The importance of engineering and physical sciences research to health and life sciences

The government places a high priority on health and life sciences (HLS) research. However, what is often less apparent is the extent to which HLS research is dependent on engineering and physical sciences (EPS). The Engineering and Physical Sciences Research Council (EPSRC) invited an independent review group to explore the relationships between EPS and HLS, looking at the role that EPS has played in key HLS developments and how this relationship is likely to develop over the next 10-20 years. The group's findings and recommendations are included in a new report *The Importance of engineering and physical sciences research to health and life sciences.*

The role of engineering and physical sciences

The UK has one of the strongest and most productive life sciences industries in the world, contributing to patient well-being as well as supporting growth. UK life science industries generate a turnover of over £50 billion and employ 167,500 people in over 4,500 companies[1]. EPS research, including mathematics, statistics and computer science, plays a major role in advancing HLS and will be increasingly important in the future.

[1] www.gov.uk/government/organisations/office-for-life-sciences

Messages for policymakers and stakeholders

- To achieve the UK's potential in health and life sciences (HLS) it is important to invest in engineering and physical sciences (EPS) which continue to play a vital part in tackling major challenges, such as an ageing population, the sustainable provision of food and the development of cost-effective medicines.
- Research organisations and funders have a major role in identifying and defining the important research challenges. However, these challenge-driven approaches should not exclude support for curiosity-driven research.
- In order to maintain a leading role in health and life sciences, it is critical that we continue to support researchers throughout their careers and across interdisciplinary environments.
- The role of EPS should be integrated into the UK strategy for life sciences. Government departments need to ensure that they fully engage with relevant stakeholders in developing and delivering a shared vision for this interface.
- To promote and encourage interdisciplinary research at the EPS/HLS interface, key stakeholders need to consider how interdisciplinary research and the environment in which it occurs can best be measured.

- An analysis of internationally-renowned organisations undertaking HLS relevant research, including the MRC Laboratory of Molecular Biology (LMB), the Howard Hughes Medical Institute and the European Bioinformatics Insitutute, shows the vast majority of cutting edge HLS advances resulted from advances in physics, chemistry, computing, mathematics, statistics, materials and engineering.

- Over the past 50 years various technological advances in instrumentation, computation, and analysis have enabled key breakthroughs in areas such as molecular biology, medical imaging and drug discovery and enabled life scientists to develop new research approaches, based on huge datasets, which are opening up new avenues of discovery.

- Around 25 per cent of EPSRC's research grant investment (more than £2 billion) over the past 20 years is relevant to HLS with EPSRC-funded research underpinning developments in areas including medical imaging, drug production, biomaterials and tissue design, clinical technologies, improvements in hospital design to reduce infection and a range of assistive and mobile healthcare technologies.

- Publication and citation analysis by Leiden University shows 10 per cent of publications from across all areas of EPS and HLS address interdisciplinary topics at the EPS/HLS interface, with areas such as medical statistics and informatics increasing significantly faster than other areas, reflecting the major developments in computing power that have contributed to bioinformatics and genomics research.

Since 2000 all except one of the Nobel Prizes for Chemistry and half of the Nobel Prizes for Physics have been awarded for discoveries with life science applications. During the last 35 years, 11 of the Nobel prize-winners for medicine have had a background in chemistry, physics or engineering.

Looking ahead

Five world-renowned experts have authored forward-looking think pieces, highlighting how EPS is likely to help enable future major breakthroughs. Summaries of the think pieces follow, whilst the full think pieces are available in the review report.

Agriculture and food

Dr David Lawrence, Non-Exec Director, Syngenta

Feeding the world sustainably is recognised as a major challenge: globally food production will need to grow by at least 50 per cent and perhaps as much as 75 per cent. This will only be possible with significant research-based innovations in areas such as crop protection (e.g. through safe herbicides and insecticides), improving crop take-up of key nutrients such as nitrogen and phosphates, improving water recycling in agriculture and understanding and applying best practice in agricultural settings. Developments will rely heavily on EPS research in areas such as catalyst technology, sensor technology, soil chemistry, advanced informatics and chemical synthesis.

Brain mapping

Professor Steve Furber, Professor of Computing Engineering, University of Manchester

The economic cost of brain disease exceeds the combined cost of heart disease and cancer in developed countries. Computing research to increase our understanding of how the brain processes information will improve the cost-effectiveness of developing new drugs to combat brain disease. Understanding how the brain processes information will require ICT research into areas such as biologically-inspired image sensors, models of computation that mimic processing techniques in biological nervous systems and improving fault-tolerance in computer systems.

> *Life science – and the UK's role in it – is at a crossroads. Behind us lies a great history of discovery, from the unravelling of DNA to MRI scanning and genetic sequencing. We can be proud of our past, but this government is acutely aware that we cannot be complacent about the future.*
>
> Prime Minister David Cameron

Future drug discovery

Professor Patrick Vallance, President, Pharmaceuticals R&D, GlaxoSmithKline

In the last two decades medicines have turned HIV from a death sentence to a chronic disease with near normal life expectancy, led to the cure of certain types of childhood cancers, radically altered the outlook for breast cancer and many other cancers and greatly improved the lives of millions of people with chronic disorders. To accelerate the revolution in healthcare, capabilities in EPS must be further developed in areas such as informatics (allowing, for example, 'in silico' prediction of drug effects and minimising testing), tissue engineering (testing of printed organs on chips), next-generation chemistry (allowing more targeted therapy including production of bi-functional molecules) and high resolution molecular imaging of drugs in the body.

Major health challenges that engineering and physical sciences can contribute to:

- an ageing UK population and its impacts on healthcare;
- health challenges arising from changing diet and lifestyles;
- the needs for developing nations to improve preventative health care;
- new therapeutics to tackle neurodegenerative diseases.

Major health challenges that engineering and physical sciences can directly address:

- multiple drug resistance of disease-causing microorganisms;
- implants that last the lifetime of the patient;
- developing our understanding of brain function and brain disease through to therapy;
- developing new, more efficient, cost-effective personalised therapies.

Medical devices and surgery

Professor The Lord Darzi of Denham, Professor of Surgery, Imperial College London

Since the start of the 20th Century, advances in healthcare have transformed human health – life expectancy has doubled in this time and surgery and medical devices have made major contributions to this progress. We face significant healthcare challenges including the threat of non-communicable diseases such as obesity and diabetes, burgeoning healthcare expenditure and the need for cost-effective prevention, as opposed to cure. The challenge will be to create new and disruptive treatments and diagnostics in order to make better health decisions for clinicians and patients. It will require the parallel advancement of cutting edge robotics, micro-processing, computer technology, miniaturisation and sensing technology, with the goal of creating bio-compatible technologies.

Genomics and healthcare

Professor Sir John Bell, Regius Professor of Medicine, University of Oxford

Rapid advances in big data, genomics and mobile health are transforming the global healthcare market. The ability to use big data in conjunction with the significant EPS-led innovations in genome sequencing will help decipher a range of diseases, including cancers, arthritis and vascular diseases. Doctors will be more able to prescribe with precision the best health treatments and preventative care available, bespoke to an individual's unique genetics and circumstances, through significant input from data scientists, computer scientists and statisticians working with health experts to analyse and interpret the data effectively. A wider take up of 'mobile health', which will shorten hospital stays, enable patients to have rehabilitation at home and improve patients' health, will require further advances in EPS areas such as sensors and detection systems, miniaturised analytical devices, information processing and communications technologies.

Case study: DNA sequencing

The advent of rapid DNA sequencing methods has greatly accelerated biological and medical research and discovery.

X-ray crystallography
Chemistry
Physics

DNA double-helix structure discovered

1953

Watson, Crick and Wilkins awarded Nobel Prize in 1962

Chain-termination reactions and radioactive labelling
Chemistry
Physics

Rapid DNA sequencing method developed

1977

Sanger awarded Nobel Prize in 1980

Fluorescent labelling
Capillary electro-phoresis
Chemistry

Advances in automation technologies
Engineering

Automated DNA sequencing

1987

1995 – EMBL-EBI established in the UK

Advances in informatics to handle large data sets
Computer Science

Human Genome sequenced

2003

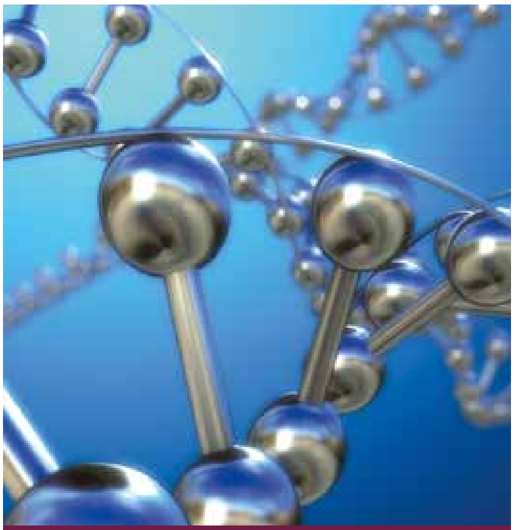
New informatics approaches

Advances in nano-materials, microfluidics and other miniaturisation techniques
Materials
Analytical Science
Chemistry

Portable, low-cost DNA sequencers including 'DNA chips'

Better understanding of the genetic basis of diseases and drug responses

Personalised healthcare based on individuals' genome sequence



In April 1953, James Watson and Francis Crick published the structure of the DNA-helix, the molecule that carries genetic information from one generation to the other. Their discovery was the result of a combination of experimental (x-ray crystallography) and theoretical approaches.

Sanger's team at Cambridge developed a rapid DNA sequencing method using chain-termination inhibitors which was widely used for the next 25 years.

In 2003 an international team of researchers, including UK scientists funded by RCUK and the Wellcome Trust, completed the DNA sequencing of the human genome.

The opportunities this offers include: genotyping of specific viruses to direct appropriate treatment; identification of oncogenes and mutations linked to different forms of cancer; the design of medication and more accurate prediction of their effects; advancement in forensic applied sciences; biofuels and other energy applications; agriculture, livestock breeding, bioprocessing; risk assessment; bioarchaeology, anthropology and evolution.

The major current sequencing technology was developed by academic researchers at Cambridge and commercialised by the company Solexa (subsequently acquired by Illumina in 2007). Another UK-based company, Oxford Nanopore, is developing portable, low-cost, DNA analysis sequencing devices by exploiting breakthroughs in the chemistry and physics of nanopores.

More case studies are included in the review report.

The importance of engineering and physical sciences research to health and life sciences is available on the EPSRC website.

www.epsrc.ac.uk