continues to refine imaging techniques so that radiation can be targeted to match the tumour shape ever more precisely. Cheaper and more compact accelerators and beam-delivery systems will make proton and light-ion therapy accessible to many more patients. New ideas, such as using nano-particles to increase the radiosensitivity of cancer cells while leaving healthy cells unaffected, will allow cancer to be treated with lower radiation doses and thus fewer side effects.

In figures

- 200 different kinds of cancer affect all parts of the body, and all can be fatal if left untreated
- 324,579 people were diagnosed with cancer in the UK in 2010
- 157,250 deaths from cancer in the UK in 2010
- 70,000 patients received proton-beam therapy in 2012 worldwide
- £5.6 bn: the annual direct cost of all cancers to the UK economy
- ⅓ of people in the UK will develop some form of cancer during their lifetime
- ½ of cancer patients will receive radiotherapy as part of their treatment
- 500,000 patients worldwide have undergone Gamma Knife treatment for brain tumours
- 43 proton and carbon-ion centres available worldwide; 23 more are planned or under construction including two in the UK
- 10,000 hospital particle accelerators worldwide, each treating 4500–6500 patients per year

PERSONALISED MEDICINE (from RSC's *Chemistry: We mean business*)

Personalised medicine involves selecting the best treatments for individuals on the basis of their genetic make-up and an understanding of how proteins interact with pharmaceuticals.

Achieving this requires better access to information about DNA, RNA, proteins and a range of other molecules. It is important to analyse these in a research setting to understand disease, and in a clinical setting to direct treatment of patients.

Oxford Nanopore Technologies Ltd is developing the devices GridION™ and MinION™, using nanopores to analyse single molecules such as DNA, RNA or proteins. A nanopore is a hole, or channel, in a cellular membrane that is one-billionth of a metre wide. This diameter is about the same size as the width of DNA molecules, meaning the DNA can thread through the hole.

When this happens, unique electrical signals are generated by the individual units that make up DNA. These signals can be decoded and the DNA sequence determined. In this way, the device is designed to determine the make-up of whole genomes from plants, humans or small organisms.

The company was founded on the basis of years of publicly-funded fundamental research carried out by Hagan Bayley, a Professor of Chemical Biology at the University of Oxford, and colleagues at other institutions. The company has since amassed intellectual property (IP) collaborations with the University of Cambridge, Harvard University, Brown University, University of California and Boston University.

Initial investigations into nanopores were carried out by his research group, which was then based in the USA. In 2003, Hagan moved back to the UK, encouraged by the construction of the Chemistry Research Laboratory (CRL) at the University of Oxford. The state-of-the-art facility was supported by capital expenditure by the UK Government and other donors.

In 2005, Hagan began investigating the idea of setting up a spin-out company. Locating the company at Oxford made sense because of easy access to the university and well-equipped science parks. Today, Oxford Nanopore Technologies Ltd is a world leader in nanopore technology and employs 140 people. The company aims to deliver devices for molecular analyses, one of which (MinION™) will be disposable and will connect to a computer USB.

Research at Oxford will contribute towards the exciting era of personalised medicine allowing people access to rapid, cheap and accurate health information.

In figures

- 1997: first paper on the use of nanopores as sensors published
- 2005: Oxford Nanopore Technologies Ltd set up
- 140 people employed across four locations
- £105m investment raised from private funders
- 350 patents/patent applications owned or licensed by the company
- $2bn: cost of sequencing the first human genome
- >$5000: current cost of sequencing a full human genome
- >3bn: DNA base pairs in the human genome
- £60m: funding committed by the Medical Research Council over four years towards personalised medicine initiatives