

Discoveries that would not survive the REF

According to Professor Donald Braben, Honorary Professor, Department of Earth Sciences, University College London, virtually every major scientific discovery ever made would not have survived the current REF regime with its emphasis on economic impact. However, herewith a few comments on some of those from the UK:

- Crick and Watson: Nobel Laureates Medicine, 1962. Sir Lawrence Bragg, also a Nobel Laureate and head of the *physics* department, raised serious objections to their proposed use of X-ray crystallography. Bragg was an expert. Neither Crick nor Watson had previously used X-rays. But having seen the X-ray crystallography photographs taken by Rosalind Franklin at Kings College, they went ahead and discovered the double helix structure for DNA.
- Sydney Brenner: Nobel Laureate, Medicine 2002. 'For many years it was widely held that molecular biology was a completely useless subject, a 'fundamental' science of no interest to those working on practical matters.' *Science* 282, 1411-1412. (1998)
- Peter D Mitchell, Nobel Laureate, Chemistry, 1978. Mitchell proposed the chemiosmotic process in 1961, arguably the most important biological-sciences discovery of the 20th century. His radical proposal challenged the conventional wisdom of the time, and was received by almost total hostility. It led to the famous 'ox-phos' wars for example.
- Max Perutz and John Kendrew, Nobel Laureates, Chemistry, 1962. They worked on the problem of haemoglobin structure for 25 years. For most of that time, they made (in their own words) only 'modest' progress.

Examples of curiosity-driven discoveries in different disciplines:

Physics

The Institute of Physics Chief Executive, Dr Robert Kirby-Harris, said recently: 'History shows us that in many cases it is basic research, undertaken purely out of curiosity to understand more about our world, that has delivered revolutionary breakthroughs. X-rays, lasers and semiconductors - technologies which are widely used in every aspect of our lives - all stem from discoveries made through fundamental research, undertaken without any immediate application in mind.'

www.sciencecampaign.org.uk/press/releases/2009/Caseimpactspr2009.pdf

Case Studies -

www.iop.org/activity/policy/Publications/Case%20Studies/page_29803.html

The Institute of Physics has produced the following set of case studies showcasing the vital contribution that curiosity-driven physics research has made to a number of major technological developments, which in turn have led to significant contributions to the UK's gross domestic product and/or improved the quality of life of its people.

The institute aims to update the case studies, particularly the timelines, on a regular basis and is keen to receive any relevant information.

Cancer diagnosis and treatment

Physics research has played, and continues to play, an essential role in improving the diagnosis and treatment of cancer.

(Updated: 16 July 2009)

DNA and physics

The discovery of the structure of DNA heralded the birth of the field of molecular biology, in which physicists, chemists and biologists work together to unravel the basic processes of life.

The global positioning system

Satellite-based navigation and positioning technology, underpinned by physics research, is no longer the preserve of the military but is now an invaluable aid in all aspects of life.

Holography

A technique creating three-dimensional images based on the physics of light waves, and invented in the UK, has a range of applications – from security to data storage.

Lasers

Lasers provide the archetypal example of how a discovery in basic physics led to an invention, several decades later, that was unpredictably world-changing.

Liquid-crystal displays

Liquid-crystal displays have become the image-display technology of choice, following a long chain of physics-based R&D initiated by pioneering work in the UK.

(Updated: 8 September 2009)

Magnetic resonance imaging

Magnetic resonance imaging, based on ideas from nuclear physics and developed in the UK, is now a routine, safe, clinical technique for seeing inside the body and diagnosing disease.

Optical fibres

Light-carrying glass fibres have transformed communications, thanks to pioneering work carried out by UK physicists.

The ozone layer

Understanding and protecting the ozone layer in the upper atmosphere has been a major achievement in physics-based environmental research.

The World Wide Web

The World Wide Web is an outstanding example of how research in particle physics changed the world in a totally unforeseeable way.

Chemistry - Sir Harry Kroto on c60

Curiosity powered research discovers c60

'I had been fascinated by carbon chains ever since my PhD work (1961-64) and David's polyynes re-awakened this interest and in particular initiated ideas about how very long carbon chains might vibrate. The image in my mind was of the way I had seen a wave blip travel along a long slack-ish wire or rope and a travelling wave in a canal or river such as the Severn Bore. I wondered how quantum mechanics would handle these sorts of problems. Could we study the highly excited vibrational levels of such chains and observe quantum properties gradually metamorphose into this sort of classical visually-imaged behaviour as implied by the Bohr Correspondence Principle?

Applications only now becoming apparent

'The discovery of C₆₀ will have its 25th anniversary next year and it is only now that applications appear to be on the horizon. One of the most important properties of C₆₀ is that it is an outstanding electron trap and the commercialisation of organic solar cells doped with fullerenes (which improve the efficiency of electricity production by about an order of magnitude) and printed on inexpensive thin plastic is now imminent. On the medical front the fullerene cages are able to trap biologically toxic atoms inside the cage physically, rather than chemically, and their application as non-toxic MRI imaging and radioactive anti-cancer agents appears also to be imminent. The Mitsubishi Company has invested some \$20M in a plant which produces fullerenes by a combustion process in tens of kilogram quantities.

Scientific method and the relationship between pure and applied science

History has shown time-and-again that the basics of the above story are very often the way that important breakthroughs occur. Indeed it is blindingly obvious that the really unexpected and unpredictable discoveries are invariably more important than those that are the result of targeted initiatives. The discovery of C₆₀ was the result of an experiment to understand stellar and interstellar chemistry and thus a totally 'Left-field' breakthrough.

Time-and-again it is only when discoveries are made that possible applications become obvious and then almost invariably made by scientists in a totally different field from that of the original discoverer.

Example - Lasers

'Excellent examples are the applications of lasers to eye surgery and bar-code scanners at supermarket cash desks which I doubt were in the mind of Charles Townes who developed the microwave amplifier by stimulated emission of radiation. I suspect, personally, that in general the mindset of those who are successful at making fundamental breakthroughs in

the sciences is fundamentally very different from those of the entrepreneurs who are successful at applications – perhaps even orthogonal in many cases.'

Professor Don Braben agrees on lasers

'The new proposals ignore valuable lessons from the past. This is eloquently illustrated by the example of laser devices cited by Donald Braben. Lasers are used today in everything from surgical procedures to light displays, but it was not until 20 years after the technology was invented by the Nobel prizewinning scientist Charles Townes that industry began to see its potential (Professor Townes certainly did not). What would happen today if a scientist sought funding from UK research councils to pursue inquiry on similar lines? The laser was described, for a very long time, as 'a solution looking for a problem.'

Maths

Professor Ari Laptev, President of the European Mathematical Society, said: 'It is true that many new results in mathematics do not have immediate applications but, eventually, most of them do become applicable. Let me mention a few recent examples where the use of mathematics has proved crucial':

- Integral geometry, dealing with so-called inverse problems, has provided a methodology used in: medical imaging for identifying tumours, weather radars, the search for oil fields, astronomy, etc.
- The creation of modern fibre optic cables would not be possible without the discovery of special solutions of non-linear equations called solitons.
- The arrival of the Internet made people fear that the world would be drowned in vast amounts of information. This problem has been successfully resolved by Google, which invariably delivers, instantly, the information sought. It seems like magic but the searching algorithm of Google was in fact provided by mathematicians.
- The theory of wavelets has been enormously important in telecommunications. It allows us to transmit information in a most compact way and ultimately gives us the possibility of all sorts of wireless connections.
- Credit card security is only possible thanks to cryptology, which uses a branch of number theory.
- Mathematicians are involved in improving the understanding of fundamental problems in genomics research, cell signalling, systems physiology, infection and immunity, developmental biology, the spreading of disease and ecology.

From same article: 'The mathematical theories used in these examples were not originally developed with any particular application in mind but purely as a result of the curiosity of scientists.'

www.ems-ph.org/journals/newsletter/pdf/2009-09-73.pdf - from page seven

Medicine and Pharmacology

Professor David Colquhoun (UCL): 'I think of the work of Heinz Schild on quantitative receptor classification which James Black later credited with the being what allowed him to discover two new classes of drug and get a Nobel Prize.'

Tim Hunt: Nobel Laureate, Medicine, 2001: Quote from his Nobel Autobiography; 'Today, cyclins and cyclin-dependent protein kinases are recognised as key elements in the regulation of cell cycle transitions, and the family of proteins has grown considerably, thanks to work in many laboratories. I well recall the scepticism in the early days, however, when most people did not believe things could be so simple as making an enzyme to catalyse mitosis, and then destroying the enzyme to leave mitosis. Moreover, in retrospect, we were very slow to realise that cyclins were regulatory and activating subunits of Cdc2 and its relatives. I do not know why this penny took so long to drop.'