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Summer 2011

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The Journal of the Parliamentary and Scientific Committee

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The Science and Technology (S&T) Select Committee, whose activities are widely advertised and are open to the general public, is perhaps one of the most important, and generally interesting activities that takes place on the Parliamentary Estate, on a regular weekly basis, with a potentially very high "impact" factor right across the nation.

The opportunity, thereby provided, to hold the Government to account, not just on the activities of a single Department, but right across the whole spectrum of STEM-related activities in Government, including the Treasury, is unique in the House of Commons.

Since I am the first Chair to be elected to this post by Parliament and not appointed, the independence of the views expressed in the ensuing discussions is thereby guaranteed and untainted by political prejudice or pressure from any external source whatsoever.

Following the General Election we have systematically tackled a broad but relevant range of STEM-related topics that are very high, not only on the Government's agenda, but which are also of concern and import to the wider science and engineering community in the UK and the public generally, who will hopefully also benefit from our activities on their behalf. Indeed, as Parliamentarians, we have a unique opportunity here, where science and politics meet, to help deliver the best possible solutions for all concerned.

A current summary of topics reviewed by the Committee is very broad ranging.

Our work commenced with an investigation and evaluation of criticisms made of the professional integrity of scientists at the University of East Anglia affected by the hacking of emails related to climate change. This was followed by an assessment of the UK's need for Technology Innovation Centres (TICs) as an essential facility promoting industrial and economic regeneration. A review of science advice available to Government in emergencies considered swine flu, cybercrime, solar storms and volcanic eruptions. This was followed by particle physics and astronomy. Strategic Metals went from nowhere to the top of the agenda very rapidly. The reasons for and likely impact of a move by the MRC (Mill Hill) to a UCL site at St Pancras in order to create the UKCMRI, was examined. The Forensic Science Service, Peer Review of Scientific Publications and the perceived need for much more Practical Hands-On Science and Fieldwork in Schools generally completes the current picture.

Andrew Miller MP
Chairman, Parliamentary and Scientific Committee

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The Journal of the Parliamentary and Scientific Committee.

*The Committee is an Associate Parliamentary Group of members of both Houses of Parliament and British members of the European Parliament, representatives of scientific and technical institutions, industrial organisations and universities.*

The Parliamentary and Scientific Committee

Science in Parliament has two main objectives:

1. to inform the scientific and industrial communities of activities within Parliament of a scientific nature and of the progress of relevant legislation;
2. to keep Members of Parliament abreast of scientific affairs.

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# INCREASING THE SIZE OF THE POOL:

## Preparing for the transfer from school and college science and mathematics education to UK STEM higher education

Professor Athene Donald DBE FRS Chair of the Royal Society Education Committee, and Professor of Experimental Physics at the University of Cambridge.

**In February 2011, the Royal Society recommended reform of the UK's A-level system in order to allow more students to progress to higher education within the core sciences[1] and mathematics, to help produce more STEM (science, technology, engineering and mathematics) specialists, including school and college teachers, and ensure that the UK remains a world leader in science.[2]**

The Royal Society's fourth 'state of the nation' report, *Preparing for the transfer from school and college science and mathematics education to UK STEM higher education*, assessed participation in science and mathematics in post-16 school leaving examinations. Detailed analysis of the pupil-level data revealed, for the first time, the combinations of science and mathematics subjects taken by students.

The report's main finding is the worryingly low level of participation in science and mathematics by 16-19 year olds in all parts of the UK except Scotland. This means that the 'pool' of students able to proceed to study STEM subjects at first degree level is too small to fulfil the needs of UK employers, as identified in the CBI/EDI education and skills survey in 2010. In England, Wales and Northern Ireland in 2009, only 28/27/37% of all A-level students respectively achieved at least one mainstream science qualification (with or without mathematics), compared with 50% of students in Scotland. Furthermore, a significant number of institutions in England, Wales and Northern Ireland do not enter any candidates for A-level physics or mathematics. In 2009, 18%, 12% and 43%, respectively, of all relevant institutions in these nations failed to present a single physics A-level candidate.

The higher proportions of students taking core sciences and mathematics in Scotland are likely to be due to the fact that most of these students take at least five Highers. Elsewhere in the UK students typically complete three A-levels. Increasing the number of subjects studied post-16 widens the options at degree level, including access to STEM undergraduate courses.

Higher education institutions tend to want STEM undergraduates to have taken more than one science subject, and many degrees require two core sciences plus mathematics. However, the entry requirements needed are often unclear to potential applicants, and there is a need for improved information, advice and guidance (IAG) for young people.

A key recommendation from the report is that there should be a review of the A-level system. A Baccalaureate-type approach to post-16 education is currently being taken forward in Wales and Scotland. The Society suggests that an A-level-based Baccalaureate or similar system is also needed in England. The precise nature of what this Baccalaureate should look like requires careful investigation and input from a variety of interested parties, most notably Government, employers, professional bodies, the teaching profession and students.

Changing the structure of the qualifications system alone will not be effective, however, unless it is supported by improvements in other areas. There is powerful evidence in the Society's 'state of the nation' reports to show that there is a need to improve significantly the recruitment and retention of physics and chemistry teachers. Inspiring and effective teachers, with subject-specific knowledge, are widely acknowledged to be a major influence on students' choice of subjects, and their performance. However, with only some 12,000 UK-domiciled graduates in core science subjects[3] the Government will struggle to recruit its target of around 5,000 new teachers in these subjects for 2011/12 in England.

A national rise in the numbers of young people opting to specialise in science and mathematics post-16 will only occur if the following are taken into consideration:

1. The numbers of specialist science and mathematics teachers in both the primary and secondary workforce must increase.

2. Information, advice and guidance for young people must improve in quality.

3. Teachers should undertake subject-specific continuing professional development (CPD) as part of their overall CPD entitlement.

4. The number of qualified laboratory technicians in secondary schools must increase.

5. Physical resources (laboratories, lab equipment and computing hardware) need to be available and of sufficient quality to fully support science and mathematics teaching.

6. The revised 5–16 National Curriculum must provide a solid, inspirational and progressive grounding in science and mathematics for students.

7. The assessment regime must not focus on narrowly constructed measures of school performance.

8. Qualifications must be appropriate, available to all students and support progression in post-16 science and mathematics.

9. Understanding of how children learn should inform teaching practices.

'The UK has great scientific strengths, which underpin our society, culture and economy: we must build on these and continue to aspire to be the best country in the world in which to do science.'[4] Our future success in science depends on the current generation of students.

The Royal Society's four 'state of the nation' reports have produced extensive data on science and mathematics education from 5-19 and the teaching profession, across all four nations of the UK; the full reports are available on our website. If you have any views on the Royal Society's educational work, or would like further information, please contact the education team at education@royalsociety.org.

(1) Core sciences includes biological sciences, chemistry and physics.

(2) *Preparing for the transfer from school and college science and mathematics education to UK STEM higher education. A 'state of the nation' report.* Royal Society, February 2011. http://royalsociety.org/education/policy/state-of-nation/higher-education/

(3) Based on the total numbers of first degree graduates in biology (biology, botany, zoology, genetics and microbiology), chemistry and physics and astronomy in 2009/10.

(4) *The Scientific Century: securing our future prosperity.* Royal Society, March 2010. http://royalsociety.org/education/policy/reports/

To access all the Royal Society's education policy reports, visit: http://royalsociety.org/Education-Policy/reports/

# HOW HEFCE AND THE RESEARCH COUNCILS ARE UNDERMINING SCIENCE AND THE NATIONAL INTEREST

Professor James Ladyman
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Until recently the system of dual support for scientific research was predicated on the principle that researchers should be free to follow the scholarly agenda set by themselves and their international peers. Dual support is based on the division of labour; the research councils provide grants for specific projects and programmes, while *HEFCE* and the other funding councils provide block grant funding to support the research infrastructure, and to provide the capacity to undertake research commissioned by the private sector, government departments, charities, the European Union and other international bodies. Individual academics could rely on the fact that they could carry out a certain amount of their own research without having to apply for funding from a research council. This makes sense because some work is so exploratory in nature that no detailed research proposal is available. On the other hand, universities expected researchers to teach and carry out administrative duties, and so extended amounts of research leave still required funding. Dual support has a clear rationale that is rarely mentioned these days, namely that research council funding is based on a prospective assessment of a plan for future work, while the funding councils award resources based on a retrospective assessment of the work done in the years prior to

> . . . Pure intellectual inquiry has borne fruit that could never have been imagined in advance. . .

the assessment exercise (the RAE, now replaced by the REF). This has been incredibly successful; the UK has around twenty of the best one hundred universities in the world by any reckoning and the latter have the status of national treasures, albeit ones that are taken for granted.

Despite their different roles both the funding councils and the research councils have embraced the impact agenda. In so doing they are distorting the incentives of researchers and universities. Pure intellectual inquiry has borne fruit that could never have been imagined in advance. When Bertrand Russell began his logical investigations into the meaning of sentences with empty names, such as famously 'the present King of France is bald', he was pursuing an intellectual agenda that had been set by the great Austrian philosopher of mathematics Gottlob Frege some years earlier, who had in turn wished to properly understand the meaning of simple arithmetical statements such as '7+5=12'. No research could seem more idle from a practical point of view, yet Russell's work gave us the artificial languages of mathematical logic without which contemporary computing would be impossible.

The American sociologist Robert Merton is credited with the phrase 'unintended consequences' (he also founded the study of the sociology of science of which more below). It is now widely acknowledged that the *Research Assessment Exercise* had unintended consequences. There is no question that in the immediate aftermath of the introduction of the *RAE* the top research universities had a very strong interest in prioritising research at the expense of teaching. This was directly or indirectly communicated to staff who realised that their own careers would not be enhanced, and might even be threatened, by allowing their research productivity to be compromised by extensive preparations for teaching new courses, or by time spent working on textbooks or pedagogy.

When people are given very clear incentives they often over-respond to them. This certainly happened with the *RAE*. While only four items per academic per seven years were required, universities and academics themselves reacted by making publication in top journals an overwhelming priority. One consequence of this has been the marginalisation and gradual elimination of academics who devoted themselves at least as much to understanding their subjects broadly and deeply, as they did to innovation. While of course we would like to have new results in science, there is a lot to be said for the importance and the difficulty of the rediscovery and transmission of what is known already. It is easily forgotten that science is not a dead body of work stored in books and journals, but a culture that is only kept alive by the individuals capable of fully grasping and communicating that knowledge. Often profound advances eventually follow when individual scientists seek to clarify and properly to understand fundamentals, and one of the ways they used to routinely do that was by teaching undergraduate or graduate courses. In the contemporary academy there is so much pressure to publish, and to win grants, that there is a positive disincentive for academics to devote much time and intellectual energy to teaching.

The impact agenda is now changing the incentive structure again by making all researchers think about the applications of hitherto unknown science. The absurdity of this is obvious to anyone with a passing knowledge of the history of science and technology. The laser, once successfully developed after much effort, was described as a solution in search of a problem. Lasers were built only because it was realised that they could exist, and the idea that its inventors should have contemplated the now ubiquitous use of lasers in supermarket checkouts, eye-surgery and information technology is preposterous. New science in one field (say lasers) often leads to technology by interacting with new science in a completely different one (say the digitisation of music, hence cd players). It is ridiculous to expect a researcher interested in, say optics, to anticipate possible applications of research they have not yet carried out, that will only be possible because of the results of other research in completely different fields that has also not yet been carried out. When researchers are encouraged to think about applications of their research they will almost always only be able to envisage them in the short-term. It is salutary to note that the great mathematician G H Hardy in his *Mathematician's Apology* explicitly claimed never to have done anything useful in his life. Little did he know that advanced number theory would become essential to cryptography in the computing age, nor that the law of population genetics to which his name is given would become a centrepiece of biology. More telling still is that this great Cambridge academic cited quantum mechanics as another area of study that was obviously completely useless, whereas it in fact is central to all of electronics and the aforementioned laser.

Those who introduced and advocated the impact agenda have never produced any evidence that researchers who identify applications at the outset produce more valuable research. In fact, many studies have shown the opposite, namely that so-called 'blue skies' research produces a better return on investment. Public critics of the impact agenda led by Don Braben include a good number of Nobel prize winners. Their public and private campaigning has been met with sophistry and spin and their evidence and arguments have never been intellectually addressed. Are we to believe that Treasury civil servants and research council bureaucrats know more about how science works than our elite scientists thousands of whom have signed petitions against the impact agenda?

It may be objected that there is no harm in encouraging researchers to think about applications even if they may not be able to foresee them all, however, the research councils are now asking all researchers even in the most pure and theoretical fields to do so at the earliest stages of research and to include an impact statement with their funding applications. The problem with this is that it fundamentally distorts scientific thought and creativity in so far as it is at least sometimes based on pure intellectual curiosity. The impact agenda incentivises scientists to neglect puzzling but seemingly irrelevant problems, and instead to work directly towards practical goals. This weakens our scientific and intellectual culture and undermines the values essential to education. As Merton pointed out, one of the key features of science is disinterestedness and a culture in which apparently selfless behaviour is rewarded.

The universities have immediately responded to the impact agenda by creating impact infrastructures and bureaucracies. In the *REF* two impact case studies will be worth as much as all the research of about two whole members of staff. One of the most obvious ways of having impact is to enjoy media attention. Universities are falling over themselves to publicise their research and to encourage their academics to court relationships with media professionals. Given the media's tendency to distort the truth in order to make it seem more interesting, it is astonishing how little critical thought is being applied to the consideration of the likely negative effects of this forced marriage.

It may be that tax-payers and policy makers only value science in so far as it produces tangible material benefits for society. However, it does not follow that all scientists should be encouraged to aim to produce those benefits. There are many goals such that aiming directly at achieving them is not the best way actually to achieve them. For example, the best way of impressing people is usually not to try to impress them. Shareholders may only value footballers in so far as they bring them a return on their investment, but encouraging individual footballers to aim at making money for the club would distract them from the goal of playing football well which is how they actually make money. Some scientists are directly motivated by practical problems, and nobody is arguing that the Government cannot set strategic priorities and goals for scientific research such as renewable energy or reducing heart disease. However, there is a great deal of science, even in relatively applied domains, that is driven by puzzlement and the desire to know for its own sake. The policies of the funding and research councils are undermining scientific culture by emphasising the pursuit of foreseeable and short-term application over the quest for knowledge and understanding. They are creating wasteful bureaucracies and encouraging scientists to engage in hype and to court media attention. The best predictor of impact is academic excellence.

The situation in UK academic research is dangerously close to disastrous for the future of education, the science base and ultimately for the economy. Academics are now increasingly only regarded as research active if they bring in grant income no matter how good their work. Researchers are spending huge amounts of time writing grant proposals and completing the baroque forms and processes of the research councils. They are being paid to compete with each other to have time to think, and since most grant applications are unsuccessful huge amounts of time is being wasted. Universities employ teams of people needed to help with these applications, and to sift research council websites and announcements for lists of funding opportunities to compile and send around the academic staff who are then encouraged to think of ways to exploit them. The research councils are increasingly abandoning responsive-mode funding in favour of launching fashionable strategies despite the lack of evidence that they are effective. They attempt top-down control of science, and employ people to travel around promoting their schemes and to court links with researchers and the growing infrastructures of research directors, research development teams and so on. There are ever growing numbers of people involved with research management and administration who do no research themselves whatsoever.

The research councils' enthusiasm for managerialism and wasteful bureaucracy has found its latest expression in their insistence that doctoral research be concentrated in a small number of doctoral training centres. This will lead to many universities having no doctoral students in subjects in which they carry out the highest rated research. Indeed, the research councils seem to be brazenly admitting that basic scientific research will not be found in every region. Doctoral training centres will promote a monoculture, whereas a certain amount of diversity is necessary for a critical culture and for innovation. The alleged need for interdisciplinarity will be used to promote spurious compulsory training modules and taught units at the expense of the kind of advanced doctoral research from which we have benefited so much as a nation. It is completely erroneous to suggest the nation cannot afford its science base. Our existing university system had produced world-beating results from a lower proportion of national income than our rivals. The radical changes in the way science is funded and organised that we are now witnessing are not a response to identified problems or inadequacies of the current system. No evidence has been produced to show that they are necessary. They all involve increasing the amount of bureaucracy, administration, and management associated with scientific research, and they all involve larger and more important roles for the research councils and their service organisations in our universities. Unless this trend is reversed, it will combine with budget cuts to create a perfect storm for UK science.

. . . The situation in UK academic research is dangerously close to disastrous for the future of education, the science base and ultimately for the economy. . .

# RESEARCH IN UNIVERSITIES: INVESTING IN EXCELLENCE

David Sweeney
Director of Research and Innovation, Higher Education Funding Council for England

**UK universities have built up a world-leading research base, with an exceptional record for the range and volume of significant new discoveries. This is due in equal measure to the efforts of our large group of excellent and highly committed researchers, and to the support given by our unique system for managing public research funding, in which HEFCE, the biggest single research funder, plays a key role.**

Sustained public investment in research in universities and other higher education (HE) institutions has given the UK a national research system which is among the strongest and most productive in the world across a broad range of subjects, generating benefits to the national economy, to healthcare, and to national wellbeing and quality of life. In 2008 the UK, with some 1% of the world population, produced 8% of the published research papers in the world and accounted for 12% of citations including over 14% of the most highly cited papers in the top 1% globally.

Research-related income into universities from business and public services, which is a proxy for impact on the economy, was £1.7bn in 2009-10, and in addition 232 new businesses derived from university intellectual property were created.

In England, universities and other HE institutions generate research income totalling around £4.5 billion each year. Around a third of this is provided by the higher education funding council (HEFCE). A further third is government funding for projects and programmes through the UK Research Councils and the National Health Service. The rest comes from other sources, notably research charities and industry.

This mixed portfolio of public funding has played a crucial role in underpinning the past achievements of the national research base and in building the capacity for excellence in the future. The system emphasises excellence, by focusing funding where the capacity exists to produce world-leading research. At the same time it cherishes the principle that detailed decisions on what new fields of enquiry should be opened up, and how, are best taken by researchers and to the organisations in which they work building on their substantial engagement with research users. By providing parallel streams of funding with differing purposes this system ensures that support is available where it is needed throughout the research cycle.

HEFCE research grant, which totals around £1.5 billion per year, is not tied to stipulated purposes or activity. It is allocated selectively, in a way that provides a powerful challenge to achieve excellence: following assessments every few years, funding is allocated to those universities and departments that have demonstrated the capacity to produce research of internationally excellent and world-leading quality. Our future allocations will depend on the next assessment (the 2014 Research Excellence Framework), which will place increased emphasis on evidence that research outcomes have delivered benefits in the world outside. Universities are able to apply this funding wherever they see a need, and which is not met from other sources. Chief among these needs are maintaining a research environment and infrastructure conducive to excellence; making room for early stage, speculative enquiry into wholly new fields and lines of research; helping to support the training of young researchers and of PhD students; and more generally supporting and encouraging a culture in which researchers and universities take responsibility for ensuring that the full potential benefits of research are achieved in practice. Examples of HEFCE-funded projects are given in this article.

Our grant also gives universities the freedom to start enquiry into new fields. The most important discoveries all grow from the moment when a researcher (or a group of researchers) think of an entirely new question, or a new way of approaching an existing question, and devote time and effort to devising ways to answer it. Typically it is only at the stage when a question or field has been defined, and there is some agreement that a particular line of enquiry may help to take it further, that project funding can be obtained from other sources. In this way core research funding complements Research Council, Charity and Business funding, ensuring that the latter can be directed to the strongest performers with the highest probability of a successful outcome.

Excellent research is produced by excellent researchers, and requires continuing efforts to maintain a steady stream of new talent. For even the most gifted aspiring researchers, it is a major challenge to make the transition from completing their research training at postdoctoral level through to becoming recognised, years later, as a research leader taking forward their own programme of work. Support is available from a number of sources (for instance, funding for research fellowships from the Wellcome Trust), but for many the best immediate prospect is that their university will provide them with a salary for a period while they find their feet. Universities are allowed and encouraged to fund such activities from HEFCE allocations.

An excellent and sustainable research base will make strong provision for the early stage of research training too. Students training for a PhD are important both as the first stage in growing new research talent: whether to work in universities or elsewhere; or as a significant contribution to a skilled, flexible and creative national workforce. Only a minority of those obtaining doctorates will go on to work in academic research, but all will have acquired valuable and transferrable skills and experience that they can apply to positive effect throughout their working life. PhD students draw financial support from a range of sources; but the HEFCE grant contributes to the cost of supervising all students, including those who have no other funding, and gives universities the flexibility to reduce or waive fees for promising students who have not been fortunate to secure significant support from an inevitably limited range of other sources.

Even world-leading research is of limited value if it is not shared, whether with other researchers or with those outside the academic sphere who could apply it to positive effect. Our funding and assessment arrangements support this sharing process in several ways. A major focus of our recent activity has been on identifying and celebrating the very broad range of ways in which the outputs of research can make a difference – to economic activity, to healthcare and quality of life, and to social wellbeing. The Research Excellence Framework now incorporates a significant component designed explicitly to give credit where universities have contributed to ensuring that their research has made a difference in any of these spheres. Our funding also supports a number of initiatives to help universities to harness the potential of the internet, such as supporting innovative provision for sharing and preserving research outputs and their underlying datasets.

## WHAT NEXT?

The national research base is currently in very good shape, following sustained government investment through HEFCE and other bodies as well as the contribution of the research charities and business and industry. The announcement in December of funding allocations for science and research covering a four year period has provided a welcome and helpful element of stability, giving universities the ability to plan ahead with some confidence. Nevertheless, a number of significant challenges are emerging to which the research base must respond. Research at the highest level is increasingly a highly competitive globalised business with a limited available workforce, and a number of other countries are now investing heavily in building their national systems. At the same time, much of the most exciting research is undertaken as a group activity and running across established disciplinary boundaries, and much cutting edge science requires the provision and regular updating of increasingly complex and expensive equipment. HEFCE remains committed to working with other funders of research, and with our partners within higher education, to ensure that the UK research base is able to meet these challenges and to retain its position as a major source of world-leading and life-enhancing discoveries.

## CASE STUDIES

**Lancaster University - Targeting treatment for tropical disease**

River blindness (onchocerciasis) is a major health problem in wet tropical regions. To tackle it, the African Programme for Onchocerciasis Control (APOC), co-ordinated by the World Health Organisation across 19 nations, has treated more than 30 million people with the drug Ivermectin. Ivermectin, however, can cause adverse reactions when given to people who also have the infection 'eye worm'. APOC therefore takes precautions before mass treatment with Ivermectin, and spatial statistical modelling at Lancaster University is helping treatment to be better targeted. Development of international partnerships such as this can take several years and therefore will depend on stable funding. The real-world impacts are clear: Lancaster's collaboration advances knowledge in tropical diseases and saves lives.

**University of Birmingham - Systems Science for Health**

Systems Science for Health (SSFH) is a new research initiative at the University of Birmingham. Launched in 2010, and underpinned by investment from HEFCE. It exploits state of the art technologies and high performance computing to unravel mechanisms of complex diseases, discover new diagnostic markers, and ultimately improve patient treatment and care. The initiative creates a new interface between three research communities at the University of Birmingham: 'omics' research (metabolomics in particular); bioinformatics & modelling; and biomedical & clinical research.

Omics technologies allow rapid analyses of thousands of biomolecules to discover diagnostic markers for disease or to measure the therapeutic responses of drugs on the body's tissues. Consequently the amount of data generated is vast, and high performance computers with mathematical modelling are required for the data analysis.

**University of Sheffield - Magnomatics**

For more than a decade the University of Sheffield has been exploring the possibilities of using high-energy permanent magnets for novel non-contact magnetic gearboxes. Following initial research, funding was awarded to drive the technology forward, and it can now be applied in sectors such as aerospace, hybrid-vehicles and the renewable energy sectors. A spin-out company, Magnomatics was established in 2006 to commercialise the research findings. This has gone from strength to strength, including contracts by the MOD and projects with European vehicle manufacturers. This commercial success has its genesis in the speculative research undertaken in 2000.

# SCIENCE AS A PUBLIC ENTERPRISE

Professor Geoffrey Boulton FRS FRSE OBE
Chair of the Royal Society's study 'Science as a public enterprise: opening up scientific information'

## SCIENCE AND THE MODERN WORLD

The increased pace of application of scientific discovery over the last half-century has been breathtaking. We have put satellites into orbit around the Earth and probed deep into the solar system; we have discovered the chemical processes that animate living things and learned to manipulate them; we have developed computers that complete calculations in fractions of a second that would previously have taken months or been impossible; we can manipulate individual atoms, and are beginning to understand how they are assembled into complex living organisms; and we have found ways of storing, manipulating and transmitting information that far surpass anything previously dreamed of.

Such discoveries have removed geographic barriers; put immense power to access, manipulate and communicate information into the hands of ordinary citizens; and created the potential to address hitherto intractable diseases. At the same time they have alerted us to the magnitude of the human assault on the natural systems of the planet, and with the computational power that science has put into our hands, we have the capacity to assess how they might evolve. Wherever we look, science has changed, is changing and will continue to change the way we live, and fundamentally influence the way we prepare for the future. It is now woven into the fabric of human culture.

Notwithstanding this roll-call of achievement, the context within which science is done is changing, and the scientific enterprise needs to adapt to it.

## THE IMPACT OF DIGITAL TECHNOLOGIES

30 years ago, in most areas of science, it was possible to publish a complete description of a piece of scientific work, including all experimental details, the resultant data, an assessment of uncertainties, and the details of analysis, that would permit anyone to validate the data and repeat the experiment. New digital methods of data collection and storage are now able to create such vast datasets that no journal could conceivably accept a full description of an experiment analogous to that of 30 years before. Unless a great amount of time is devoted to describing an experiment in immense detail (crafting the "meta-data") and in archiving the full dataset, it has become very difficult to replicate it faithfully. The published paper merely becomes an advertisement for the science: the real science lies in the underlying data.

We have reached a point where replication and re-use of data, that have been fundamental to the progress of science, are being undermined unless we can make the underlying data quickly available and useable by other scientists. There is a strong imperative for a regime of open data, to ensure that scientific data are made available to others.

A further impact of digital technologies has been in the use of computers to investigate complex coupled systems in ways that were hitherto impossible. It has added a third basic tool to the armoury of science, that of computer simulation, to the classical tools of observation and theory.

But this compounds the problem of reproducibility. The computer code of researchers are relatively inaccessible, even to experts in the same field. The computational manipulation is contained in a black box, so that it is often extremely difficult to state with clarity and rigour why the results are as they are. In a world where we are now able, for the first time, to analyse truly complex problems, and where the policies derived from such analyses can impinge so strongly on society, finding ways to unlock model construction and operation to inspection is a high priority.

## A CHANGED SOCIAL ENVIRONMENT

The pressure for change comes not only from powerful digital technologies, but also from society. As old habits of deference fade, growing numbers of citizens are averse to accepting *ex cathedra* statements from scientists, and ubiquitous digital media offer a powerful means for the public to interrogate, question and re-analyse scientific priorities, evidence and conclusions. Though it has its difficulties, the developing vigorous engagement by many citizens is something to which the scientific enterprise must adapt. Arguably it is a realisation, though in a more democratic and boisterous form, of the hopes of the Royal Society's report on *The Public Understanding of Science*(1) in 1985, which is widely held to mark the birth of a movement towards public engagement with science in Britain.

Given the impact that science increasingly has on the lives of citizens, and the fact that much is paid for from the public purse, it is important that science is not, and is not seen to be, a private enterprise, conducted behind the closed doors of laboratories, but a public enterprise to understand better the world we live in and our place in it.

Some of the debate involving citizen scientists is excessively polarised, characterised by a stand-off across a gulf that is rarely bridged by reasoned discourse. Each side portrays itself as the standard bearer of reason, and accuses the other of an irrational, quasi-religious belief, often underlain by self-interested motives, or even by global conspiracy. But many interventions generate tough and illuminating questions and expose important errors and elisions. At the same time, novel initiatives are being created that bridge between citizen and professional scientists in areas such as astrophysics, climate prediction and malaria control, and many individuals create incisive and often highly creative blogs on specific issues. The purpose must be to ensure that the public can see, grasp, and take part in scientific research to a much greater extent than has been possible hitherto.

## A NEW ROYAL SOCIETY INQUIRY

It is in this context that the Royal Society is undertaking an inquiry, due to be completed by Spring 2012, *Science as a public enterprise: opening up scientific information*(2). Its purpose is not to cover the whole domain of scientific governance and public engagement, but to recognise that opening up scientific information is a vital first step in ensuring that scientific results and analysis are more accessible both to other scientists and to members of the public who have developed specialist knowledge.

## LIMITS TO OPENNESS

For science funded from public sources, exceptions should clearly apply to scientific work that has implications for national security. The degree to which personalised information, gathered for example through medical or social science investigations, is exempted, can also be problematic. To what extent, for example, should the public health benefits that might accrue from the use of population health records, outweigh an individual's desire for privacy? Is too high a price being paid by people collectively in order to protect the privacy of people individually through inappropriate data protection legislation, including the EU data protection directive?

Should scientific data held by government and its agencies be freely available? The Government's National Infrastructure Plan launched last October focuses on physical infrastructure(3). Why not also a strategy for national information infrastructure, including scientific information?

At first sight, there might seem to be a clear limit to the opening up of scientific information according to whether the science is funded from public or private sources. In practice, there are many areas that are more complex. There is a strong argument, for example, where the activities of private companies involve a public hazard, as in the recent examples of Fukushima and Deep Water Horizon, that the scientific safety cases should be publicly available. If there is shared hazard, should there not also be shared information?

A powerful example of the benefit of transgressing the public/private divide comes from clinical trials, to which the public freely contribute, and where great potential for benefit is unrealised. Persistent failures to place even summary results of such trials in the public domain have led to a bias that seriously undermines their immense potential for public benefit. The way that sharing data can lead to healthcare improvements has been shown by the meta-analysis of the raw data from clinical trials on the effects of aspirin in the prevention of cardiovascular disease which was able to use data from 95,000 patients. The extension of such processes offers an opportunity to use data from routine clinical use of drugs to provide high quality pharmacovigilance on a hitherto unprecedented scale(4).

## MOTIVATING CHANGE

Making scientific results available in a useable form both to professional scientists and the public would be expensive, and would demand either additional funding or a shift in the balance of the scientific effort.

Achieving change requires a change in the priorities of funders of science, and of scientists themselves and their institutions. Scientists have tended to regard their data as personal property. After all, it is they who worked hard to generate it, and ownership has never been seriously challenged. How can the systems of acknowledgement, reward, professional advancement, and institutional assessment of science be evolved to properly recognise contributions other than the traditional peer-reviewed paper? One way forward might be to recognise the provision and archiving of data and computer code in assessment of research, for example the Research Excellence Framework for university research.

## WHAT DOES THE PUBLIC WANT?

While the issues above should concern policymakers, scientists and interested citizens, what does the wider public want from the science that it indirectly funds? A recent survey indicated that many do not feel informed about science, but it seems that the vast majority have no desire to become involved in scientific processes(5). They want reassurance that there are efficient processes that will progressively eliminate error and reduce uncertainty(6). But these results are only indicative, which is why the Royal Society inquiry is considering further public dialogue processes, asking the public what it wants of its science.

1 The full report can be downloaded: http://royalsociety.org/Public-Understanding-of-Science/

2 More information: http://royalsociety.org/policy/sape/

3 HM Treasury, National Infrastructure 2010: http://www.hm-treasury.gov.uk/ppp_national_infrastructure_plan.htm

4 The Lancet, Volume 377, Issue 9778, 14 May 2011-20 May 2011, pp1633-1635

5 51% of the public think they hear and see too little or far too little about science, but only 32% would trust research more if they saw the original paper. Ipsos MORI / Department for Business, Innovation and Skills, 2011, Public Attitudes to Science Survey, p32&39: http://www.ipsos-mori.com/researchpublications/researcharchive/2764/Public-attitudes-to-science-2011.aspx

6 Ibid, p39.

# THE LEONARDO CENTRE'S INDUSTRIAL SAVINGS

Professor Rob Dwyer-Joyce,
The Leonardo Centre for Tribology and Surface Technology,
University of Sheffield.

Professor Allan Matthews,
The Leonardo Centre for Tribology and Surface Technology,
University of Sheffield.

Tribology is the study of friction, lubrication and wear and is at the heart of modern machines, everyday life, and saving energy. The Leonardo Centre for Tribology and Surface Technology collaborates with industry leaders across a range of sectors to make energy savings through the science of tribology. With dozens of partners, working with over 30 researchers, the Leonardo Centre's mission is at the core of the Department of Business Innovation and Skill's knowledge transfer initiative, "ensuring good research becomes good business". Recent projects have included optimising airplane engine manufacture with Rolls-Royce and working with Tecvac and NMB-Minebea to produce lightweight yet durable landing gear – which resulted in Airbus placing a £19m order.

*But what is tribology? Why is it important? And what does any of it have to do with Leonardo da Vinci?*

## TRIBOLOGY

In the early 1960s, after a steep increase in reported failures of machinery due to friction and wear, a conference on Iron and Steel Works Lubrication was set up. This led in 1966 to a report which estimated potential savings of £515 million per annum (in 1966 terms) for industry if existing tribological principles and practices were better applied. The report also suggested that as the United Kingdom's livelihood was tied to the success of its industrial efficiency, it could not afford to overlook the economic and commercial advantages to be gained by the study of tribology. In order to link education and research with industrial efficiency, it recommended the establishment of Centres or Institutes of Tribology.

After considering the report, the then Minister of Technology

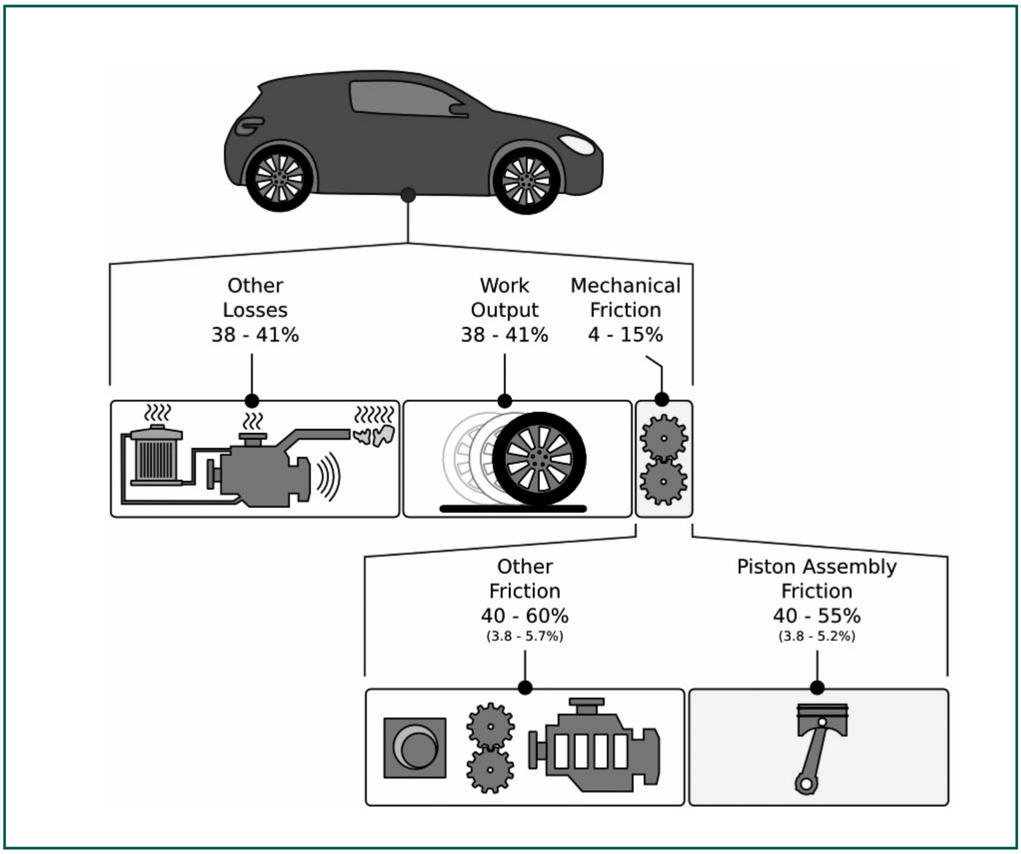



Figure 1. Depending on the vehicle and the operating conditions somewhere between 4 and 15% of the energy from the fuel is lost in overcoming friction in engine and transmission. The piston rings alone account for 3.6p in every litre of fuel. Understanding, predicting, and reducing the lost energy is at the heart of Tribology.

announced to the House of Commons, in September 1966, the establishment of the Committee on Tribology to advise on the implementation of the report.

From its beginnings in UK Government, tribology has attained global significance, tribology centres being established from Nigeria to the Netherlands and a total of 36 countries are currently represented in the International Tribology Council.

The savings predicted by the Iron and Steel Work Committee are no less pertinent today. The report of a two year investigation in China estimated the savings obtainable by the application of tribological principles to be equivalent to 1.5% GNP, this for an average R&D expenditure of US$200,000 for US$1 million savings. Professor H Peter Jost, President of the International Tribology Council, has said, *"adjusted for UK conditions, it could be estimated that savings through tribology in the UK can be in the region of £8-£10 billion for an applied R&D expenditure of approximately £60-£100 thousand."*

With Chancellor George Osborne's recent incentives to encourage business in the UK, including the lifting of tax relief on the enterprise schemes from 20 to 30% and that on research and development activities from 140 to 200%, the extra savings provided through tribology could allow businesses to flourish, Sheffield's Leonardo Centre having an important role to play.

## LEONARDO DA VINCI

It may seem surprising that a tribology research centre should be named after a person who to the public is generally known for his paintings; however, he was a genius in Engineering Design. The fundamental principles of tribology – friction and wear – are innately connected to the process of rubbing surfaces. It was Leonardo da Vinci who conducted some of the first experiments in this field.

Leonardo kept illustrated note books in which he detailed his experiments. Sketches showing blocks being pulled along surfaces appear in the Codex Atlanticus, while in the Codex Forester he expressed for the first time the laws of friction, *"the friction made by the same weight will be of equal resistance at the beginning of its movement, although the contact may be of different breadths and heights".*

Leonardo also investigated methods to reduce friction. One particular experiment, described in the Codex Madrid, illustrates perfectly the link between this pioneering work and its continuation at the Leonardo Centre for Tribology and Surface Technology at the University of Sheffield.

Instead of the sliding motion that had typically been used, Leonardo designed many bearings which used a rolling action. Of these he wrote:

*"Their movement will be facilitated by interposing between them balls and rollers. But if the balls or rollers touch each other in their motion, they will make movement more difficult than if there were not contact between them, because their touching is by contrary motions and this friction causes contrariwise movements."*

While Leonardo discovered how to make ball bearings operate, the Centre's work is being used to make them more efficient. A recent project, directed by Professor Allan Mathews and Dr Adrian Leyland, discovered a surface coating which could increase a bearing's life span by 84.1%. Considering it can cost up to £400,000 to replace the bearing in one off-shore wind turbine, there is a real economic imperative of building on the work of this 15th Century pioneer to meet this century's needs.

Figure 2. Leonardo's designs for a rolling bearing from the Codex Madrid 1490. Leonardo understood the importance of reducing friction, including a spacer to separate the balls and how lubricants could be used. A modern bearing, in 2011, retains many of these features.

## THE LEONARDO CENTRE, SHEFFIELD

Located in the former steel producing heartland, the Leonardo Centre is building on a rich heritage to provide cutting edge solutions for manufacturing and innovation. It is ideally placed to help businesses, taking advantage of Sheffield's newly announced enterprise zone, one of 21 in England, achieve maximum efficiency in both their manufacturing processes and products.

While the knowledge and expertise is developed in the University, it is the Leonardo Centre's links with industry which drives its research. Current national and international projects work with wind, rail, automotive and aerospace industries, while a new toothbrush designed last year with Unilever took 20% of the European market on release.

Tribology is concerned with tiny distances, gaps, and tolerances. Millions of pounds can be saved by micrometre scale adjustment. The piston rings in a car engine operate with a micrometre size oil film and yet consume 3.6p out of every litre of fuel in friction losses. Professor Rob Dwyer-Joyce, of the Leonardo Centre, has developed new sensors to tune piston ring performance and potentially halve these losses. Dr Matt Marshall recently worked on a project investigating abradable linings in aero-engines and how their efficiency directly corresponds to fuel consumption. It is estimated that saving 1% of fuel consumed could save the airline industry $160m a year. Dr Marshall's project investigated how to make this adjustment safely in a mechanism that must operate at temperatures of up to 1800°C.

## GROWTH

After the announcement of March's budget, there is a clear need to promote business and innovation in order to stimulate the economy. Research and development being undertaken at the Leonardo Centre is a key to this process by offering businesses the opportunity to make savings through the science of tribology – the study of friction, lubrication and wear. By using the Centre's expertise in these areas as well as its knowledge of surfaces and coatings, the Centre is able to help stimulate growth in a wide range of industries including automotive, aerospace and energy: a unique and productive legacy for the enquiring mind of Leonardo da Vinci.

# FIXING PHYSICS TEACHING

Professor Peter Main
Director, Education and Science,
Institute of Physics

**For many people, their school years pass without them having much of an idea of where they want to go or what they want to do. But for others their educational and career paths are subject to many influences along the way. Often the strongest influence is exerted by a teacher. A good teacher can bring a subject alive, inspire students and instill a deep and lasting understanding of the topics they teach.**

There are many factors that make an effective teacher. Personal skills and pedagogical ability are important, as is a strong knowledge of the subject. While that last point may seem obvious, particularly in the later stages of education, there is actually no formal requirement for this to be the case. Many shortage subjects, such as physics, are taught by non-specialists even to GCSE level.

## A SHORTFALL IN TEACHERS

In the case of physics, there has been a drastic shortfall in the number of specialist teachers for many years, which inevitably has a major impact on young people's education in the subject. There are 500 maintained schools in England with no specialist physics teacher. It is not necessarily that non-specialists cannot be good physics teachers, but on average specialists have been shown to teach better-quality lessons, and secondary-school departments without any specialist physics teachers tend to have fewer students who go on to study the subject at A-level.

The Institute of Physics is pleased to see that the latest batch of newly qualifying teachers – whose new-teacher conference took place on 14 July, followed by a celebratory event in Parliament – is the largest cohort for 30 years, with 650 new physics teachers ready to take up their places in instructing the next generation in the most fundamental of the sciences. As encouraging as this news is, the figure is still short of the new Government target of 925 physics teachers recruited annually – a target that the Institute sees as a crucial step towards rectifying the drastic shortfall, in England, of specialists, which we estimate to be between 4000 and 4500 teachers. It is even further behind the more ambitious target identified by the Institute, of 1000 new teachers per year – the level at which 15 years of steady recruitment would finally put the number of physics teachers back on a par with those of chemistry and biology.

The desired target of physics specialists making up one third of all teachers of science subjects begins from a starting point of around 19%. Until recently, only around 400 new teachers began teacher-training courses each year, and 15% of those who start PGCE courses drop out before completing their training. To make matters worse, half left the teaching profession within four and a half years.

## POSSIBLE SOLUTIONS

The prospect of graduates with good degrees in physics having their student loan repayments met by Government is reassuring. But such incentives are required not only to attract the best graduates into teaching generally, but also to ensure that they are using their specialist knowledge most appropriately – a quarter of the physics graduates who do enter teaching end up teaching maths instead of physics. It has been suggested that they are put off becoming science teachers as it will mean offering chemistry and biology as well as their own subject.

If the requirement to teach other sciences besides physics deters physics graduates from teaching physics, it may be more useful for the subject to be decoupled from the other sciences and, if anything, be taught together with maths – this would also encourage greater recruitment of engineering graduates into physics teaching, providing a greater pool of talent from which to draw teachers.

The Institute has recommended that in addition to schools making every reasonable effort to employ enough physics teachers to ensure that all of their students can be taught by a specialist at GCSE level and above, they should also deploy those teachers appropriately. One way this requirement could be introduced is by making it impossible for a school to get a top grade at their Ofsted inspection without having a specialist physics teacher.

Curiously, given the dramatic shortage, many physics graduates are rejected from teacher-training. The way in which the admissions system is set up makes it difficult to understand why this happens, but it is clearly something that needs urgent attention.

## IOP'S ROLE

Given that for the foreseeable future much physics teaching up to GCSE will be carried out by non-specialists, the Institute is also working to improve those teachers' subject-knowledge, confidence and 'pedagogical content knowledge' – the specific ability to teach the subject of physics. The Stimulating Physics Network, managed by IOP in partnership with the Science Learning Centres and funded by the Department for Education, works with non-specialist teachers to deepen their knowledge of physics and skill at physics teaching and restoring the culture of physics. The initiative provides teachers with a programme of workshops, activities and continuing professional development that is intended to be inspiring, coherent and sustainable.

The Network operates by offering every secondary school in England support from a team of physics network coordinators. Meanwhile, in more than 250 targeted schools, a network of teaching-and-learning coaches provides support to whole departments, working in schools to help their non-specialist teachers be more effective. Support will include discussions of, for example, common difficulties that children have with tasks such as wiring up an electrical circuit, typical misunderstandings that they might have, or explanations of phenomena that are often used by non-specialists but which are incorrect.

And the programme works, too: the pilot project from 2006–09, which ran in 30 English schools, saw an increase of 30% in the number of secondary-school children going on to study A-level physics. Participation in A-level physics among children from those schools went from 4% below the national average to 14% above it. There was also a dramatic increase in the number of students studying triple science.

Further work relates to the Institute's recommendation of more, and better, mentoring for new teachers. Since 2004, the Institute has offered mentoring to those taking six-month, pre-PGCE, subject-knowledge courses, continuing into their first two years working as a teacher. The assignment of a mentor, along with phone and email support and attendance at conferences, are intended to enhance the teacher's professional network. Surveys of those that have taken part in the scheme have shown that they believe it to be beneficial to both the teacher and the school, which can help address the high drop-out rate that has aggravated the shortage of recruited teachers.

To try to attract more physicists into the teaching profession, the Institute has developed a marketing model, based around specific events at universities. These are in partnership with university physics departments, and the Institute is working with the Royal Academy of Engineering and others to include engineering departments.

Students who express an interest in becoming teachers can sign up to receive frequent updates of news relevant to teacher-training. At the time of writing, this year's events have identified more than 300 prospective teachers.

Although we believe that IOP's activities have helped to reverse the decline in the number of physics teachers and ensure better teaching from non-specialists, further support will be required from Government to remove the shortfall completely. It's important that it is.

## WHY PHYSICS TEACHING MATTERS

Benjamin Franklin described education as "the investment with the greatest returns". This is particularly applicable to physics, which underpins so much of science, engineering and medicine. It is crucial for the future of UK science, and therefore the country's economy, that this shortage of physics teachers be resolved. Physics punches well above its weight in the economy, with physics-based businesses accounting for almost half of all manufacturing jobs in 2008 as well as supporting more than £50bn of gross value added in the UK as a whole and £8bn in Scotland alone – figures comparable to the finance or construction industries.

Similarly, the UK's science base depends on actually having the scientists to do the work, and they all need someone to teach them. With fewer of them around to make the subject seem intuitive and logical, fewer students go on to study physics at 16-19 level or at university. As well as affecting the number of physics graduates coming through the pipeline and into research and academia, potentially harming the UK's standing in the international science community, it also exacerbates the very problem that caused it by reducing further the number of potential physics teachers.

So while the largest batch of new physics teachers for 30 years is certainly an occasion worth celebrating, there is still work to be done.

Naturally, the shortage of physics teachers has strong local variations. In Blackpool in 2008, for example, the constituency's eight schools only sent five students on to do physics A-level – all of them boys. With the greater autonomy of schools in the future, it is important that those schools recognise the importance of having a specialist physics teacher. By keeping aware of who is teaching physics in their constituencies, MPs can play a key role in ensuring that the next generation of physicists receive the best possible education.

. . . At the time of writing, this year's events have identified more than 300 prospective teachers. . .

# WHY SUPPORTING AND PROMOTING ENGINEERS IS VITAL FOR THE WORLD'S FUTURE

Stephen Tetlow
Chief Executive of the Institution of Mechanical Engineers

**Engineers solve problems. As the UK grapples with its deficit, and the world tackles climate change, a population unable to feed itself and dwindling fossil fuel supplies, we need them more than ever.**

In the UK we have a serious challenge. We need to recruit 13,000 mechanical, automotive and aerospace engineers every year just for our engineering industries to stand still. Add 20% to ensure a balanced, growing economy means we need at least 15,600 every year. Figures for 2009/2010 show that just 2,395 UK students completed courses in mechanical, automotive and aerospace engineering. The UK is falling behind: currently just 6% of UK students are studying engineering and technology subjects, compared with 20% in India and 40% in China and Singapore. Either we choose to become a second rate nation, or we act now to ensure our future place in the world.

## WHY ARE WE IN THIS SITUATION?

Unlike the past when the likes of George Stephenson and Isambard Kingdom Brunel meant engineering was hailed as a profession for heroic pioneers, engineering in 2011 is rarely fêted, and not enough youngsters dream of pursuing a career in engineering.

This is despite the fact that there are currently thousands of engineers around the world doing work just as critical and just as exciting as the work of the early pioneers.

Engineers drive vital technological change. They are in the front-line in moving the UK from a society dependent on high carbon, low security energy to the vital mix of wind, wave, nuclear, solar and carbon capture energy sources we desperately need.

Engineers are working on programmes to improve the UK transport infrastructure, including projects on the UK High Speed Rail network, charging infrastructure for electric cars and the development of low carbon vehicles.

Engineers are also working on technologies which will revolutionise the way we live. Technologies like sub-orbital aeroplane flights, which could cut travel times by more than half, and ever more sophisticated surgical robots to complete medical procedures more accurately than a human surgeon can. Engineers are developing air-capture machines which capture gases which cause global warming from the atmosphere for storage in used oil and gas fields, as well as designing the cities of the future – where buildings will be built to cope with the inevitable and severe consequences of the change in weather behaviour caused by climate change.

We want engineering to be celebrated, not just by engineers but by society as a whole, for the exciting and vital role it plays in all our lives and those of future generations.

The need to stimulate enthusiasm about engineering in young people is urgent. We need to ensure we motivate schoolchildren and students to pursue careers in engineering, so that they can become problem solvers for tomorrow. If we don't solve the impending skills shortage we will have no chance of creating a low carbon economy or finding solutions to man's greatest challenges.

The Big Bang Fair, the UK's biggest single celebration of science and engineering for young people, is a project which is helping to inspire the next generation of engineers and scientists. Led by EngineeringUK and involving over 150 organisations, including the Institution of Mechanical Engineers, and from across the private, public and voluntary sectors, it reaches out to schools and over 30,000 students across the country. The Big Bang is an example of the UK's science and engineering communities working together.

Activities such as these are important in stimulating children's interest in engineering and in showing the key relationship between science, engineering and design.

But we have a problem. The school curriculum hardly even recognises engineering.

Schoolchildren wanting to pursue careers in design and engineering often have to make a choice of either pursuing art and humanities subjects or science and maths. Schoolchildren should be given the opportunity of linking interests in subjects like art, design, physics and mathematics – which together are the ideal building blocks for careers in design engineering.

The proportion of females entering engineering in the UK is also the lowest in the western world.

Despite the considerable work done by the engineering community, more needs to be done by Government to encourage schoolchildren and students to pursue engineering careers.

First, the Government needs to ensure that the planned all-age careers service provides informed, industry-led careers advice in schools. This would benefit not just pupils, and engineering, but also other professions currently facing a skills shortage like nursing, science, medicine and dentistry.

According to a YouGov poll earlier this year just 13% of students thought that their careers advice was of any use and there is the real danger that the problem will get worse. The Education Bill now going through Parliament places a duty on schools to provide access to impartial and independent careers advice, yet it has removed careers education from the curriculum. Thousands of pupils could start school next year with little or no access to professional careers advice.

The Government's announcement of support for 250,000 apprenticeships is an important step but will be meaningless if there are not enough young school-leavers qualified and willing to take them on.

For those wishing to pursue a degree in engineering, there is also the huge stumbling block of tuition fees. We already know that in response to cuts in university tuition funds, many universities plan to charge the full £9,000 tuition fee for their courses. At the moment universities appear likely to levy those fees uniformly across all subjects – including subjects deemed strategically important and vulnerable, such as engineering.

Interestingly, in a recent survey by the Institution carried out by ICM, 80% of the 1,000 members of the public surveyed showed strong support for Government subsidies for costly university courses like engineering. The Government needs to consider whether it is necessary to provide subsidies for courses in subjects vital to society and the economy like engineering and medicine.

It is clear that the UK and the world need engineers – it's so obvious as to be almost a cliché. It is the responsibility of Government in partnership with employers to help ensure we have enough people wanting to pursue engineering careers. It is only with this support that we will find the George Stephensons and Isambard Brunels vital to our future.

## KEY ACTIVITIES BY THE INSTITUTION OF MECHANICAL ENGINEERS

### Formula Student

Run by the Institution of Mechanical Engineers, Formula Student challenges universities from across the world to design, build and race a single-seater racing car in one year. The teams are tested on their design, costing and business presentation skills before their cars compete in terms of acceleration, braking, speed and endurance. Formula Student builds in an exciting practical and business element to University courses and courses that have involvement in Formula Student are always oversubscribed. Formula Student 2011 will feature a record 125 teams from 34 different countries.

### Bloodhound Super Sonic Car

The Institution is one of the sponsors of the Bloodhound Super Sonic Car (SSC), which aims to inspire the next generation of scientists and engineers, by building a jet and rocket powered car capable of travelling at over 1,000 miles per hour and breaking the world land speed record.

The Bloodhound SSC project is unique as it has a philosophy of open access to all aspects of the research, design build and test of the car. So far more than 4,300 schools, colleges and universities have signed up to Bloodhound, gaining access to a range of learning materials, as well as regular updates on the project. Many of these schools and colleges want enthusiastic engineers, many of which are members of the Institution, to go into the classroom and use Bloodhound to reach out to and inspire these young scientists and engineers.

### Primary Engineer

The Institution also partners Primary Engineer, which helps primary teachers with design and technology by demonstrating the practical application of science, mathematics, literacy and information and communication technology.

### Manufacturing Excellence

Developed in conjunction with the Warwick Manufacturing Group, Manufacturing Excellence is the most successful and long established manufacturing awards programme in the UK, and the only one that provides such a detailed benchmarking and assessment process to help improve your business.

Manufacturing Excellence works with all manufacturing businesses, whatever their size, age, sector or area of expertise to help improve their processes and showcase their excellence. It is also completely free to enter.

## INFLUENZA: WHAT ARE THE LIKELY THREATS OF FLU FOR THE UK AND HOW CAN SCIENCE HELP AMELIORATE THE CONSEQUENCES?

Meeting of the Parliamentary and Scientific Committee on Tuesday 26th April

The meeting was organised with financial support from the Society for General Microbiology, and in collaboration with Dr Ron Fraser, SGM Chief Executive. Although the threatened H1N1 'swine flu' pandemic was less severe than feared, the influenza virus nevertheless poses a continuing and evolving long-term threat to human health. Preparedness for control of outbreaks is essential. This involves many types of research and development, to inform and facilitate good public health practices.

# THE EMERGENCE OF INFLUENZA PANDEMICS

Professor Wendy Barclay
Chair in Influenza Virology,
Imperial College London

**We have just lived through the first influenza pandemic of the 21st century. In early 2009 a novel influenza virus emerged from pigs in Mexico that had the capacity to infect and readily transmit between humans. The virus showed the hallmarks of a pandemic in that it spread rapidly across the world, had recently emerged from an animal source, and took its toll mainly in the young.**

Across the world WHO reported an excess of 20,000 laboratory confirmed deaths in the first wave of the pandemic although this is certainly an underestimate of the true numbers. In the UK 474 deaths were attributed to the virus as it spread through the summer and autumn of 2009. Even more people died the following winter as the virus re-emerged in 2010 and at Christmas time 2010 more than 200 intensive care beds were occupied with swine flu patients. Thankfully, for most people infection with the swine flu virus led to mild self limiting disease and in many ways we are fortunate to have had a chance to rehearse our pandemic response under circumstances that are forgiving of a few glitches. It is certain that there will be future influenza pandemics but predicting when and the extent of their severity is difficult. Understanding why this particular virus sparked a pandemic whereas other influenza viruses that circulate in swine or in the natural wild bird hosts do not, is key to being able to predict and ultimately control pandemic emergence at the source. This knowledge will allow us to focus surveillance, prioritise vaccine strategies, and modify any practices that might increase the likelihood of a pandemic emerging.

Influenza viruses of many different antigenic subtypes circulate in wild birds. Fortunately, avian influenza viruses replicate so poorly in human hosts that they usually do not spread. However avian viruses can become adapted for better replication and transmission in humans by mutations in their genomes. It has been proposed that this may occur when the virus finds its way into alternative hosts such as pigs or chickens, which might act as intermediates in its evolutionary pathway from wild birds to humans.

The avian influenza H5N1 known as 'bird 'flu' became notorious in the first decade of the 21st century when a new variant evolved that spread through birds across 3 continents. Although the virus remains largely an avian influenza strain that has killed millions upon millions of chickens, it has also infected a wider range of hosts than any other influenza virus before. Around 500 people have been infected with this virus after exposure to high doses such as during plucking feathers from contaminated poultry, and two thirds of them have died. Thus this virus has been the focus of our pandemic plans since the consequences of a pandemic caused by an H5N1 virus would be severe. However, despite the widespread geographical spread of the virus and the huge number of infected hosts, no H5N1 bird 'flu pandemic has happened. It is clear that unlike typical avian influenza viruses, H5N1 is not deficient in its capacity to replicate in human cells. The people who have died from H5N1 carry huge viral burdens during their disease. Rather, the reason there is as yet no pandemic is that the virus does not spread from one infected person to another. In the laboratory setting we can study influenza transmission using animal models such as the ferret. If one animal is directly inoculated with infectious virus and then a day later another animal is exposed, the second animal can be tested to see if it has acquired infection from the first. Exposure can be by placing the animals in the same cage perhaps modelling direct contact transmission in a household situation, or by placing the cages side by side so that they share the same air, perhaps more like standing next to someone on the tube where respiratory droplet transmission would occur. Whereas the 2009 pandemic H1N1 swine flu virus transmits readily in these animals, H5N1 does not; even though the first directly inoculated animals become robustly infected with the H5N1 virus.

. . . Influenza viruses of many different antigenic subtypes circulate in wild birds. . .

In order to assess the real risk from H5N1 and other avian influenza viruses to the human population we need to understand how likely it is that this deadly virus can learn to spread between us. To consider where the block to H5N1 human transmission might lie, we need to consider the site where transmission takes place. Viruses are inert unless they find access to a host cell. On the outside in the environment they are rapidly inactivated by ultraviolet light and other environmental factors. Avian influenza viruses have evolved to infect the intestinal tract of their natural hosts whereas spread between people occurs through the air. The mammalian respiratory tract is a very different environment than the avian gut. The receptors that the virus can bind to in order to mediate cell entry are of a different biochemical linkage in humans than they are in birds. We know that avian influenza viruses have mutated before to accommodate the human receptors. However if we study the genetic code for H5 we can see that it would require more extensive mutation to achieve this switch, an event that is 10,000 times less likely than for the creation of the H3N2 influenza virus that caused the Hong Kong pandemic in 1968. Moreover this receptor switch might not be the only change the virus has to make before it can survive in the human respiratory tract long enough to mediate transmission. The brackish water in which avian influenza viruses are exchanged between ducks is above pH7.5, whereas the mucus that lines the human nose is below pH6.0. Since proteins of the virus are inherently acid labile, especially the HA, mutations may be required that enhance the acid stability of the virus particle before human transmission can occur. Human influenza viruses cope with the respiratory mucus barrier by using a specialised neuraminidase enzyme to chew it up. However the activity of the equivalent enzyme in a virus like H5N1 is compromised. We don't know why, but in passing from ducks into the chicken host, the virus loses a chunk of the genetic code for a part of the enzyme. This must have an advantage for replication in poultry but it may mean that viruses like H5N1, that have become adapted for chickens, are unlikely to be able to cope with the human mucus barrier. In other words chicken viruses may pose much less of a pandemic threat than viruses that have remained in wild birds or viruses that have adapted to other species such as the pig. Indeed there are many other avian influenza viruses circulating in wild birds that might have pandemic potential and we should be careful not to focus all our efforts on protecting ourselves from viruses like H5N1, rather we should remain prepared for other eventualities.

. . . it seems likely that tiny changes in this highly mutable virus can lead to the emergence of novel microbial agents with gargantuan consequence. . .

It was from the pig that the 2009 pandemic emerged. The H1N1 pandemic virus itself was a complex mixture of genetic material derived from viruses that previously circulated in swine on two different continents. The manner in which such viruses met and mixed is not clear and whether the mixing event itself was sufficient to spawn the pandemic or whether other mutations were also required before the pig to human transformation was complete is a matter of intense research at the moment.

However like the butterfly in Edward Lorenz's chaos theory that flapped its wings on one side of the world and caused a tornado of public health sequelae on the other, it seems likely that tiny changes in this highly mutable virus can lead to the emergence of novel microbial agents with gargantuan consequence.

INFLUENZA: WHAT ARE THE LIKELY THREATS OF FLU FOR THE UK AND HOW CAN SCIENCE HELP AMELIORATE THE CONSEQUENCES?

# UNIVERSAL INFLUENZA VACCINES

Dr Sarah C Gilbert
Jenner Institute, University of Oxford

**At the end of the 20th and the beginning of the 21st centuries, influenza immunology had become an unfashionable research area. The procedures for monitoring influenza viruses, defining the composition of the trivalent vaccine (against H1N1, H3N2 and influenza B viruses) producing vaccine seed stocks, manufacturing and annual immunisations of specified groups within the population were well established. The newer, more urgent threat posed to human health by the Human Immunodeficiency Virus (HIV) virus drew many viral immunologists away from their research on influenza. Now the tide has turned, drugs to treat HIV infections have been developed, and the potential and actual harm caused by an influenza pandemic frequently makes news headlines.**

Seasonal influenza vaccines have served us well, but are far from perfect. The efficacy of these vaccines varies between 50 and 90% in young adults, depending on the match between the vaccine and the circulating virus, but drops to 30 to 40% in older adults. In the 1997/1998 influenza season when the H3N2 vaccine component did not match the circulating H3N2 virus, 84% of the vaccinees over 75 years of age who were tested failed to develop a protective immune response. Testing of the new vaccine formulation each year takes place in healthy young adults, whereas the elderly are one of the main groups offered the vaccine. Influenza infection in the elderly accounts for a large number of deaths, but also high rates of hospitalisation, loss of physical function, loss of ability to live independently and exacerbation of cardiovascular and pulmonary symptoms. Although the annual vaccination campaign targets those aged over 65, and represents a considerable health care cost, in the best case scenario where there is a good match between the influenza strains in the vaccine and those in circulation, vaccination is estimated to prevent one in five cases of influenza-like illness, one in four hospitalisations for pneumonia and influenza and one in four deaths following hospitalisation for these conditions.

A further difficulty in producing influenza vaccines is that it is necessary to know the exact genetic sequence of the virus causing disease in humans before a vaccine can be produced, resulting in a six month lag between virus identification and widespread vaccine availability. Even after six months, there will not be enough vaccine for the whole world. Some biotech companies have therefore set out to produce recombinant protein vaccines that use newer technologies for influenza haemagglutinin (HA) production, shaving weeks off the

> . . . Influenza infection in the elderly accounts for a large number of deaths, but also high rates of hospitalisation. . .

production time. However any vaccine based on a specific HA sequence can only be produced after a new pandemic virus has been identified, and the requirements for testing prior to widespread use mean that there will always be a significant delay before people can begin to be vaccinated.

> . . . requirements for testing prior to widespread use mean that there will always be a significant delay before people can begin to be vaccinated. . .

A more innovative approach is to target a different part of the virus surface. HA is the major highly polymorphic coat protein of the virus but a small part of the M2 protein, known as M2e, is well conserved, and is also on the surface of the virus and therefore susceptible to antibodies that can recognise it. Although antibodies to M2e do not appear to be part of the natural immune response to influenza, they can be induced by vaccination, and this has been achieved in clinical trials. It is not known whether antibodies against M2e can provide useful immunity to influenza in humans, and the pandemic H1N1 virus contains four differences in the amino acid sequence, (out of a total of 22) from seasonal viruses on which the vaccine is based. This unexpectedly large difference has halted efforts to develop an exclusively M2e-based vaccine, although it may be possible to include M2e as a component of a more complex vaccine.

An alternative method to induce cross-reactive immunity is to induce antibodies against only the conserved portion of HA, rather than the whole molecule. It is known that these antibodies form a small part of the natural immune response to flu, but the challenge will be to work out how to produce a vaccine that results in only the cross-reactive responses.

The other approach that is being taken is to harness the second arm of the immune system, the T cell response. Any cell in the body contains specialised molecules on the surface that display a sample of the cell's contents to passing T cells that move through the body on 'surveillance'. This display enables the immune system to recognise any virally infected cells, as portions of viral proteins will be displayed, and if detected by a T cell that recognises influenza proteins, the infected cell will be killed, along with the virus that is hiding inside it. Whereas the external proteins of the flu virus are highly diverse, the internal proteins, which are protected from attack by antibodies, are highly conserved. Thus once we have recovered from infection with one influenza A virus, we have a T cell response that is capable of protecting us against other influenza viruses even when the two viruses are not closely related. However, as a few years pass, the quantity of T cells patrolling the respiratory tract on the look-out for influenza virus-infected cells gradually decreases, and we become susceptible to influenza disease again. At the Jenner Institute in Oxford, new methods of vaccination originally developed to provide a strong T cell response against malaria are now being deployed to make a cross-reactive influenza vaccine using two highly conserved influenza proteins, nucleoprotein (NP) and matrix protein 1 (M1).

Clinical trials of this new approach have demonstrated that it is possible to boost circulating T cell responses to these two proteins to a high level following a single immunisation. Importantly, when tested in older adults, there does not appear to be any decline in the immunogenicity of this new vaccine, known as MVA-NP+M1. In addition, the first efficacy testing in humans indicated that this approach to vaccination does indeed protect against the influenza A virus. More clinical development is now indicated.

The ultimate influenza vaccine will produce a broadly cross-reactive immune response employing both T cells and antibodies, and provide high efficacy in all sections of the population. This will take time, money and a willingness to try and then refine new approaches. Several new vaccines have entered early stage clinical trials, but many years of increasingly large and expensive trials will be required before any of these will be ready to be licensed. Obtaining funding for this stage of vaccine development is particularly difficult, as charitable funders do not have deep enough pockets and large vaccine companies are reluctant to fund research that they see as high risk. Companies wish to see sufficient evidence that a new type of vaccine will be highly effective before committing funds to late stage development and licensing, but it is not yet clear exactly what the new type of vaccine should be. There is a global public health need for improved influenza vaccines, and consideration should be given to committing public funds to advance research in this area. Once we understand how to achieve broadly protective immunity by vaccination in all sections of the population, vaccine companies will be willing to develop their own versions, which will have the potential to achieve major improvements in public health.

I think it is unlikely that we will ever have an influenza vaccine that gives protection for life, but it will be possible to make a vaccine that is given perhaps every five years to maintain immunity. This would result in a complete change to vaccine deployment and would make it possible to protect the whole population against all subtypes of influenza A, removing both the threat of a new influenza pandemic and the major economic losses currently caused by seasonal influenza.

## INFLUENZA: WHAT ARE THE LIKELY THREATS OF FLU FOR THE UK AND HOW CAN SCIENCE HELP AMELIORATE THE CONSEQUENCES?

# GOOD SCIENCE TO SUPPORT PUBLIC HEALTH POLICY

Professor Maria Zambon
Director of the HPA Centre for Infections, Health Protection Agency, Colindale

"In this world, nothing can be said to be certain, except death and taxes" (Benjamin Franklin 1789). To this we could reasonably add the emergence of infectious disease threats. The uncertainty and unpredictability of influenza, and the devastating impact that a pandemic can cause, underlies the description of influenza as the "last great plague of man", and ensures that it remains close to the top of the threat list for United Kingdom in 2011.

We now recognise that interventions can be applied to control epidemics of infectious disease, and that planning and maintaining a response capability will reduce the toll of human misery. Interventions include hygiene and use of protective equipment, quarantine, social distancing and more specific measures involving vaccination, and antiviral therapy. Intelligent and timely use of accurate communications about the nature of risk and the type of precautions that can be used supports operational responses and ensures that policy decisions are understood.

Translation of scientific knowledge and experience underlies the application of specific control measures, public health practice and accurate communication. Detailed analysis of the epidemiology of infectious diseases provides a framework for understanding which interventions will control particular epidemics. Two parameters, the basic transmissibility of infection and the ability to transmit when an individual is asymptomatic, do affect the way in which interventions are applied. In pandemic influenza, transmission predominantly occurs when individuals are beginning to be symptomatic and early in illness. Children have the lowest immunity to influenza and therefore have the highest viral replication and viral load. They are therefore particularly important in transmitting infection. This indicates that quarantine and travel restrictions will not be effective in preventing the spread of an epidemic. Key control measures for influenza involve the use of vaccines to induce development of protective antibodies, intended to reduce the impact of infection in the individual rather than eliminate transmission altogether, and the use of antiviral drugs.

Having a detailed understanding of the characteristics of individual infectious diseases provides much better information for operational decision support, during nationally coordinated response. This is provided by

- Intelligence about clinical illness case numbers and age attack profile, rate of growth of epidemic, risk factors associated with severe disease.
- The development of specific diagnostics to confirm cases identified by clinical diagnosis.
- Estimates of the total burden of infection in the community, cumulated from all cases of infection, mild, moderate and severe, so as to provide an estimate of severity of pandemic using case fatality index or hospitalisation ratios.

Estimations of case numbers of a widespread infection, which is transmitted easily, derived through surveillance, can be fraught with uncertainty. Indeed, surveillance indicators are only usually used during seasonal influenza to provide a picture of trends in illness in the community rather than absolute numbers of cases. Accurate confirmation of a new viral infection requires that, within a national laboratory infrastructure, there is scientific expertise to develop, validate and disseminate appropriate diagnostics within a matter of weeks, as part of an operational response. In 2009, from the identification of first case on 27th April, it was six weeks before regional NHS laboratories had a diagnostic capability on 1st June. During this period, intensive work at the HPA Centre for Infections in Colindale produced specifications for robust diagnostic tests for the NHS. This is a significant undertaking, which can be likened to the 100 metres sprint, an event for which extensive training and preparation are required in order to achieve the most explosive launch.

As an epidemic unfolds, the application of laboratory diagnostics switches from confirming cases in the community to confirming cases being admitted to hospital, a key measure of disease severity. Understanding the extent and duration of virus shedding in an individual is also important. If the new virus has similar shedding patterns to seasonal influenza, normal infection control advice can be applied, enabling health care resources to be directed in the most effective way.

In a newly emerging pandemic of influenza, where the countermeasures may be in short supply, it is important to delay epidemic progression if possible. For our first pandemic of the 21st century, we had antivirals to treat and prevent (prophylax) infection, a significant development over all previous pandemics. A new class of specific influenza antivirals, neuraminidase inhibitors (NI), were first licensed in 1999/2000. The use of antivirals can now be planned for, with recognition that efficient targeting of antivirals is operationally extremely complex. Antivirals can be used in a variety of different ways. They can be used to prevent the acquisition of infection following contact with an infected person (prophylaxis) or to treat individuals who are unwell. Antivirals are most effective when taken early, within 48 hours of illness onset. Arrangements for antiviral treatment need to focus on rapid, efficient delivery, when they are likely to be most effective. This requires that we can accurately identify clinical cases, treat them and then prophylax household and community contacts. Mass prophylaxis (containment) is a mammoth undertaking within any health system and does lead to the use of drugs in exposed but apparently healthy households and communities. In the United Kingdom in the 2009 epidemic a containment phase lasted for approximately eight weeks until there was sustained community transmission. Analysis of the outcome of antiviral prophylaxis in the first few hundred cases in the United Kingdom clearly indicated that prophylaxis slowed household transmission, reducing the likelihood of cases arising when index cases were treated within 48 hours. This confirmed the scientific advice underlying the policy decision to try to slow the epidemic growth and buy time for vaccine development.

Vaccines are clearly the key measure to be used against pandemic influenza. Much work has been done in the last decade, as a result of the H5 bird flu threats in South East Asia, to improve the licensure process for pandemic vaccines. The time to develop pandemic strain vaccines is anywhere between four and six months and is critically dependent on the generation of candidate vaccine strains. These are normally prepared in expert public sector institutes, and given to manufacturers for preparation of bulk vaccines. The first vaccines were available in the UK mid-October 2009, and approximately 80% of all the candidate vaccine strains supplied to manufacturers globally were from HPA National Institute for Biological Standards and Controls, another demonstration of the value of rehearsal and planning of response capability undertaken in the last few years.

As a pandemic unfolds and time to apply vaccine comes closer, the key questions arise as to the major risk groups for vaccination and the greatest susceptibility in the population. These questions are answered by analysis of confirmed cases. The analysis of susceptibility of remaining population needs to be approached in a different way, requiring that we have measurable immune correlates of protection or suitable surrogate. This will help estimate the residual population susceptibility, which in turn will influence whether vaccination should be applied selectively or universally.

Work in the last ten years had established the type of comparative data necessary to support decisions about how to deploy different vaccines in a pandemic. Head to head vaccine trials were conducted in children and adults using the available licensed vaccine in the United Kingdom. This demonstrated that the stockpiled vaccines generated good immune responses. Further monitoring demonstrated that the vaccine which was most extensively used had an efficacy comparable to or better than seasonal influenza vaccines. Key data used by the Joint Committee on Vaccination and Immunisation (JCVI) to recommend which groups receive vaccination and in which order, an important operating constraint when vaccines are in very short supply, were dependent on knowledge of the susceptible and risk groups in the population, the attack rates by age and measures of vaccine effectiveness. Stocks of available vaccine then determined the rate at which mass vaccination could proceed.

Individuals aged six months to 65 years were targeted for vaccination as a result of the data cumulated during the first few months of the pandemic, which showed most infection in younger age groups. Pregnant women were at particular risk of severe outcome and all pregnant women were advised vaccination. The over 65 in clinical risk groups were the next target group. This vaccination policy is in reverse to the normal seasonal influenza vaccine policy where over 65s are usually targeted first, but was appropriate given the observed patterns of greatest clinical risk.

Whilst much excellent communication was undertaken during the pandemic, there are still opportunities to improve this. Terminology to describe modelling estimates of severity described within bounds of statistical uncertainty gave rise to misleading communications, such as "UK prepares for 65,000 deaths from swine flu". It is now recognised that this is an area where more attention needs to be given to find better descriptions of results of early statistical and modelling analyses as epidemic unfolds.

We can conclude a few things about our use of scientific information to guide the response to 2009 pandemic. The independent Hine review praised the overall public health response "I heard nothing but praise for the public health officials". The areas which had benefited from most planning and preparation: diagnostics and vaccine seed development, antiviral distribution, design of head to head vaccine studies and estimation of vaccine efficacy, were well executed. The linkage between case counting and estimates of severity requires further attention, a problem recognised at global as well as national level. Providing better estimates of case numbers through seroepidemiology needs further development, and may be best accomplished by developing this activity as part of the overall seasonal influenza response, so as to improve our ability to use different data sources to make predictions about population susceptibility.

We are left with a scientific agenda where key development requirements include the improvement of seroepidemiology, application of more user friendly alternative laboratory tests which tell us about exposure rather than immunity and better ways of assessing overall disease severity. Alternative vaccines and increasing the repertoire of antiviral drugs and their delivery mechanisms are long-term scientific aspirations which the 2009 operational response confirms continue to be worthy goals.

The 2009 pandemic influenza demonstrated the dearth of systematic prospective patient orientated clinical research. The ability to undertake high quality R&D at the same time as responding to the pandemic should be more explicitly embedded in operational response. Emergency use of new drugs and novel therapeutic options, where there is not time to go through lengthy protracted RCT study design, may be an important countermeasure for treatment of severe cases in a more virulent infection. This requires thoughtful planning in light of the increasing regulatory burden for clinical research, where guidelines intended to help regulate drug trials have spilled over into observational, clinical studies, acting as barrier to the conduct of high quality observational research during unforeseen natural events.

In completing this article, I would like to acknowledge the contribution, help, companionship, support and sheer professionalism of my Health Protection Agency colleagues during the response to the 2009 influenza pandemic, the first, but probably not the last pandemic of the 21st century.

# THE UK IN SPACE

The Rt Hon David Willetts MP
Minister for Science and Universities

**I was delighted to introduce this year's annual National Science & Engineering Week seminar for the Parliamentary and Scientific Committee. The theme *'Space – How Can We Use It?'* and the subjects covered by the other contributors, were a reminder of how we are using space in more ways than ever before and how the UK is at the forefront of innovation.**

## UK EXCELLENCE IN SPACE

In my introductory remarks, I highlighted the UK's areas of expertise in telecommunications, particularly satellite navigation and broadband. I highlighted the launch last November of Europe's first dedicated Ka-band broadband satellite – HYLAS-1 – as an example of our technological prowess and of the strength of the public-private partnership business model. We invested some £40 million of funding into advanced telecommuni-cations technology by the UK Space Agency through the European Space Agency's ARTES programme. That initial investment was then commercial-ised by Avanti Communications, raising more than £525 million in capital for their first satellite, and creating jobs and revenue for the country.

This is an excellent example of how strategic investment in space technology can yield benefits for the wider economy. As a technical application, HYLAS-1 can provide the same high-speed broadband to a farmer in the Highlands that it can provide to a banker in the City. As a growing UK industry, the space sector as a whole already provides an estimated £7.5 billion a year to our economy.

But the value of UK involvement in space became apparent in other ways with the tragic events in Japan on 11 March. Less than two hours after the Tohoku earthquake and tsunami struck Japan, the International Charter on Space and major disasters was activated. This international network of satellites provided free images of the affected area to assist disaster response efforts and the Charter members' earth observation satellites continue to provide essential imagery to assist Japan's recovery.

The response to this disaster highlights the international nature of space and marks the first time that multiple space agencies – European Space Agency, the German Aerospace Centre and the Japan Aerospace Exploration Agency – are freely sharing data for understanding tectonic processes. The UK will also chair this initiative from May this year.

The UK has excellent earth observation capabilities. The radar instrument aboard the European Space Agency satellite ENVISAT was designed and built in the UK. ENVISAT itself, launched in 2002, was delivered by Astrium UK and remains the largest and most complex earth observation satellite ever built.

The UK is also building partnerships around the world. In the past year, we have signed agreements with Russia and the United States. In February I opened the UK-Russia Year of Space 2011 to commemorate the 50th anniversary of Yuri Gagarin's space flight, one of the iconic moments of the 20th century.

## POSITIVE POST-SCRIPT

In the Budget on 23 March, the Government ear-marked £10 million to start a national space technology programme with industry aimed at promoting economic growth and self sustainability. Funding will be channelled through the UK Space Agency.

We have committed to reforming the Outer Space Act – which will introduce an upper limit on the third-party liability of UK satellite operators, making the industry more internationally competitive.

We are also committed to working with the international regulatory authorities to enable space tourism operations in the UK and to define regulations for novel space vehicles that offer low cost access to space.

On 1 April the UK Space Agency became an executive agency of the Department for Business, Innovation and Skills, taking over responsibility for the majority of the UK's commitment to space exploration and science. Its efforts will be targeted at areas that have the greatest potential for delivering economic benefits, scientific excellence and national security. Priority areas include developing scientific advancements in space technologies, gaining a better understanding of our planet through earth observation spacecraft, and nurturing our next generation of space scientists and researchers. The organisation's strategy for 2011-2015 has been published for consultation and we invited comments on the Agency's draft strategy before 8 July 2011.

http://www.bis.gov.uk/ukspaceagency/who-we-are/strategy

## COMING UP….

The economy and education continue to be major areas of focus for the Government's involvement in space over the coming months and will be at the core of the inaugural UK Space Conference which takes place in July.

Recently, Jodrell Bank Observatory was selected to host the project office for the Square Kilometre Array (SKA) radio telescope project, a global initiative to develop one of the largest science facilities in the world by the early 2020s.

# SPACE FOR SCIENCE

John Zarnecki
Professor of Space Science,
The Open University

**Yesterday we had a wonderful day at the Royal Aeronautical Society celebrating the 50th anniversary of Gagarin's flight. Twenty-five years ago the Giotto spacecraft flew 594 kilometres past Halley's comet and this typifies the sort of thing I wish to talk about. These comments are very much my own and the first may be a form of political suicide! I'd like to start by saying that we don't primarily do Space Science because of a desire to generate either money or economic activity. We do Space Science because it is "Blue Skies" research and it might even lead to Nobel Prizes for some!**

Paul Gauguin's 1898 painting, entitled "D'où venons-nous? Que sommes-nous? Où allons-nous?" encapsulates all the drivers for space science: Where do we come from? Who are we? Where are we going? Or to translate these into Space Science terms – "How did our Earth, our Solar System, our Universe originate and evolve?"; "Where are we in the Universe?"; "Where are we going?"; "Where did life come from, and are we alone?".

Methods for "doing" Space Science either involve "going there" for example, to Mars, Saturn, or the Sun, or it simply requires putting our telescopes above the Earth's atmosphere. The atmosphere is like a dirty window and obscures radiation coming to us from our universe.

80% of our space science is done through the European Space Agency (ESA), though there are also important missions done with other agencies. Some ESA Missions go to places, such as Cluster for example, which placed spacecraft in the Earth's magnetosphere; Mars Express which is a spacecraft in orbit around Mars; on the other hand, the Hubble Space Telescope remains in low Earth orbit and is sometimes closer to London than is Edinburgh! Some are purely European Missions with the UK playing a large part such as XMM Newton. Hubble is 20% European with a NASA lead. Double Star is a Chinese Mission with British and European involvement, Akari is a Japanese led Mission, together illustrating that there are many different modes for doing space science in terms of international collaboration.

Examples of "going there" include Mars Express, a purely European Mission, which has been in orbit around Mars very successfully for several years. It provides wonderful resolution images of the surface of Mars. Data like these are an absolute goldmine for interpreting Martian processes in great detail. A fly-by Mars Express photo of Phobos, one of the two Moons of Mars, shows the best detail yet of this small body and in particular of potential landing sites for a Russian mission which is due to be launched later this year.

The Cassini-Huygens mission is one of the most sophisticated, and has been operating since 2004 and will operate until 2017. The Huygens Probe landed on Titan, the largest Moon of Saturn, in 2005, while Cassini performed fly-bys of the moons of Saturn and of Titan, thereby providing a wealth of data that will be analysed for decades to come with UK involvement in many of the instruments on board.

Rosetta is a purely European Mission, launched in 2004, and is due to arrive at a comet in 2014. Europe has a very strong tradition in cometary research. This mission will attempt to put a lander, the first ever on a comet surface, on 10 November, 2014. Comets are important as they represent the most pristine material within our Solar System, so put the date in your diaries!

Turning now to the other type of space science that we do. Galileo Galilei, in August 1609, was the first to turn his telescope to the heavens. Well now we do something similar, but we put our telescopes above the atmosphere, escaping its absorbing and blurring effects. The most famous is the Hubble Space Telescope, which started work in 1990. One of the most interesting results is the Hubble Deep Field, the result of staring for ten days at an apparently blank piece of sky. This produced an array of previously unseen objects, almost all of them being very distant galaxies. By looking into space we are effectively looking back in time to early epochs, see Figure 1. Many of the galaxies visible from Hubble are extremely young in

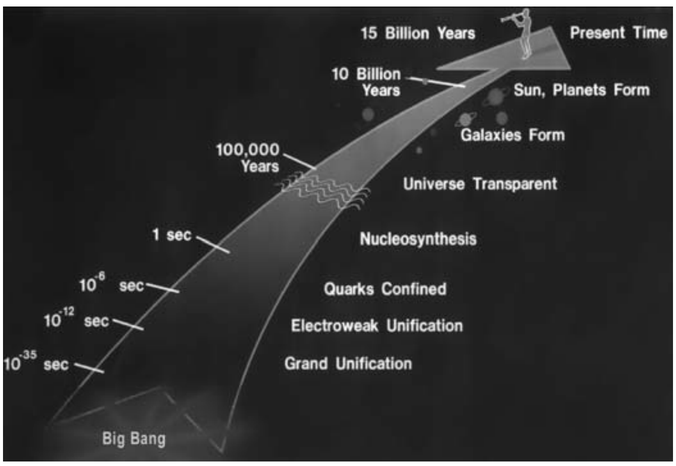



Figure 1 Look out in Space – Look back in time

cosmological terms.

The electromagnetic spectrum can be represented by a rainbow of which visible light is only a tiny part. This includes Gamma Rays, X-Rays, Ultraviolet, Infrared, and Sub-mm rays which are mostly absorbed in our atmosphere. That is not very helpful for astronomers, but probably lethal for us if they were not absorbed by the atmosphere! The space age has however enabled satellites to carry telescopes sensitive to these different radiations. A couple of these are worth mentioning here, namely Herschel and Planck, both European Space Agency missions and covering the infrared and microwave part of the spectrum which are essentially inaccessible from the ground. Herschel is the largest telescope ever put into space. Planck looks at microwaves and therefore measures the cosmic microwave background. If we want to go back more than the first 400 million years, we cannot see any light, and the microwave spectrum thus enables us to go back even further than the galaxies we can see with visible light and probe even earlier epochs in a scientific manner, see Figure 2.

Those are a few of the examples of space science. The spacecraft we use carry technological wonders usually built in universities and research institutes, whereas the spacecraft are built by industry. An analysis of contractors for the Huygens probe shows companies throughout the world, but mainly based in European countries, who contributed towards the construction of that wonderful probe. The main UK contributions included flight software, descent subsystems, parts procurement and parachutes.

Some recent examples of "spin out" from the technology of Space Science include medical imaging detectors, security applications, air quality monitoring in submarines and in-situ disease detection. Apart from the specialised technology developed through Space Science missions such as these, we produce a cohort of highly skilled graduates and technicians, many of whom go on to use their skills in the wider world.

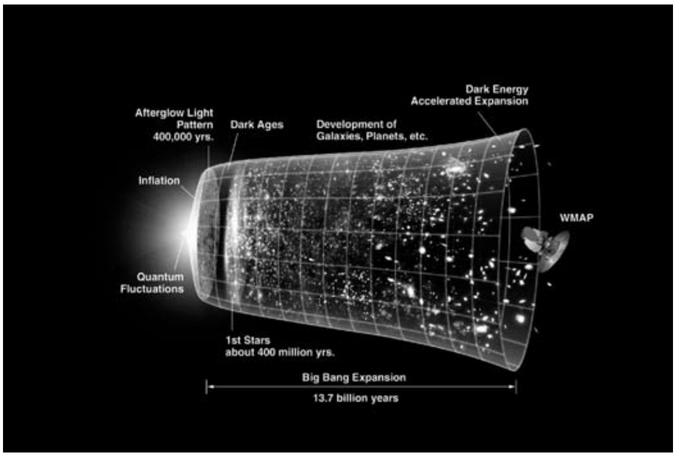



Figure 2. Herschel/Planck (ESA, 2008)

## SPACE – HOW CAN WE USE IT?

# EARTH OBSERVATION FOR SCIENCE, SOCIETY AND SERVICES


Professor Paul S Monks
Professor Earth Observation Science, University of Leicester

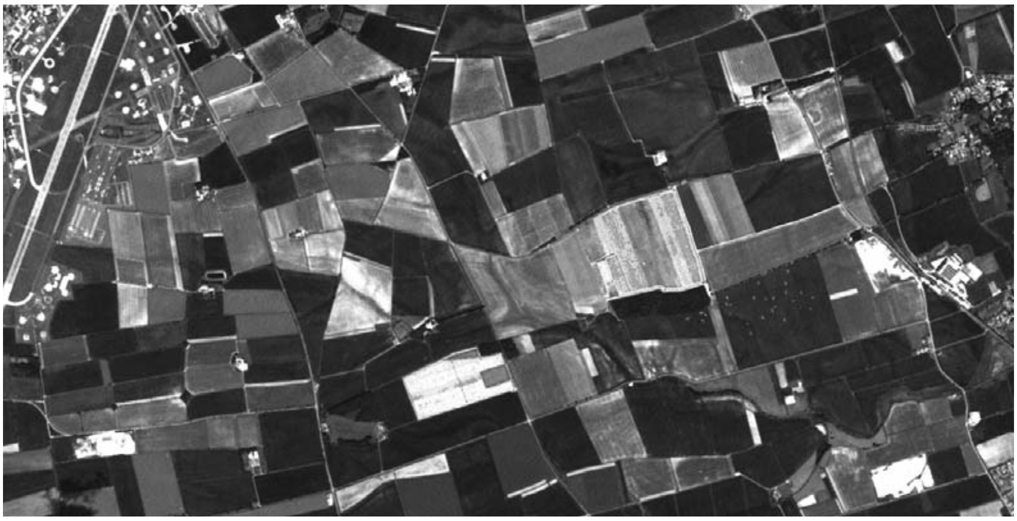

What is Earth Observation from space and how can it make a difference? Satellites impinge on many people's daily existence but without them realising, from the use of your "Sat" Nav to the weather forecast. Earth Observation is essentially looking at the earth from space using instruments on satellites; the application and exploitation of data from such instruments drives the three S's – science, society and service.

The first S is Science. Earth Observation Science is important as satellite data can tell us all about the different parts of the earth system from the cryosphere to the tropical regions, from the ocean to the atmosphere. The challenge of monitoring change in the earth system should not be underestimated from the rate of deforestation of rainforests, hazardous weather, flooding to dynamic changes in the ice-caps. In a way earth observation science allows us to give the earth a "health check".

You can observe earth in many different ways but satellites give us a unique view because they are accurate, they are global and they are independent. These properties make satellites a very important part of our global observing system.

The second S is society. Society faces a number of challenges moving forward such as food security, natural resource security, climate change, public health and environmental security. In many natural disasters Earth Observation acts as a first responder delivering maps and detailed impact assessments of the devastation to allow aid teams to target their efforts. Earth observation is integral to monitoring climate change be it by measurements of sea-surface temperature, a thermometer of change, or the emissions and concentrations of carbon dioxide in our atmosphere.

The third S is service. With all this data coming from satellites are there commercial benefits to be had? The pieces of the jigsaw are falling into place. In a European programme called GMES (Global Monitoring for Environment and Security) science will be put into service for the benefit of society by flying essentially uninterrupted missions to give us a continuous high quality data stream. This is important as it gives us the backbone on which to build services. Future services can help, for example, farmers to be more efficient in use of



fertilisers, the insurance industry assess risk, local government control air quality in their towns or cities. As satellites can provide data in near real time decision makers will have access to an unheralded view of the earth from the local to the global.

Earth observation – 'What can we do with it?' The answer is really only limited by our imagination. Earth observation does change our life and make a difference, from observations over the scientific bridge to societal impact and finally commercial service. In the future we face the challenge of making this seamless. The UK is a world leader in all areas of Earth observation. Science, society and services in a seamless way is going to be the clarion call for earth observation moving forward.

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## SPACE – HOW CAN WE USE IT?

# DRIVING INNOVATION IN SPACE

Michael Lawrence
Head of Special Projects,
Technology Strategy Board

**The Technology Strategy Board is working with the space industry, academia and the UK Space Agency to enable the development, commercialisation and exploitation of space technologies and applications.**

The Technology Strategy Board is the UK's innovation agency and is based in Swindon. It is a national body supporting innovation to support business, to drive economic growth and to improve quality of life. The title of the Technology Stratgey Board's original strategy, 'Connect and Catalyse', describes how the organisation has worked since it was established three years ago. A new strategy, 'Concept to Commercialisation', was published in May 2011 and defines how the organisation will move forward in the next three years.

Most of the Technology Strategy Board's activity supports companies who have moved beyond the blue sky research and have technology that needs to be developed and demonstrated prior to being launched into the commercial market. Resources are focused on areas where innovative UK businesses can thrive and exploit large global markets. Support through public funding for research and development makes a difference, it helps companies take risks, build new collaborations and open new markets.

Space is clearly a growth area, the Space Innovation and Growth Strategy published last year takes a twenty year view of how the industry could develop in the UK and defines how the UK can take a 10% share of a global market forecast to be worth £400 billion by 2030. The creation of the UK Space Agency in April 2011 confirms the importance of Space and the Technology Strategy Board supports the Space Agency in five areas.

1. Managing the UK involvement in telecommunications and navigation programmes run

by the European Space Agency.

2. Promoting business opportunities for UK space companies across all the growth areas that the Technology Strategy Board works in such as energy, transport, digital and healthcare.

3. Providing technology demonstration opportunities for UK organisations to prove their technology in orbit and remove a barrier to market.

4. Encouraging knowledge transfer between the academic base and industry as a driver of economic growth.

5. Promoting open innovation to accelerate the commercialisation of R&D activity.

The Technology Strategy Board ran its first Space R&D competition this year. Over 200 applications were received, 76 projects were successful and received small grants of around £25,000 towards projects which will run from May to July 2011. Some of these projects will take advantage of the facilities available at the newly opened International Space Innovation Centre at Harwell. The idea of these feasibility studies is to allow early work to assess the technical or business feasibility of innovative ideas for Space technology or applications of data from Space. The Technology Strategy Board put £1.2 million into this competition, with SEEDA contributing a further £0.6 million, and industry contributing £0.6m

The Technology Strategy Board is currently establishing a small number of elite Technology and Innovation Centres across the UK. The idea is that business focused research centres can fill a critical gap between excellent research and commercial exploitation. Space is one of ten potential areas for the next three TICs and the Space industry is building a case for a technology innovation centre in Space that can help deliver the ambitious growth objectives it has set itself.

The Space sector in the UK is changing with the UK Space Agency providing a single focal point for Space policy and the Technology Strategy Board providing its innovation expertise to the sector. This approach to innovation and growth bodes well for the future and makes the UK target of 10% share of the market by 2030 look achievable.

*The Technology Strategy Board (www.innovateuk.org) is a business-led government body which works to create economic growth by ensuring that the UK is a global leader in innovation. Sponsored by the Department for Business, Innovation and Skills (BIS), the Technology Strategy Board brings together business, research and the public sector, supporting and accelerating the development of innovative products and services to meet market needs, tackle major societal challenges and help build the future economy.*

## SPACE – HOW CAN WE USE IT?

# GALILEO, THE EUROPEAN GLOBAL SATELLITE NAVIGATION SYSTEM

Philip Davies
Surrey Satellite Technology Ltd

**Galileo is a joint initiative of the European Commission (EC) and the European Space Agency (ESA). Galileo will be Europe's own global navigation satellite system, providing a highly accurate, guaranteed global positioning service under civilian control. It will be inter-operable with GPS and GLONASS, the two other global satellite navigation systems.**

The Galileo system is a major undertaking consisting of a space segment of 30 satellites in the Medium Earth Orbit (23,000 km altitude), the launch of these satellites, a global network of 30-40 sensor stations, 9 navigation command stations, 5 satellite control stations and 2 European control centres plus the network to interconnect these facilities. The system also includes the equipment used by the system's end users to receive Galileo's signals.

Galileo offers 5 services to its users:

- An open signal, broadcast at two frequencies for mass market use,
- A commercial signal with better accuracy and service guarantees,
- A safety-of-life signal for high integrity services capable of being certified for use in safety related applications,
- A search & rescue service allowing emergency services to locate users "in distress",
- A public regulated signal for use by government approved users.

Compared with the situation today Galileo will improve navigation for anyone who makes use of one or more of the services offered. Galileo is

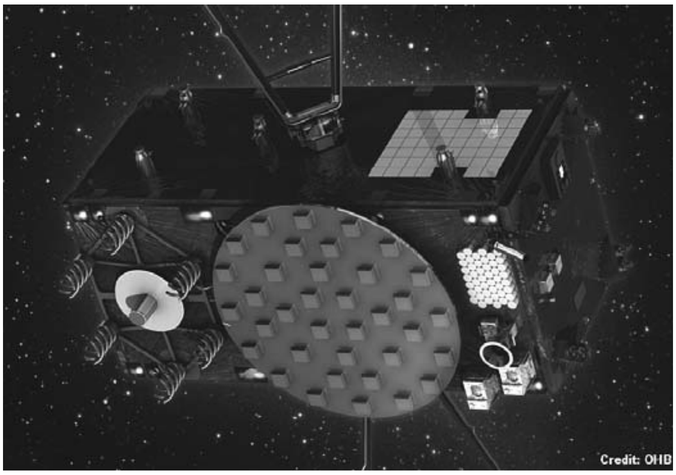


Image: Galileo FOC Satellite Credit: OHB

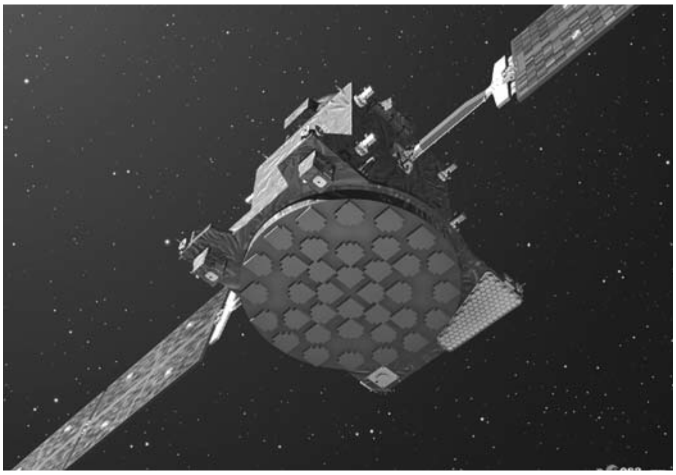

Image: GIOVE-A Credit: ESA

easily interoperable with GPS and the combination of Galileo with one of the existing systems such as GPS will double the number of satellites being received giving much improved availability in areas with marginal view of the sky such as city centres and valleys in mountainous regions. Galileo brings technical innovation such as better atomic clocks and broadcast on multiple frequencies which will improve the accuracy of satellite navigation and Galileo will be more resilient to effects such as multipath interference and jamming. Finally, an additional global system brings better residence to systematic (common mode) failures which could, in theory, make all of the satellites from one system inoperable due to a common cause.

Industrially, the UK has played a major role in developing the system. Surrey Satellite Technology Limited (SSTL) built the first test satellite called GIOVE-A and is now under contract to supply 14 navigation payloads for the next batch of "fully operational" (FOC) satellites being procured by the EC through ESA. Astrium built the navigation payload for the second test satellite GIOVE-B and for the earlier batch of 4 "In Orbit Validation" (IOV) satellites being procured by ESA. UK space segment companies such as COM DEV and ABSL are supplying equipment for the satellites. UK ground segment companies such as Astrium, Qinetiq, Scisys, Logica, Vega, NSL and NPL are involved in the building of the ground system.

The system development is now well advanced. The system has been validated by the two GIOVE test satellites and the ground systems built to support those missions. SSTL's GIOVE-A was launched in 2005 and continues to operate after more than 5 years. In 2008 ESA declared this mission a "100% success". GIOVE-B was launched in 2008 and continues to operate after more than 3 years. The next 4 IOV satellites will be launched starting in the second half of 2011 and the next batch of 14 satellites will be available for launch in 2013 and 2014. The batch of 14 satellites will be very efficiently produced and will roll off a production line at the rate of one satellite every 6 weeks. Given that the full system is 30 satellites and that only 18 are currently contracted there are still 12 satellites yet to be procured before the system can be fully operational.

The production line for the building of the payloads for the batch of 14 satellites will be based at SSTL's new technical facility, the Kepler building, which is due for opening in May 2011.

In conclusion, the development of the Galileo System is well advanced. The complete ground segment is under development and there are 18 satellites under contract – the initial 4 IOV satellites and the first batch of 14 FOC satellites. The 4 IOV and the first 10 FOC satellites also have launches booked – using Soyuz from French Guyana. The 14 FOC satellites are currently being designed and the production line will soon be up and running delivering a pair of satellites every 3 months.

Legal disclaimer: SSTL's work on Galileo FOC is funded under a programme of the European Union and executed under a contract with the European Space Agency. The views of the author expressed herein can in no way be taken to reflect the official opinion of the European Union and/or ESA. The OHB project is funded by, and part of, the Galileo programme which is an initiative by the European Union (EU), and where the European Space Agency (ESA) acts in the name of, and on behalf of, the EU. "Galileo" is a trademark subject to OHIM application number 002742237 by EU and ESA.

Image: SSTL's Kepler Building Credit: SSTL

# THE FUTURE OF SPACE – PUBLIC PRIVATE PARTNERSHIPS?

Bill Simpson
Trident Sensors Ltd

**In 2010 Eric Lindstrom of NASA and his co-authors from many other agencies [1] summarised the problem of research satellite missions. *"Satellites are expensive to design, build, and launch, hence the time from mission concept to launch is measured in years. This characteristic can leave data gaps in time with negative consequences for the essential inter-calibration between successive satellites that is critical to producing consistent time series suitable for climate research (especially decadal variability)."***

Public Private Partnerships (PPP) are joint projects that are to the Partners' mutual benefit, in this instance where government agencies wish to fly sensors and companies are willing to host the payloads. In order to maintain their businesses, satellite communications companies need to build, launch and operate satellites and constellations and this means that governments can benefit from rides into space at a fraction of the cost of conventional agency practices. In return, the companies can offset high capital costs by charging fees for payload hosting, sensor integration and data delivery in real-time to anywhere in the world. Between now and 2030 there will be well over 300 communications satellites launched – that's potentially 300 hosted payloads. So first, PPP's can drive down costs for both parties; second, heritage sensors can be flown with short time scales, ie 2 years rather than 7 to 15 years typical of Agency projects; third, many of the commercial satellites have long design lives (10 to 15 years) thus mission continuity is less of an issue; fourth, duplication of sensors in constellations means that launch or satellite failures are not catastrophic.

An essential requirement from the private sector is that the company is commercially viable. The communication sector is very buoyant with the total Mobile Satellite Services market turnover increasing from $0.6B in 2001 to $1.8B in 2010. Constellations operate both in geosynchronous (eg Inmarsat) and low earth orbits (eg Iridium). Both companies are in PPP's, Inmarsat with ESA on the Inmarsat XL/Alphasat project where Inmarsat gets an extended L-band payload to augment its BGAN service and ESA flies the Alphabus, an experimental communications payload. The launch is scheduled for 2012. Likewise Iridium Communications Inc needs to replace its LEO constellation of 66 satellites between 2015 and 2017, and hosted payload space has been designed into the satellites. Many of these slots have been reserved – ADS-B tracking of aircraft outside of land based radar range, GPS radio occultation, defence and other payloads. Earth observation missions are being encouraged by the Group on Earth Observations and these include ocean and land imaging, altimetry, cloud motion wind vector and Earth's radiation budget, the last two led by UK consortia. The total cost of integration, launch and 10 years operation is approximately $1M to $2M per year per Iridium satellite.

This low cost opens up the possibility for both research and business investment in single sensor constellations. Professor Monks (this issue) suggests that missions should fulfil the requirements of science, society and security. Altimetry, to monitor sea surface height and wind speed, fits these requirements. The research community has asked again for consideration to be given to such a constellation to resolve meso-scales eddies(2) and there are good business reasons for mariners to pay for a reliable service relating to real-time sea state. $3B of shipping losses per annum can be attributed to bad weather, often inadequately predicted by standard Met practices. Other factors make a polar orbiting altimeter constellation timely, such as the risks of oil and gas exploration in the Arctic and the opening of the North East and North West passages to shipping in the summer months. With respect to security, the Navy is an obvious beneficiary but so are regions prone to flooding due to storm surges or rising sea level. There are precedents for private companies operating profitable Earth observation operations (GeoEye, RapidEye and Astrium GEO Information Services), and often a public partner had the foresight to invest.

We can expect the private sector to play a greater role in all space activities. Entrepreneur Elon Musk serves as inspiration to youth during NSEW in that he founded SpaceX in 2002 and already has achieved great things, including the first commercial company in history to recover a spacecraft from orbit (see the video on www.spacex.com). SpaceX has won several $B contracts, including the support of the International Space Station and the launch of Iridium NEXT. The aim is to *"ultimately reduce the cost and increase the reliability of space access by a factor of ten".*

Lastly, on March 16, 2011, Charles Baker of NOAA gave a presentation at Satellite 2011 in Washington entitled *"Hosted Payloads, Thinking Outside the Box"* which acknowledges the maturity of commercial enterprises in space and the new opportunities offered. The UK is well placed to play its part in the exploitation of PPP's

[1] Lindstrom, E., et al. (2010), *'Research Satellite Mission',* Proceedings of OceanObs 2009, Venice

[2] Bonekamp, H., et al. (2010), *'Transitions towards operational space-based ocean observations: from single research missions into series and constellations',* Proceedings of OceanObs 2009, Venice

# UK SPACE AGENCY CHALLENGES STUDENTS TO TRAIN AS ASTRONAUTS

Heather MacRae
Director, Venture Thinking

**Four Astronauts were on hand at the House of Commons in December 2010 to launch a new space mission – a challenge to young people aged 9-11 to improve their health by training as astronauts. Three of the astronauts are well-known and regular visitors to Parliament: Dr Piers Sellers OBE, Dr Helen Sharman OBE, and Richard Garriott, British born private space participant and son of Dr Owen Garriott.**

The fourth visitor would have been spotted by eagle eyed observers as the diminutive mascot of Mission X – Flat Charlie (inspired by NASA Administrator, Major General Charles Bolden), pictured here with Piers Sellers before his adventure to the International Space Station as part of the space doctor Michael Barratt's payload for STS 133 Discovery. Dr Michael Barratt and the STS 133 Discovery Crew visited Parliament on June 29 2011 as guests of the Parliamentary Space Committee.


Dr Piers Sellers with Flat Charlie outside Big Ben




270 students, from 7 Essex schools(1), responded to the challenge and embarked on a unique mission to train like an astronaut and boost their health and fitness.

The international educational outreach pilot led by NASA involved 9 different countries including the USA, Columbia, and European nations. Mission X challenges students to be more physically active; increases awareness of the importance of lifelong health and conditioning; teaches students how fitness plays a vital role in human performance for exploration; and inspires and motivates students to pursue careers in science, technology, engineering and mathematics.

Supported by the UK Space Agency and Venture Thinking The Train Like an Astronaut Competition challenge 'blasted off' in December with a visit from Astronaut Richard Garriott to the lead school Mountfitchet

Mathematics and Computing College. Students took part in a launch day held at the secondary school on January 14th 2011. Input from rocket scientist, Jon London, Astronaut Instructor, Dr Iya Whiteley, and nutritionist Caroline Harper gave students expert insights into health off-world and back on earth. Jeremy Curtis from the UK Space Agency provided insight into the growth and innovation within the UK Space Industry and the exciting range of jobs available for future scientists and engineers.

In a message to the UK students embarking on Mission X, British Astronaut Dr Piers Sellers OBE, said, "Being an astronaut is one of the coolest jobs ever. Keeping fit has been key to me being able to go into space three times … and walk in space."

Major Tim Peake, the first British ESA astronaut, added, "Exercise and eating right while you are young is so important. Getting fit and staying fit helps you do what you want with your life, even reaching for the stars!"

Richard Garriott, the sixth private citizen to fly in Earth's orbit, and one of the Mission X ambassadors, said, "I had to overcome major medical issues before I could get to space. Being healthy and fit is important to get into space and to enjoy your time off-world."

The Mission X UK team took part in a range of physical activities and science activities during the 6-week mission. Each school organised their own training camps using the high quality resources available on www.trainlikeanastronaut.org. Teachers and students were invited to submit team points, post blog updates, pictures and videos of their training and download quizes, games and songs!

Much of the activity was completed in teams within a classroom setting but students were set some interesting extra-curricular tasks including food diaries, hydration logs, and physical fitness challenges. All the activities were aimed at showing the importance of an active lifestyle, healthy nutrition and also the fun of conducting hands-on science enquiries.

Team challenges in the UK include 19 different physical missions. Examples include:

- Energy of an Astronaut
- Base Station Walkback
- Let's Climb a Martian Mountain
- Crew Assembly
- Do a Spacewalk
- Hydration station
- Space Rock N Roll
- Zero gravity/Low Fat
- Astro-agility
- Speed of Light
- Get on Your Space Bicycle

Students gained skills in scientific reasoning and teamwork while participating in hands-on training missions targeting strength, endurance, coordination, balance, spatial awareness, biology, chemistry and physics.

Students enjoyed the hands-on activities – especially activities that involved simulated urine, testing bone strength using chocolate bars.

The pilot ended with an astronaut graduation event – with students skyping with Major Tim Peake and NASA Houston and with parents learning more about nutrition, exercise and space alongside industry experts including Jeremy Curtis, Head of Education and Outreach at the UK Space Agency.

The Mission has been a highly successful one – for students, parents, and teachers. Catherine Anderson, Headteacher of Mountfitchet Mathematics and Computing College commented:

"It's been a fabulous project on many levels. It has enabled our secondary school to work closely with our feeder primary schools on a great hands-on project that pulls together science, PE, and healthy living topics. All the students have been excited by the space context and the excellent teaching activities. We are hoping to build this into our curriculum over the coming year and extend to other schools within our local community."

Dr Glenys Jones, from the Medical Research Council Human Nutrition Division, one of the experts who took part in the Astronaut Graduation event noted: "Childhood obesity is a growing problem. This project has been great because it has allowed children to have fun whilst exercising, and has given them an insight into what makes a good diet in an interesting and engaging way."

Heather MacRae, Venture Thinking and the UK Co-ordinator for Mission X explained: "We only had a month to get Mission X off the ground after we were given the 'good to go' by the UK Space Agency. The fact that the schools were so enthusiastic about getting involved, took on the project and extended it is a sign that the project has a really inspirational and aspirational quality. All the schools involved took the materials, adapted them to their students, and extended and enriched the science content with art and music activities. It was great for the students to speak live to Houston, and say Houston, we have a success!"

Jeremy Curtis from the UK Space Agency is optimistic that the UK will be able to take part in the three year multi-year programme proposed by NASA as the next stages Jeremy said: "Mission X has had a huge impact. The UK Space Agency showcased Mission X activities at the Big Bang Fair in March 2011. We could see how exciting the mission challenges were to the general public and how they led into some really exciting discussions about life in space. We were delighted when the Red Arrows team joined in on some of the reaction and teambuilding activities."

A planning meeting is taking place at ESTEC in The Netherlands in July 2011 to identify the next phases in the mission. All being well a new set of young astronauts will be training and getting excited about the world's future in space in the UK from January 2012.

Further information on the project is available from:
Heather@venturethinking.com
www.trainlikeanastronaut.org
http://www.ukspaceagency.bis.gov.uk

*Heather MacRae as Director of Venture Thinking has been working closely with the UK Space Agency, Queen Mary University of London and Astrium Ltd on a range of education curriculum projects to inspire students in STEM areas. Current projects include Mission X - Train Like an Astronaut, Bridget Surfaces – outreach programme for the Mars Rover, and Media Space – a science communication project with The Metro newspaper. Heather has worked closely with the Parliamentary Space Committee on the education themed Christmas receptions.*

1 Essex Schools Involved are Mountfichet Maths and Computing College, Bentfield Primary School, Elsenham Primary School, St. Mary's Primary School, Birchanger Primary School, Henham and Ugley Primary School, Grove Primary School (Redbridge)

# BEYOND THE CLASSROOM – Outdoor learning and science education

Annette Smith
Chief Executive, Association for Science Education

*"When on board HMS Beagle, as naturalist, I was much struck with certain facts in the distribution of the inhabitants of South America, and in the geological relations of the present to the past inhabitants of that continent. These facts seemed to me to throw some light on the origin of species -- that mystery of mysteries, as it has been called by one of our greatest philosophers."*

This quote from the introduction of Charles Darwin's "Origin of Species" is perhaps the ultimate argument for outdoor science. If we examine the process by which Darwin came by the theory of evolution by natural selection, there is a fascinating process in action. During his employment as a naturalist on the "Beagle", Darwin made numerous detailed observations which he recorded diligently, collecting specimens to help him to continue the work when back in England. Using the results from his "outdoor science" Darwin developed the elegant theory of evolution by natural selection which is the central plank of modern biology. The nature of science is precisely that process – of making observations of the real world and developing theories which fit the observations and allow predictions to be made and the theories further tested.

If we look at the development of scientific theories in this way it is easy to make the argument for teaching science using the outdoors. In teaching young people to understand and enjoy science, the world beyond the classroom is essential. If we limit a student's experience of science to the classroom, we lose the connection with the real world and the opportunity for young people to emulate Darwin in observing in nature what can be described by scientific theory and explanation.

Another example of outdoor science in action is my own observation of the solar eclipse that was total in Cornwall in August 1999. I was actually on holiday in Italy, and unlike the weather in Cornwall on that day it was bright and sunny. At the time of the eclipse, which was partial in that country, it could be clearly observed by looking at the image of dappled sunlight through the leaves on the trees as it fell on the paving surrounding the pool. Each image had an eclipse shaped "bite" out of the circle of the sun's image, thus demonstrating that normally dappled sunlight is made up of many images of the sun, and that when there is an eclipse, this image changes. I found that observation incredibly exciting as it brought the scientific explanation of the eclipse to life as well as demonstrating the principle of the camera obscura.

So, if we deny young people the opportunity of developing an interest in science through relating their classroom based studies to the real world, we do them a great disservice. As illustrated above with an example from physics, many aspects of science can be usefully demonstrated by experiences beyond the classroom and it requires just a little imagination and a willing teacher to bring science alive in this way. The full residential field trip is at one end of the spectrum of outdoor science experiences and this has additional social benefits as well as the opportunity to carry out longer experiments, but outdoor science can also be much more informally organised to very good effect.

There are barriers, however, to using the outdoors even in a low key way. These are less marked in primary schools where it is relatively easy to use the school grounds (whether rural or urban) effectively to do science compared to secondary schools. Primary schools can be more flexible about their curriculum as the exit of one class for an hour doesn't disrupt the entire school timetable. Secondary school teachers may consider that outdoor science involves onerous arrangements for a residential field trip but a scientific principle can be investigated or demonstrated with minimal disruption to the school day with some creative thinking and forward planning.

The recent report on Outdoor Science produced by the Association for Science Education's Outdoor Science Working Group makes a number of recommendations which highlight the benefits of using the outdoors to complement classroom science. Among these are suggestions which would help teachers at the beginning of their careers to become confident in using the outdoors for teaching science. Mainstreaming outdoor science in this way, so that it becomes part of a science teacher's repertoire, alongside practical experiments in the laboratory, will help students to relate the science they learn about in the lab or the lesson to science in the real world. This will help them to be excited and engaged with science and make them more likely to continue their studies.

The pressures on initial teacher education and professional development, not to mention school budgets and technical support could, in these straitened times, put pressure on teachers and schools such that the use of the outdoors in science for regular observations and experiments or in the context of a longer field trip, reduces. This would be very unfortunate for the development of young people's learning in science.

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# EXTREME TECHNOLOGY EXPLORES THE WORLD'S HOT-SPOTS

Prof Nick Wright
Newcastle University

Dr Alton Horsfall
Newcastle University

Interesting things very rarely happen in safe and secure circumstances – a maxim that is just as true for scientists as it is for explorers. Unfortunately, scientists have struggled for generations with the limitations of fragile equipment to take data outside a relatively limited environmental range. Recent developments in technologies that can withstand hostile environments may at long last allow scientists to explore fully the 90% of the Universe that lies outside the -55C to 125C range of conventional electronics whilst operating technologies under high pressure is of crucial importance for our understanding and safe exploitation of the oceans. Such interesting environments are of course of great importance not just for scientists but also for UK industrial sectors such as space, defence, energy and health.

The Extreme Technology program at Newcastle University has led the way in bringing together both academic and industrial expertise to extend the range of crucial technologies that can operate in such interesting places. An approach that is critical for society as well. For example, more than 600 million people worldwide live in the shadow of a volcano and many more can feel the effect of a major eruption. Recent headlines following the eruptions of Eyjafjallajökull (2010) and Grimsvotn (2011) in Iceland and Puyehue (2011) in Chile described the chaos caused to air travel, with over 500 flights cancelled in Europe within the last year. Between 1995 and 2010, the Soufriere Hills volcano on Monserrat destroyed half the island (including the capital, Plymouth, and the airport), killing 19 people and resulting in some 8,000 refugees being relocated in the UK.

Fortunately the prediction of volcano eruption has progressed since the Romans used the shape and texture of goat's entrails. A key breakthrough was the understanding (developed by David Johnston in the 1970s) that prior to eruption the components of the gas emitted from the volcano crater changes (Fig 1). This was demonstrated at the 1991 explosion of Mount Pinatubo in the Phillipines, where the flux of sulphur based gas changed by an order of magnitude in the days before the eruption.

Currently, the gas is evaluated using optical means, which requires equipment to be installed at the volcano site, or through the use of remote earth sensing. These techniques measure the content of the plume whilst in the sky, the readings are therefore diluted by the air and so highly sensitive equipment is required. Of course, once a volcano shows signs of activity, people are evacuated to a safe distance, limiting the possibility of further scientific study. There is therefore a requirement for a system which can be installed in the volcano and relay information relating to the concentration of key gas species to a remote location. The primary challenge is the conditions inside the volcano where the emitted gas is typically around 400°C and contains a high concentration of corrosive acids. These conditions are so extreme, that conventional silicon based electronics cannot function.

Fig 1 - a gas mixture of steam and acidic gases (typcially $CO_2$, $SO_2$, $H_2S$, $H_2O$ and HF) venting from Mt Etna (photo courtesy of Dr A McGonigle, Sheffield University).

Within the Extreme team at Newcastle University and supported by the Engineering and Physical Sciences Research Council (EPSRC), we have demonstrated the key components of a system to monitor the concentration of gas in a volcanic fumaroles using an exciting new electronic material, an alloy of silicon and carbon – silicon carbide. The chemical and thermal stability of the carbon-silicon bond is greater than that of a silicon-silicon bond and this results in the ability to operate at higher temperatures (operation beyond 600°C has been demonstrated – Fig 2) and results in a material which is not affected by any known acid. Due to the relatively mature wafer and process technology, coupled with the excellent electrical and mechanical properties, silicon carbide is now the material of choice for the realisation of electronic sensor and control systems for deployment in aggressive environments.

Fig 2 - Silicon carbide electronics under a flame test in the Newcastle Laboratory (the insert at the bottom shows the construction of the sensor and associated electronics).

Over the last 10 years we have established at Newcastle University one of the world's leading academic groups in this field – collaborating with a whole raft of UK and international companies. This technology includes gas sensing arrays (capable for example of measuring gases such as hydrogen sulphide in the parts per million range), energy harvesting and power management systems, amplitude and frequency modulation transmission systems and instrumentation amplifiers, all capable of operation in such extreme conditions (Figs 2 and 3). The Extreme team thus stands at a unique threshold – we might at last be able finally to measure in real-time what is going on inside a volcano and realise the millennia-long hope of accurate eruption prediction.

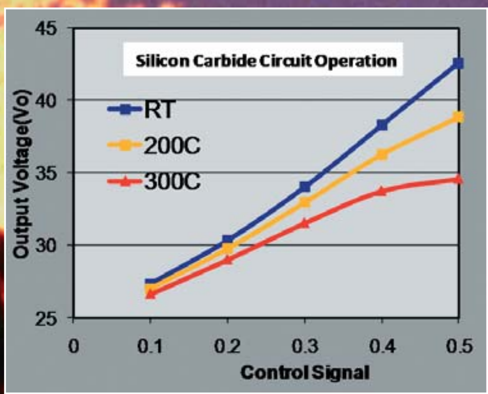


Fig 3 - Graph showing the comparative temperature stability of a silicon carbide electronic module.

In terms of UK research policy a key question is: how did we get to this exciting position? Firstly, we did not set out to study volcanoes – in the early days of our 10 year journey we were driven by simple curiosity and interest in the properties of new materials and their application to electronics. We felt that this would be useful (in fact we have advised dozens of prominent UK companies on such electronics over that period) but we were not quite sure where and how – our experience is inconsistent with the new requirements of research councils that academics must draw up so-called "impact plans" in advance of performing the actual research. We would contend that the most interesting applications of technology are rarely envisaged at the beginning – in fact not many people were even aware of volcanoes in Europe until the Icelandic eruptions of 2010. The work that we do is also highly multi-disciplinary and we could not have achieved the success that we have without close involvement with industry. In our direct experience, there is a lot of truly astonishing science and technology in UK companies – it has been very much a two-way knowledge exchange facilitated by fantastic schemes such as the Royal Academy of Engineering Industrial Secondments and consistent support from the EPSRC supplemented in recent years by our regional RDA, OneNorthEast.

And what of the future? Our colleagues in the Extreme Technologies program are also working on highly innovative technologies such as "through-metal communications", deep-water autonomous vehicles, and radiation-tolerant electronics. Driven by curiosity but inspired to apply our knowledge to lots of interesting places – check out our science and technology at http://www.ncl.ac.uk/eece/industry/extreme/or contact us at nick.wright@ncl.ac.uk

# SCIENCE AND EMERGENCIES IN JAPAN

Chris Pook
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**Before 11 March 2011 an article on science and innovation in Japan would have focused on the country's unwavering and longstanding commitment to investment in science and technology, a commitment which propelled it to the position of the world's second largest producer of advanced science and technology over a period of 30-40 years. During this time Japan has created some of the world's most recognisable and successful advanced engineering and IT companies – including Toyota, Panasonic, Nissan and Sony – as well as securing 15 Nobel prizes in science and countless patents and publications.**

However, after 11 March 2011, when Japan was hit by a multiple disaster of a kind that had never been seen before, it became apparent that one of the biggest challenges facing S&T in Japan lies in the softer side of science and innovation – the systems, processes and relationships which underpin science and which influence the relationship between science and society. This is an area which Japan has long recognised needs greater attention and which was thrown into sharp relief by the crisis at the Fukushima nuclear power plant.

It is only now, 3 months after the event, that details of what actually happened over the first few days of the crisis are starting to emerge. At 14.46 on 11 March a magnitude 9.0 earthquake struck off the coast of North Eastern Japan unleashing a 14m tsunami that swept away coastal towns and villages and hit the Fukushima Dai-ichi and Dai-ni nuclear power plants, 110 miles from the epicentre. A total of seven reactor units at the two sites were operating at full power when the earthquake struck.

Fukushima Dai-ichi lost all power and all back up capacity. Fukushima Dai-ni retained a single power supply to one unit and engineers, working without break for three days, were able to use this to restore power and cooling functions to each of the reactors. 9km of power cable were laid by hand in a single 16 hour period and by 14/15 March all four reactors at Fukushima Dai-ni were on track for cold shutdown.

But at Dai-ichi the story was different. Although only 10km away, the site had been hit by a larger and more devastating tsunami. With no power supply, no instrumentation and no cooling capability engineers were powerless to stop the deterioration of conditions in reactor units 1-3 and the spent fuel pond at unit 4. It is now accepted that at least one reactor (and probably all three reactors) suffered a partial meltdown due to loss of water from the reactor vessels and exposure of the fuel rods to air. Between 12 and 15 March the world watched as a series of explosions and fires destroyed the outer containment buildings of units 1,2 and 4. A total of 770 terabequerels of radiation appears to have been released from the reactors, roughly the same order of magnitude as was released from Chernobyl and justifying the highest rating of 7 on the international nuclear emergency scale.

The impact of this triple disaster – earthquake, tsunami and nuclear crisis – has been devastating. Nearly 25,000 people are dead or missing as a result of the earthquake and tsunami. None have died as a direct result of the Fukushima nuclear crisis, but over 10,000 households have been displaced from the 20km evacuation zone surrounding the plant. Supply chains have been disrupted and many businesses have taken a big hit. However many commentators also talk about a fourth disaster – the loss of public confidence in the ability of science, of business and of government to maintain proper checks and controls on nuclear technology, and to provide robust and independent advice to the general public.

The FCO and British Embassy in Tokyo were in the frontline of this, with a responsibility to provide accurate and up-to-date advice to British nationals on the situation in Japan and to provide support and assistance to those who may have been caught up in the disaster. There was a huge demand for information in the first few days of the crisis driven by the need to provide an accurate assessment of the threat from Fukushima as well as the status of power supplies, food, water and transport links. In the first week of the crisis the Embassy provided over 40 situation reports to the FCO crisis response team in London, working 24 hour shifts around the clock to report on the latest situation on the ground. By the end of the first month we had provided over 60 reports.

The nuclear situation at Fukushima and the threat from radiation soon came to dominate the information being provided to London, and became one of the key issues with respect to the travel advice being issued by the UK and other foreign governments. The Civil Contingencies Committee in the UK, meeting in Cabinet Office Briefing Room A (COBRA) commissioned the Scientific Advisory Group in Emergencies (SAGE), chaired by the Chief Scientist, Sir John Beddington, to provide advice on the risk from Fukushima – particularly to residents in Tokyo.

Working closely with expert agencies from across the UK and independent advisors, the group developed reasonable worst case and enhanced worst case scenarios which were to provide a robust and enduring basis for the British government's advice. In addition, the group established a modelling capability which would produce predicted radiation dose maps every four hours, should the situation at Fukushima deteriorate. A response system was established which would enable the Embassy in Tokyo to receive advice within 30 minutes of an event at Fukushima.

One of the most frequently asked questions in Tokyo and elsewhere was what information was available, where could it be found, and was it reliable. With the exception of the first few days, when very little data could be obtained from the plants, it soon became apparent that the Japanese government was doing all that it could to make as much information available as possible, as quickly as possible. The government made clear to TEPCO (the power company responsible for the Fukushima site) and other agencies that there should be full transparency, insisting for example that results of the Japanese radiation dose modelling system (SPEEDI) should be made available to the public. A wealth of data became available on government and industry websites and the Japanese Foreign Ministry held daily briefing sessions for the diplomatic community. It was not uncommon to see government spokesmen giving press briefings in the small hours of the morning.

Key pieces of data, such as reactor temperature, pressure and water levels, were absent due to lack of instrumentation and in some quarters became something of an obsession. However the issue was not so much the volume of data, but expert interpretation of the data and what it meant for the general population. There was a sense that what was needed was an authoritative, independent, consensus view of the risk.

At the Embassy, we were confident that the advice and monitoring system were robust and reliable. But we would be, wouldn't we? It helped that as Science Counsellor I had previously visited some of the UK's own nuclear legacy sites and had a good grounding in science. We had access to the best advice available and to experts in radiation health and safety and we were confident that the approach adopted by SAGE – advice based on the worst case scenario – meant that we did not need to know the detail of attempts to stabilise the reactors. Our advice was based on the worst that could possibly happen, and the calculations had been confirmed by experts in other countries. But this was not enough. There was a maelstrom of conflicting advice from foreign governments, media reports, expert opinion, speculation and just plain suspicion of anything said by the government and TEPCO.

As a result, it was just as important to find a way to communicate the British government's advice to the British community in Japan, as it was to get the advice right. To do this, between 15 March and 7 April, Sir John Beddington and experts from the Health Protection Agency and DOH, joined four telephone conferences with British nationals and British businesses in Japan to explain the basis of the science advice and answer questions on the risk from radiation.

The transcripts of the telephone conferences were posted on the website within 24 hours and broadcast on Twitter and Facebook. It quickly became apparent that the advice and transcripts were being tweeted and retweeted throughout Japan, with feedback from an international law firm noting that the Beddington transcripts had "had a huge impact in the international business community, with major law firms, banks and key multinationals using the advice extensively" and that "it had been a source or reassurance and informed decision-making to an extent that perhaps we in the Embassy hadn't realised". The importance of providing transparent, independent and accountable advice had emerged as one of the key issues of this crisis.

At the end of May, we explored this issue further at a symposium hosted jointly by the Embassy and the Graduate Institute of Policy Studies (GRIPS) in Tokyo. Sir John Beddington spoke about the challenge of providing science advice in emergencies and the British government response to Fukushima. There was a strong desire to learn more from the UK system and to find ways to increase the transparency, accountability and independence of science advice in Japan. Japanese advisers have since visited the UK to learn more about SAGE and the Cabinet Office Civil Contingencies Secretariat. The Embassy will continue to work with Japan to develop this exchange further, as well as to look for ways to promote UK expertise gained from managing our own nuclear legacy.

Cold shutdown is not expected to be achieved at Fukushima Dai-ichi until the end of the year, but this will only mark the end of the beginning. Work lasting many years will be needed to clean up and decommission the site and monitor the extent of contamination in the surrounding area. It will be difficult and challenging, but there is no doubt that Japan will eventually succeed.

However, the bigger question is whether Japan will emerge from this crisis stronger than before. Fukushima has shown that there is a pressing need to reform the cosy relationship between business, government and the regulators, and to take a fundamental look at the safety culture within the nuclear industry. The government must take steps to rebuild public confidence in science and technology and develop robust sources of independent and transparent advice.

This will take a long time but has huge implications. Thirty of Japan's 54 nuclear reactors are currently shut down for maintenance or safety reasons and plans to build an additional 14 reactors by 2030 are being reviewed. Japan needs to rebuild confidence in the industry if nuclear is to remain a long term source of clean and secure energy. More broadly, the country's overall relationship with science and technology needs to be refocused. The fourth basic plan for science and technology, which sets out government priorities for S&T investment from FY2011-2016, is being reviewed in order to give greater priority to disaster recovery and safety and an even greater emphasis on green innovation and energy R&D. It will also look more closely at how communication on risk and emergencies can be improved within Japan and with other countries and the role of the Cabinet Office Council for Science and Technology Policy.

This is to be welcomed. Japan spends 3.6% of GDP on science and technology, with the government consistently spending about £25 billion (Yen 3.6 trillion) annually. The fourth basic plans sets a goal to increase expenditure to 4% of GDP and to "cultivate science and technology as a culture". Fukushima has shown that public acceptance of technology cannot be taken for granted, and that scientists, engineers, industrialists and politicians must pay greater attention to the needs of society and the importance of building public trust and acceptance.

The UK has a strong and mature relationship with Japan and many links at expert level. We have been able to help in many ways. During the crisis the Nuclear Decommissioning Agency and UK industry provided protective radiation equipment and monitoring equipment, while others offered to provide technical support and expertise. The UK science base offered practical support to Japanese researchers affected by the disaster by making available additional time on UK research facilities – the supercomputer HECTOR and the ISIS neutron scattering facility for example – and British scientists are participating in research programmes to look at the impact of radiation releases into the marine environment, drawing on experience from Sellafield. But when the UK-Japan Joint Committee on Science and Technology next meets in London this Autumn, one of the most important areas for discussion will be the provision of science advice in emergencies and what we can do jointly to help the world learn from the terrible crisis experienced by Japan.

# The Global Experiment, the world's largest-ever chemistry experiment

**On Wednesday 22nd June children from Oasis Academy and Trinity School, both in Croydon, went to Portcullis House to test the water quality there.**

The Global Experiment will be the largest single collection of data on water quality ever undertaken at one time and will be achieved by hundreds of thousands of school children from around the world becoming scientists for a day.

Anthony Upton/PA Anthony Upton ©

Anthony Upton/PA Anthony Upton ©

Desree (13) from Oasis Academy, and Khizr (13) from Trinity School are seen here with Professor David Phillips, President of the Royal Society of Chemistry, and Gavin Barwell, MP for Croydon central, at Portcullis House in Westminster, checking the pH level as part of The Global Experiment.

Anthony Upton/PA Anthony Upton ©

Children from Oasis Academy and Trinity School, both in Croydon, meet Gavin Barwell, MP for Croydon central, Professor David Phillips, President of the Royal Society of Chemistry, and Stephen Benn from the Royal Society of Chemistry, taking part in The Global Experiment at Portcullis House.

# 25 YEARS OF TRANSCRANIAL MAGNETIC STIMULATION – where are we now? Where are we going?

Dr Mark Stokes
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**Electricity is the language of the brain: neurons communicate with one another via electric impulses known as action potentials, which constitute the basic unit of information processing in the central nervous system. A key goal in neuroscience research and clinical application is to manipulate this electrical brain activity.**

Early pioneers in neurosurgery applied microelectrodes to the surface of brain to determine the functional role of specific areas. By constructing a functional map on the brain surface, surgeons can then minimise, as much as possible, post-operative loss of function. Patients, who remain conscious during this type of surgery, describe the effect of stimulation, including the evocation of old memories, smells or associations. These vivid first-hand accounts provide fascinating insights into the workings of this remarkable mass of grey matter; however, by necessity, such invasive procedures are limited in scope.

Ultimately, the goal is to stimulate the brain non-invasively, by somehow crossing the barrier of the cranium. So-called *transcranial* stimulation was first achieved with currents applied directly to the scalp[1]. However, because of the relatively high electrical resistance of the skull, a large current must be applied to the scalp in order to deliver enough current to activate underlying brain cells. Therefore, although strictly non-invasive, transcranial electric stimulation (TES) is in practice too painful for general use.

The breakthrough in non-invasive brain stimulation came in 1985, when Barker and colleagues at Sheffield University published a seminal paper in the Lancet describing a painless procedure for human transcranial stimulation[2]. In this brief, but landmark scientific report, they described how they could use magnetic fields to generate local electric currents in the brain. This novel approach, now known as transcranial magnetic stimulation (TMS), exploits the principles of electromagnetic induction. During TMS, an insulated coil is placed against the scalp surface overlying the targeted brain area. When discharged, the coil generates a brief magnetic pulse that passes unimpeded through the skull and into the brain. This time-varying magnetic field in turn generates a secondary current within the underlying brain region.

Barker and colleagues originally developed TMS as a clinical diagnostic tool for assessing the integrity of nerve pathways following damage caused by disease, stroke or spinal cord injuries. In subsequent years, applications for treatment have also been explored. Early enthusiasm for the therapeutic use of TMS focused on psychiatric conditions, particularly depression. Although modest improvements have been observed, there remain methodological issues associated with identifying the therapeutic mechanism. Therapeutic applications have also been explored for a range of other psychiatric conditions, with some promising results; however, more research is needed to establish the clinical relevance of TMS in psychiatry[3].

As a research tool, the success of TMS is unqualified. Even today, 25 years on, TMS is the only available method to activate specific brain areas. Most commonly, TMS is used to probe the functional role of a given brain area by introducing a sudden burst of activity that effectively disrupts normal function. As a tool for brain disruption, TMS complements measurement techniques such as functional magnetic resonance imaging. Where brain imaging can identify which brain areas are more or less active under specific conditions, TMS can be used to test whether the observed activity directly contributes to the function of interest.

What does the future hold for brain stimulation? One of the most important limitations for TMS is depth. Currently, TMS can only be used to stimulate relatively superficial brain areas. A non-invasive method for stimulating deep brain structures would have a profound impact in both research and clinical settings. One potentially exciting lead comes from ultrasound. Recently, researchers have provided proof-of-principle evidence that high-frequency sound waves emitted outside the head can generate focal activity in deep brain structures without damaging neural tissue[4]. Nevertheless, it may be many years before ultrasound stimulation will be approved for human use.

Since Barker's landmark demonstration of painless, non-invasive brain stimulation, TMS has become a standard tool for neuroscientific research, clinical diagnoses, and increasingly, therapy. Local industry has also capitalised on this UK innovation. For example, The Magstim Company Limited, based in Whitland, is now a world-leading manufacturer, and distributor of TMS, and was recently awarded the Queen's Award for Enterprise, in recognition of their expanding worldwide operations. This company continues to work closely with the development team at Sheffield, as well as other UK research centres, demonstrating how fundamental research and innovation can directly benefit UK industry, and economic competitiveness.

1 Merton PA, Hill DK, Morton HB, & Marsden CD (1982) Scope of a technique for electrical stimulation of human brain, spinal cord, and muscle. (Translated from eng) *Lancet* 2(8298):597-600 (in eng).
2 Barker AT, Jalinous R, & Freeston IL (1985) Non-invasive magnetic stimulation of human motor cortex. (Translated from eng) *Lancet* 1(8437):1106-1107 (in eng).
3 Ridding MC & Rothwell JC (2007) Is there a future for therapeutic use of transcranial magnetic stimulation? (Translated from eng) *Nat Rev Neurosci* 8(7):559-567 (in eng).
4 Tufail Y, et al. (2010) Transcranial pulsed ultrasound stimulates intact brain circuits. (Translated from eng) *Neuron* 66(5):681-694 (in eng).

# REACH and the Metals Industry – Unintended Consequences Causing Concern for Cobalt

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Director, Cobalt REACH Consortium Ltd

**The EU's chemical management policy for the Registration, Evaluation and Authorisation of Chemicals (or REACH) has many ambitions and compelling aims to protect EU citizens and workers from exposure to chemicals, and these are supported by Industry. However, we are also seeing that there are many unintended consequences of the application of the Regulation, in particular it is becoming evident that REACH is creating a barrier to trade for cobalt and it is also inhibiting the innovation platform so prized by UK industry.**

The metals industry has spent several years organising for participation in REACH, by forming Consortia and planning extensive work programmes. Significant funds have been committed towards fulfilling their REACH obligations, and there are expected to be substantial further costs for Industry.

REACH was not designed initially to encompass metals, the focus being on organic Persistent, Bioacumulative and Toxic substances (PBT) and very Persistent and very Bioaccumulative (vPvB) substances, however metals were included and here the problems began. First of all the metal industry is essentially data rich as it is already controlled through existing legislation. Secondly, the methodologies used to measure human and environmental effects are not easily adapted to metals and the industry has devoted considerable resources to developing new methodologies. Thirdly, because metals are naturally occurring they exist in the environment, and therefore should not be categorically linked with the PBT substances. In fact certain metals such as cobalt, which is an oligo element, are required by humans and animals for vitality and growth (vitamin B12 has cobalt as a co-factor).

Where Industry experiences the problems is in the application of the regulation which is far too complex, inflexible and in some cases disproportionate, inadequately defined and applied heavy-handedly. The goalposts are constantly moving – for example the issue of intermediates under strictly controlled conditions is a point in question where the European Chemical Agency (ECHA) amended the guidance mid-term when the whole of industry had already embarked on Registration of their substances. This important matter is still not adequately resolved and some of the implications for the metals industry are dire – the surface engineering industry is under particular threat. Also, the application of the REACH Regulation is 'hazard' focused even though Industry has explained the difficulties with such an approach. In short Industry strongly supports chemicals management based on Risk not Hazard.

The UK is an important user of cobalt and there are a broad base of industries that are dependent on cobalt and cobalt compounds, from superalloys (eg aerospace and land based gas turbines; hard wearing castings in renewable energy applications), catalysts (clean fuel technology and removal of harmful gases such as NOx), digital storage (essential in computer processing), industrial cutting tools (eg high speed steels and hard metals), driers in paints and pigments, rechargeable batteries (mainly Li-ion systems), high strength permanent magnets (eg for wind turbines) and many other applications. Cobalt is very much a technology enabling metal and is important to achieving the stated ambitions of the UK Government's 'Green' agenda.

Cobalt is a minor metal and is essentially a by-product of copper and nickel mining. Cobalt also has a broad range of highly specialised and important uses. However, cobalt is not an obvious metal like copper as it is only ever used in small amounts to alloy with other metals to considerably improve operating characteristics and attain greater operating efficiencies, or it is used in a chemical form for many critical applications ranging from safety in radial tyres to energy storage in rechargeable batteries. Out of sight often means out of mind and this seems to be an area that the Regulators failed to consider fully when including the metals industry in the REACH Regulation.

Of course such considerations are outside the ECHA remit but when embarking on such an ambitious Regulation it would have been advisable to have undertaken an impact assessment as, without such analysis, the risk of unintended damaging consequences for industry, employment, and the environment is high. In REACH of course each substance, if called to be Authorised, has to provide this information in evidence to justify usage – however the cost of preparing such a defence for any cobalt substance which might be subject to Authorisation is very high. Given the small tonnage and broad range of uses involved, this will probably not be sustainable for the economic survival of some chemical compounds. A case in point is the disproportionate treatment of cobalt salts in the REACH Authorisation process.

The criticality of supply of strategic metals (and minerals) is another issue. The UK Department of Environment, along with the USA Department of Energy and the EU with the Raw Materials Initiative, seem to have suddenly discovered that cobalt is actually critical to their base industry, and so they wish to work with industry to protect the position. DG Enterprise is also tasked to look at improving the competitiveness of EU industry. Most regrettably there appears little joined up Governance here as the application of REACH could inhibit or even prevent the utilisation of some cobalt substances in the EU because of the cost of compliance, and other unintended consequences of the Regulation, and cobalt is not alone.

All the issues that the REACH Authorities believe they had with the import and manufacture of substances will doubtless move towards other (non-EU) countries where regulations and controls are nowhere near as effective as those in the EU (even before REACH!). In simple terms, this amounts to an off-loading of the responsibility for safer chemicals management, without any guarantee that this can be accomplished in practice.

Substitution is the end game of REACH for substances prioritised for Authorisation, and this could be the case for several cobalt salts. However, it is notoriously difficult to substitute cobalt substances without suffering serious reductions in efficiency and/or performance. In the catalyst sector this is particularly apparent as well as for high performance alloys and in other technology enabling processes. For some critical applications for example there are no substitutes that could provide the advantages offered by use of cobalt substances. For example in the catalyst industry, 1 kg cobalt contributes to a SOx emission reduction of 25,000 tonnes and a NOx emission reduction of 750 tonnes per annum. If substitution provided enhanced characteristics or better economy then industry would automatically do this. With cobalt it is not appropriate just to talk about substitution as a means to an end as this could cause serious economic damage to the sector and at the same time cause a reduction in efficiency of some important processes and applications. The substitution approach of REACH pre-supposes that this hasn't been considered before. There is little credit given to the fact that industry has already spent many years and significant investment to identify their substances of choice. The cobalt substances used today in many specialised applications have resulted from earlier programmes, and now the future technology developments are being cast into jeopardy!

The costs of REACH are a major factor affecting the current and future plans of industry, and we will undoubtedly see some chemical compounds dropped, without any appreciation of what damage this could ultimately do to the overall UK (or EU) industry. The Cobalt Industry under the REACH Consortia will have expended some 7 million Euro[(1)] (and counting!) in preparation of the registration dossiers. Evaluation of these dossiers demonstrates that there is negligible Exposure[(2)]. It is therefore most surprising that of all the substances that could be proposed to the Candidate list for Authorisation, five cobalt salts were selected, even though there are many compelling reasons why they should not go forward, such as, being covered by existing legislation, largely intermediate and no consumer exposure. Consequently we believe this illustrates a disproportionate application of the REACH Regulation to the cobalt sector. The cost of this process will be levied on part of an industry with a global refined production of 76,000[(3)] tonnes, not the 20 million tonnes of copper or 40 million tonnes aluminium or the 1.4 Billion tonnes of crude steel[(4)].

These are the practical problems associated with a well meaning Regulation that has become too complex and overbearing for the metals industry. REACH should be part of a regulatory Agenda which seeks to improve the real health and safety of its citizens as well as the competiveness of industry by working in conjunction with other important initiatives. It should be applied proportionately, fairly and in a non-discriminatory manner. For cobalt, with its unique technology-enabling properties, there is a risk of seriously damaging the innovation platform which is essential for the Research and Development initiatives and vital for the wellbeing of UK industry and for the environment.

(1) CDI/CoRC Consortia Costing Estimate;

(2) Cobalt Reach Consortium Extract of Exposure Scenarios from Registration Dossiers;

(3) CDI Cobalt News April 2011;

(4) World Bureau Metal Statistics for 2010

# IMPORTANCE OF STRATEGIC METALS TO THE GLOBAL ECONOMY

Andrew Bloodworth
British Geological Survey

**Global concerns are growing over the long term availability of secure and adequate supplies of the minerals and metals needed by society. Consumption of most metals has increased steadily since World War II and demand is expected to continue to grow in response to the burgeoning global population, economic growth (especially in the emerging economies of Asia and Latin America) and the requirements of new and/or environmental technologies.**

Minerals and metals are probably the most important pillar of the global economy - 'if you can't grow it, you have to mine it'. We need minerals for food production (fertilisers, drinking water, food preparation and packaging); energy (fossil fuels, power generation, transmission); construction (houses, schools, hospitals, shops, offices); transport (roads, railways, airports, cars, buses, trains, ships and aircraft); technology and communications (computers, telecommunications, electronic applications); 'green' economy (renewable energy, energy efficiency, low carbon transport).

We produce metals and minerals in very large amounts. In 2009, global mines produced 18 million tonnes of copper, 2.2 billion tonnes of iron ore and 7 billion tonnes of coal[1].

Aside from the major industrial metals such as iron, copper, lead and zinc, we also utilise a group of 'critical' or 'strategic' metals, so called because of their growing economic importance and high risk of supply shortage. They include metals such as antimony, beryllium, cobalt, gallium, germanium, indium, lithium, niobium, platinum group metals, rare earths, rhenium, tantalum and tungsten. In order to assess concerns regarding supply security for the global economy, it is necessary to understand some of their key characteristics and how they differ from other metals and minerals.

## KEY CHARACTERISTICS OF CRITICAL METALS

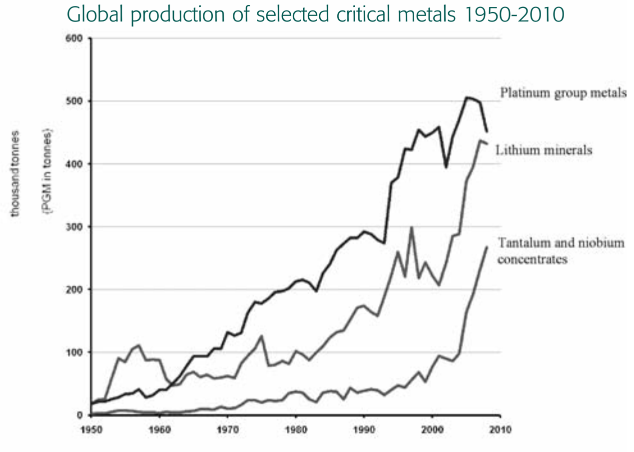
Critical metals have some economic characteristics which distinguish them from the major industrial metals. The volumes of critical metals produced are currently much smaller than for the industrial metals. In 2009, the world produced over 1.2 billion tonnes of steel and almost 40 million tonnes of aluminium, whereas total production of rare earth elements was only 123 thousand tonnes. Global production of platinum group metals in 2009 was only 429 tonnes[1].

Although production is modest compared to industrial metals, consumption rates of critical metals are rising quickly from a very low base (see graph). Drastic changes in production rates over time are illustrated by the fact that, for example, of all the platinum group metals and niobium-tantalum we have ever utilised, 75 per cent has been extracted since 1980.

Compared to industrial metals, and precious metals such as gold and platinum, the size of the global markets for most critical metals is relatively small. With some exceptions, this is currently a disincentive to investment by many of the major mining companies[2]. This situation, combined with concerns related to supply security, appears to be leading towards an alternative approach to maintaining supply by close collaboration between producers and consumers or even vertical integration of mining companies and industrial consumers. This provides certainty for the metal producers and security of supply for manufacturers and is a similar business model to that used by a number of industries including, for example, fluorochemicals.

Another consequence of this lack of economic interest until recently is the fact that their life-cycle in both the natural and anthropogenic environments is poorly understood in comparison to metals such as iron, copper, lead and zinc which we have been using for thousands of years. We know relatively little about the processes by which these metals form, are transported

Global production of selected critical metals 1950-2010




Data from British Geological Survey Survey and concentrated in the Earth's crust – vital information if we are to find enough to satisfy demand. We also have a good deal to learn about efficient and environmentally-friendly ways of extracting and processing these metals, as well as in using them efficiently and recycling them effectively when products reach end of life. Compared to metals which have been in long term use, we have a poor understanding of the ultimate fate of many of these more exotic metals when they are released into the natural environment.

Many critical metals are not mined in their own right, but are derived as by-products (or coupled products) from the extraction of 'carrier metals' from ores in which they present in low concentrations. Examples include gallium (found in aluminium ore) and germanium (found in zinc ore). Production from these ore types is predominantly driven by demand for the carrier metal. This factor may constrain any possible increase in production of the coupled product should demand increase independently of the carrier metal.

Although many of these metals are used in small quantities per unit, they perform vital tasks in significantly enhancing the way many industrial products function. For example, the average family car contains just 2-3g of platinum group metals (PGM) in its exhaust system. These metals enable the catalytic conversion of petrol and diesel engine emissions, such that over 90 per cent of hydrocarbons, carbon monoxide and oxides of nitrogen to less harmful carbon dioxide, nitrogen and water Given that 51 million cars were built worldwide in 2009, the environmental and economic benefits of PGM use in autocatalysts are extremely large.

Delivery of other environmental technologies, and particularly those needed to move toward a low carbon economy will require critical metals in some quantities. Major consumers are likely to be renewable energies, such as wind and solar photovoltaics, as well as low-carbon transport modes powered by electricity or fuel cells.


Most wind turbines require considerable quantities of critical metals (principally rare earth elements) in their manufacture. Photo copyright BGS/ NERC.

Recycling, substitution and resource efficiency will be hugely important in meeting the challenge of burgeoning demand for critical metals. However, because demand is rising rapidly we must accept that for the foreseeable future, the vast bulk of our requirements for these metals will have to be sourced from primary resources within the Earth's crust. Most metals normally remain in use by society for 40 to 60 years and the upper limit on what is available for recycling is determined by what comes back from society. By way of illustration, global consumption of copper in 1970 was approximately 8 million tonnes per annum. Five million tonnes was from mining, with 3 million tonnes from recycling. In 2008 global copper consumption was about 24 million tonnes, of which 8 million tonnes were derived from recycling, with the remaining 16 million tonnes from primary production. For most critical metals the ceiling on availability will be much lower because consumption in the past has been very small.

For most other metals recycling provides only 10-20% of demand, although work by UNEP[3] and in research carried out as part of the recent European Raw Materials Initiative[4] suggests that recycling rates for elements such as gallium, indium, tantalum and rare earths are currently less than 1%. Even if recycling rates for these materials were much higher, we must recognise that the critical metal 'resource' currently residing in the anthropogenic environment is very small compared to that needed to meet predicted demand from manufacturers of electric vehicles, wind generators, solar panels and digital devices.

## WILL WE RUN OUT OF CRITICAL METALS?

The total stock of metal in the crust is finite, but it is also extremely large. Metals for which we know the precise location, tonnage and which we can extract economically with existing technology (known as 'reserves') are tiny in comparison to the total amount. Concerns that surface periodically regarding physical exhaustion of metals are generally based on a flawed and over-simplistic view of the relationship between reserves and consumption (number of years supply remaining equals reserves divided by annual consumption). This approach ignores the fact that consumption and reserves change continually in response to markets and scientific advances. Reserve levels depend on current scientific knowledge of mineral deposits and target mineral price. As our scientific understanding improves, we can replenish reserves from previously undiscovered resources. Most metals occur in graded deposits: if prices rise, reserves will extend to include lower grade ore; if prices fall, reserves will contract to include only higher grade material. The reality is that despite increasing metal production over the past 50 years, reserve levels have remained largely unchanged[4].

In the longer term, advances in science and technology have improved our ability to find and extract metals. Current reserve and consumption data are not reliable indicators of metal depletion as these figures are closely related to the current state of the global economy and scientific/technological knowledge.

## MEETING THE SUPPLY CHALLENGE FOR CRITICAL METALS

Although physical exhaustion of primary metal supply is thus very unlikely, there are no grounds for complacency. Since the beginning of the Industrial Revolution, science has been key to extending our resource base. The classic 'Malthusian' approach failed to appreciate the impact of science on agricultural productivity and access to earth resources. To illustrate this argument in a modern context; mineral deposit types which were largely unknown 50 years ago (such as porphyry deposits which are now the principal sources of copper, molybdenum and rhenium) contribute significantly to global reserves. These were discovered and developed largely as a result of scientific understanding of their metallogenesis derived from research.

However, our knowledge of transport and concentration processes of many critical metals is very poor. Put simply, collaborative science is vital in predicting and finding deposits of these critical metals which to date have been of limited economic interest, but are now being used in rapidly increasing amounts.

The more pressing threats to supply are uneven resource distribution, geopolitics and looming environmental limits. Metal deposits are unevenly distributed across the globe and patterns of supply and demand shift continually. Rapidly increasing demand from emerging economies such as Brazil, Russia, India and China has led to a scramble for access to resources, particularly in the developing world. Economic and diplomatic tensions between those who have mineral resources and/or means of production, and those who have not, are common. Current concerns in western countries regarding China's near monopoly of production of rare earth elements clearly illustrate this.

The likelihood is that tensions over resources will increase over the next few years. It is therefore essential that the UK retains its world class capability to monitor and analyse global mineral production, consumption, trade and reserves(1). This should be done in conjunction with other EU member states, the US and Japan in order to develop an early warning system to better predict future supply problems.

Extraction and processing of metal is energy intensive and carbon emitted as a consequence represents a significant environmental limit to our resource use. Major research and innovation is required in order to break the current link between metal extraction and greenhouse gas emissions. Current examples of where low carbon technology may be heading include in-situ leach mining of metals such as uranium and microbial bio-leaching of metals such as copper and nickel from extracted ores. Such approaches have the potential to significantly extend the resource base by allowing working of previously uneconomic ore types and grades.

Critical metals are vital to the global economy and their importance will grow in the coming decades as we strive to meet the twin challenges of population growth and climate change. In order to mitigate current and future geopolitical and market constraints on supply, we urgently need to carry out research to identify and utilise new resources from the Earth's crust and by recycling material already in our society. Similar endeavour will be needed to break the link between metal extraction and human-induced climate change.

This article is published by permission of the Executive Director, British Geological Survey.


(1) British Geological Survey (2010) Mineral Statistics home page http://www.bgs.ac.uk/mineralsuk/statistics/home.html

(2) Ernst and Young (2010) Material risk: Access to technology minerals. http://www.ey.com/Publication/vwLUAssets/Material_risk:_access_to_tecnology_minerals,_Sept_2010/$FILE/Material%20risk_final.pdf

(3) UN Environment Programme (2009) Critical Metals for Future Sustainable Technologies and their Recycling Potential. http://www.unep.fr/scp/publications/details.asp?id=DTI/1202/PA

(4) European Commission (2010) Critical Raw Materials for the EU. Report of the ad-hoc working group on defining critical raw materials. http://ec.europa.eu/enterprise/policies/raw-materials/critical/index_en.htm


## STRATEGIC METALS - HOW CAN GEOSCIENCE HELP INCREASE RESOURCES? HOW WILL A SUPPLY SHORTAGE IMPACT ON THE UK?

# GEOSCIENTISTS – the scientists who locate Geological Resources of Strategic Metals


Dr Hazel Prichard
Mineral Deposits Studies Group and Geological Society of London


### THE CRITICAL ROLE OF GEOSCIENTISTS

Geoscientists play the vital role in the discovery of new metal deposits. A strong presence in the Geosciences is possible in the UK as it has an unusually great variety of geology for its land area and we have a long history of mining. Today there is an active extraction industry with the production of aggregates and coal and new ventures such as gold quarrying in Northern Ireland and a world class resource of tungsten to be extracted at Hemerdon in Devon. However inevitably the UK is small and has to source the majority of its metals from overseas. So to secure supplies, traditionally, we have been a world leader in research in metal deposits globally. We still have a great concentration of researchers who, with nourishment and support, have the skills to produce high quality science to improve security of supply of metals and make UK manufacturing more competitive.

## METAL SUPPLY

Sourcing metals is essential both to maintain our standard of living and to provide the rare metals necessary to develop a low-carbon global economy. This has been highlighted recently by metal shortage scares such as the REEs. There is now much interest in metal scarcity with publications being produced, for example the recent House of Commons Science and Technology Committee report on Strategically Important Metals (5th report Session 2010-2012). There are sufficient geological resources of metals in the Earth to supply our future needs but this will only be assured if Geoscientists continue to explore for and discover new metal sources worldwide. Indeed their efforts need to increase as the demand for metals is increasing exponentially as world population increases. Giant developing economies such as China and India now desire the metal hungry goods that we, in the western world, take for granted as essential. Unless we plan to secure metal supplies we will be increasingly exposed to shortages as there is a substantial time lag, typically of at least 10 years, between a shortage and the time taken for a new geological source to be developed and brought to market.

## GEOSCIENCE ORGANISATIONS

Within the UK we have a very active group of Societies that focus on the Geosciences. The principal Society is the Geological Society of London that hosts within it the Mineral Deposit Studies Group (MDSG). Other Societies include the Institute of Materials, Minerals and Mining (IOM3) and the Mineralogical Society. Exploration for metals by Geoscientists is carried out by companies targeting new ores and many still have their headquarters in the city of London making up about 15% of the FTSE 100. Institutes provide a focus for applied research in this field and include the Minerals Section at the British Geological Survey and the Mineralogy Department at the Natural History Museum. Universities also pursue applied research on understanding ore forming processes and in training students. The UK has exported many exploration geology graduates into this global business of metal sourcing. The MDSG runs meetings that bring together those whose task it is to understand the geology of mineral deposits and so discover new metal supplies. At these meetings students are encouraged to meet industry personnel and build valuable contacts.

## GEOLOGY

Metal supply depends on many political and sociological factors as well as the Geosciences. Increasingly also metals are being recycled as, unlike oil, gas and coal, they are not destroyed during use. However natural metal supplies still dominate and these are controlled by the geology. Close to the Earth's surface different metals vary in abundance and concentrate by different geological processes. For example, although rare, gold is concentrated by a multitude of complex geological processes and is widely distributed in different types of geology. Other metals are restricted by their geology as for example platinum with the major deposits located only in RSA and northern Siberia.

## PLATINUM: An Example Of Exploration Using Geoscience Skills

Many aspects of the Geosciences can be employed to explore for and secure more supplies of all metals and the approach to explore for more platinum resources can be used as an illustration. The major platinum deposits are located in giant magmatic bodies where there has been extensive deep melting in the Earth producing magma that concentrates platinum as it crystallises into mineable surface deposits. Also there are many marginally economic occurrences of platinum in other rock types. Future exploration will focus on both geology similar to the economic ores and on the many different currently non-economic occurrences. For example a new source is anthropogenic platinum, now accumulating in road dust, due to emission from vehicle catalytic converters. Platinum in road dust is now present at extremely elevated values compared with natural background values. Research has shown platinum is rapidly dispersed as it is washed down drains but it is reconcentrated in acid mine drainage and in incinerated sewage ash. Anthropogenic platinum is in a different mineral form to that of natural ores and attempts to recycle this platinum will require new mineral processing techniques. Therefore investigation of just this one metal requires a whole set of Geoscience skills ranging from understanding magma generation deep in the Earth to the sedimentary processes of collection of waste in the urban environment.

## GEOSCIENCE TECHNIQUES

So the Geoscientist needs to decide how and where to search for more sources of metals. This uses a great variety of techniques that range in scale from satellite imagery to sub-micron microscopic studies. Modelling can predict additional conventional and new types of ore. The Geoscientist uses geology, geochemistry, geophysics and mineralogy and needs to adapt and search for new opportunities as for example new rock exposure revealed by deforestation of the Amazon or retreating ice sheets. It is likely that in the future we will need to extract metals from lower grade ores using new extraction and processing techniques.

## GEOSCIENCES IN UNIVERSITIES

There are several UK universities with a great tradition and considerable expertise in the Geosciences specifically teaching applied geology for metal exploration. The training is both theoretical and practical emphasising field skills, mapping, making measurements, understanding ore forming processes. Some university Geoscience departments run Society of Economic Geology chapters that keep the students in touch with the international exploration community. Lecturers in universities, who run these applied courses, also carry out research on exploration using high tech equipment currently held in universities allowing in-depth studies that provide valuable insights for metal exploration.

## GEOSCIENCE STUDENTS

There is a great demand for exploration geology degrees, often from students who have had some contact with the industry, and/or have often travelled extensively and seen mining operations. They therefore also have some of the many non-science related skills that are necessary for a successful career in the exploration industry, including self confidence, a foreign language, team work skills, including the ability to survive in hostile environments, working in foreign communities where no tourist would venture. The UK has many talented young people who wish to study the Geosciences and go into the metal exploration industry. Graduates return to the UK from all over the world and feed back information on the current state of the exploration industry and metal exploration.

### SUPPORT FOR TEACHING AND RESEARCH

Although numbers of students have recently increased substantially the appointment of metallogenesis lecturers has declined. Universities are set goals by Government that tend to exclude the appointment of metallogenesis lecturers because research assessment exercises tend to favour blue sky research. Although Government is encouraging vocational training NERC has just removed funding for MSc courses which affects the Geosciences. Our great British tradition of teaching exploration for new metal sources in universities is being threatened. Research funding for metal exploration is also difficult in universities because of competition for blue sky research funds, the time lost from research due to enormous amounts of time writing unsuccessful research proposals disguised to attract funds from other areas and the funding of short term research. Much research is too applied for Research Councils and not applied enough for companies.

This non-applied research culture is beginning to change. There are indications that the situation is easing as there is a realisation about the potential threat of metal shortages. The next Government inspired university research assessment exercise (REF) contains a section (if relatively small) on the impact of research. We welcome the recent initiative by NERC to ring fence some research funds for ore deposit research.

### THE DEBATE

Does the UK want to take an active interest in the supply chain of metals for UK industry, to predict which metals will be scarce in the future and so smooth out metal shortage crises to maintain its competitive edge?

### WHAT CAN BE DONE?

• We need to expand Geoscience research to discover new metal sources and processing techniques to secure supply. Government can make subtle changes in policy to strengthen teaching and research in the Geosciences and further encourage scientists to carry out applied research. This is necessary to attract, inspire and educate young geoscientists who can search for metals for our future.

• We need to co-ordinate the monitoring of metal supply to keep a presence on the world stage. It is difficult to predict which metals will become scarce first because experts tend to specialise in one metal and companies plan exploration for 15-20 years ahead for commercial reasons and neither give an overview of future supplies. We (Government, institutes, universities and companies) should establish a network of stakeholders (perhaps through the Societies and Knowledge Transfer Networks KTNs) to bring together individual Geoscience experts for different metals, along with experts in the extraction, processing and manufacture for each metal so that we will be able to identify better specific needs and predict shortages. Such a body would give an overview and would promote collaboration.

There will be increasing competition for metals worldwide and the UK needs to be prepared for this. The UK Geoscience community stands ready to engage and play its part.

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## STRATEGIC METALS - HOW CAN GEOSCIENCE HELP INCREASE RESOURCES? HOW WILL A SUPPLY SHORTAGE IMPACT ON THE UK?

# How will the UK Manufacturing Industry respond to a shortage of Strategic Metals?

Tony Hartwell
Knowledge Transfer Manager
The Environmental Sustainability Knowledge Transfer Network

### BACKGROUND

The development of extractive industries and manufacturing facilities worldwide and the improvements in transport and communication systems has resulted in globalisation of business operations and productive capacities. Product and equipment manufacturers can source their inputs of raw materials and/or components from wherever they can negotiate the most favourable terms. This has resulted in a tendency for businesses to locate basic manufacturing facilities in countries that have a low cost base. Economies with a higher cost base strive to compete through higher productivity and by investing in innovations which often rely on advanced materials and technologies. Manufacturers must now aim for continuous improvements in their productivity, resource efficiency and product performance to remain competitive in the global marketplace. With a complex global supply chain how can UK based industry manage supply risks? According to Kirchain et al[1] "a resource becomes 'scarce' when the effort needed to access the marginal amount of material is greater than the amount of effort one would be capable of or willing to exert".

Globalisation has resulted in extended supply chains that rely on highly efficient logistical management which has been facilitated by modern information and communication technologies. At present there are concerns about the security of supply of some of the strategic metals that are required for the delivery of the advanced technologies (eg aerospace, ICT and renewable energy systems). The 'Just in Time' concept has driven tighter production schedules along the complex supply chain networks of products based on advanced technologies. Companies aim to simplify and streamline their processes, whilst collaborating more effectively with a range of partners, suppliers and clients around the world. In these complex systems it is important to analyse and manage risk. Advanced manufacturers may not be direct purchasers of strategic metals but they must be aware of the value that they deliver to their products and must examine the supply chain risks for their resources.

Manufacturers can reduce supply risks through long term relationships with reliable partners and by securing several sources of supply. A recent EU study[2] on materials that are critical to the European economy has suggested that the risks associated with 14 materials should be carefully considered.

## WHY MIGHT SHORTAGES OCCUR?

Concerns about access to resources are not new although over the years the materials classified as 'strategic' have changed. Following the industrial revolution the demand for, and ability to extract, metals grew and nations sought greater access to raw materials through colonisation and/or international trade. Many advances in military technologies have been based on developments in the use of systems and technologies that require specific metals to deliver superior military capability. Therefore access to these metals, and the ability to process them into suitable forms, has been considered to be strategically important. Indeed access to strategic metals has been a significant factor in many military confrontations. The trend towards multinational corporations and globalised supply chains and the end of the 'Cold War' meant that concerns about the military need for strategic metals became less intense.

In the past some analyses considered that the markets for the major metals were mature and saw little prospects for growth in global demand. However these overlooked the discrepancy between the specific consumption rates for materials in economies at different stages of development.

Since industrialisation there has been a tendency for specific material utilisation (kg/person/year) to increase as an economy becomes more affluent. When the growing world population is also taken into account the demand for materials can be projected to grow in the foreseeable future unless there are fundamental changes in consumption patterns.

In addition to the growing demand for 'traditional metals' the special properties of a wider range of elements are now being exploited to create the advanced materials and systems required for modern ICT and low carbon technology applications (PV systems, batteries, motors, magnets, etc).

Due to geological and other factors such as low production costs and the development of specialist knowledge and technologies, there has been a tendency for the production of some of these strategic metals to be dominated by a few organisations or regions (eg Rare Earth Elements and Magnesium in China, tantalum in the DRC, Niobium in Brazil, etc).

Some analysts have combined the demand for a metal with a published figure for reserves and projected when resources will be exhausted. This is really a misunderstanding of the situation. It is far more likely that the cost of extracting materials – in monetary and/or environmental terms – will be exceeded rather than the ultimate depletion of the Earth's resources. The total costs of the energy required to recover a specific metal from primary sources may rise to exceed the value derived from its use or it may become more viable to recover more metal from secondary sources. The development of modern societies has been based on the output of industrialised systems powered by relatively low cost fossil fuels. Based on current trends it has been projected that, since industrialisation, human consumption of fossil fuels will have released one trillion tonnes of carbon (1,000,000,000,000) into the atmosphere by 2045[3]. The scientific evidence suggests that increasing levels of GHGs in the atmosphere pose a significant risk to the ecosystems that provide the resources necessary to support the human population. Hence the global efforts to promote more sustainable development by developing low carbon economies.

The attempts to make parallels between oil and minerals – such as the 'Peak' concept for oil can be misleading. When oil is used as a fuel it is consumed and cannot be recovered or recycled. Metals are, to a greater or lesser extent, consumed or dissipated in some applications (eg magnesium in flares, metals used in sacrificial anodes and metallothermic reduction, zinc in galvanised coatings) but in many others a significant proportion is available in forms that could be recovered easily. In developed economies there is a significant volume of anthropogenic material that is in what has been called the 'Technosphere'[4] – these have been extracted from the Earth and are in use – such as bridges, rails, motor cars, electronic devices, etc, or are available for reclamation. The useful life of metal varies with the application but in effect the material in the 'Technosphere' is an inventory of resources that is available for recovery and re-use.

## WHAT CAN MANUFACTURERS DO?

There are many stages in the supply chain between extraction of metal from primary resources and the deployment of the material in a finished product and so manufacturers will need to co-operate with, and rely on, good partners and suppliers.

Perhaps there will always be a degree of tension or balance to be struck between local versus global sourcing, self-sufficiency versus mutually beneficial trade and between short term and long term requirements. All organisations, be they national governments, trading blocks, multinational agencies or small/medium sized enterprises, need to manage risks. Different approaches have been adopted at the national level. The USA has maintained stockpiles of strategic materials but they also aim to ensure that the US economy has the downstream capability to convert these into forms suitable for their strategic (military) requirements. Primary Magnesium producers in Canada, Norway, France and Italy have shut down because they couldn't compete with imports from China. However a primary magnesium producer has survived in the USA because import duties have been applied on material from China. Recent concern about the Rare Earth Metal supply chain has stimulated the re-development of domestic operations in the USA. Japan has retained the capacity to produce significant volumes of primary metals and has a co-ordinated programme to ensure that the materials required for its value added industries is available (through stockpiling, careful monitoring of global trends, investment in global prospecting and extraction opportunities, implementation of their 3R policy and R&D on new development/substitutions). To date there has been no effective co-ordination of resource policy in the EU. Some of the major resource companies are listed on European stock exchanges but they do not necessarily have operations within the EU. Nevertheless some EU based businesses have retained strong connections with primary extraction operations both local and in other parts of the world (Copper, Boliden, Sweden; Nickel & Manganese, Eramet, France-Gabon-New Caledonia). Efforts to develop an EU strategy on raw materials are currently under way.

The UK no longer produces primary copper, zinc, or tin and but has retained primary capacity in steel and aluminium albeit at lower output levels. Specialist capacity exists for processing special metals and recovering alloys from some secondary materials (such as nickel and nickel based alloys, titanium, magnesium, aluminium, Rare Earth & Platinum Group Metals, etc). If the UK is to retain a share of the development of high value added manufacturing it must build on and expand the skill base in materials science. It must invest in the infrastructural developments that recognise the value and benefits obtained from the knowledge gained from producing and converting metals into forms suitable for resource efficient applications (eg through the application of special casting and working facilities, or the production of powders and nano-materials). To do this effectively the UK must enable research groups to develop the critical mass to contribute on a global scale in niche areas associated with primary production (in the UK and globally), the development of substitutes for critical applications and in recovery and recycling. The UK is a net exporter of metallic scrap and whilst this is a source of export revenue it is important that the optimum value is recovered from these resources. Exports of scrap to areas without the facilities to process materials according to global standards of best practice should not be allowed.

Some manufacturers have recognised the value that can be gained from a broader engagement in the life cycle of their products. By engaging with the end-of-life management they can ensure that they can have access to the resources that they need by promoting recovery and recycling. In times of crisis one way of ensuring some access to critical materials has been from those present in the 'Technosphere' – but better management of materials should be developed without waiting for a crisis. This would be a logical approach from the point of resource efficiency and climate change because efficient recovery of secondary materials is usually less energy intensive and has a lower impact on the biosphere than primary recovery from low grade ores (this should be verified by LCA studies for each situation).

If a specific metal becomes very expensive there are strong drivers to investigate ways of substituting alternates. This could be achieved by developing materials that can deliver the same or better cost effective performance (direct substitution) or through the development of a new technology that makes that specific functional need obsolete (indirect substitution).

Commercial and military organisations will have different perspectives on strategic metals. If the UK Manufacturing Industry is to be competitive in the global market all stakeholders (Government, OEMs, Tier 1-n suppliers, raw material suppliers, recyclers and end-users) must participate and collaborate in risk management programmes. These can reduce the risk of shortages of critical materials. The UK should align with European programmes and ensure that it has the world class research and industrial production capability to participate in important sectors. These should include the development of primary resources, the development of substitute materials/technologies and the development of recovery and reprocessing systems. If all of the stakeholders in the supply chain collaborate to address these issues the potential for price spikes will be reduced. It would also be prudent for each organisation to conduct risk assessments to determine the nature of their exposure to short, medium or long term disruptions in the supplies of strategic metals.

The legend of King Midas illustrates how access to even a precious metal is of little value without the knowledge or capacity to convert it into a useful form. Measures to encourage UK manufacturers to engage in sustainable materials management systems throughout the supply chain would make a significant contribution towards establishing a 'green economy' in the UK and across the globe.


(1) http://dspace.mit.edu/handle/1721.1/35728

(2) http://ec.europa.eu/enterprise/policies/raw-materials/critical/index_en.htm

(3) http://trillionthtonne.org/

(4) www.mdpi.com/2071-1050/2/5/1408/pdf

# HOUSE OF COMMONS SELECT COMMITTEE ON SCIENCE AND TECHNOLOGY

The Science and Technology Committee is established under Standing Order No. 152, and charged with the scrutiny of the expenditure, administration and policy of the Government Office for Science, a semi-autonomous organisation based within the Department for Business, Innovation and Skills.

The current members of the Science and Technology Committee are:

Gavin Barwell (Conservative, Croydon Central), Gregg McClymont (Labour, Cumbernauld, Kilsyth and Kirkintilloch East), Stephen McPartland (Conservative, Stevenage), Stephen Metcalfe (Conservative, South Basildon and East Thurrock), Andrew Miller (Labour, Ellesmere Port and Neston), David Morris (Conservative, Morecambe and Lunesdale), Stephen Mosley (Conservative, City of Chester), Pamela Nash (Labour, Airdrie and Shotts), Jonathan Reynolds (Labour/Co-operative, Stalybridge and Hyde), Graham Stringer (Labour, Blackley and Broughton) and Roger Williams (Liberal Democrat, Brecon and Radnorshire).

Andrew Miller was elected by the House of Commons to be the Chair of the Committee on 9 June 2010. The remaining Members were formally appointed to the Committee on 12 July 2010. Stephen McPartland was formally appointed to the Committee on 14 February 2011 in the place of Alok Sharma.

## CURRENT INQUIRIES

### Forensic Science Service

On 19 January 2011 the Committee announced an inquiry into the Government's decision to wind down the Forensic Science Service. The Committee invited written submissions by 14 February.

The Committee held two oral evidence sessions in March taking evidence from the Forensic Science Service, Prospect Union, academics, private sector providers, the National Policing Improvement Agency, the Crown Prosecution Service, the Metropolitan Police Service and Association of Chief Police Officers (full details in Journal 68/2).

On 27 April the Committee took evidence from: Andrew Rennison, Forensic Science Regulator, Professor Bernard Silverman, Chief Scientific Adviser, Home Office; and James Brokenshire MP, Parliamentary Under-Secretary of State for Crime Prevention, and Stephen Webb, Director of Finance and Strategy, Crime and Policing Group, Home Office.

The written evidence received in this inquiry is on the Committee's website. A Report is expected to be published in the summer.

### Forest research

On 11 May 2011 the Committee announced an inquiry into forest research. The Committee invited written submissions on the following issues by 9 June:

1. The effect of the Spending Review on forest research;
2. How priorities in forest research are set and resources allocated;
3. How the UK's capability in forest research compares with other countries;
4. Are there threats to forest research in the UK.

The Committee expects to hold an oral evidence session in July. The written evidence received in this inquiry is on the Committee's website.

### Peer review

On 26 January 2011 the Committee announced an inquiry examining the peer review process. The Committee invited written submissions by 10 March 2011.

On 4 May the Committee took evidence from: Dr Nicola Gulley, Editorial Director, Institute of Physics Publishing Ltd, Professor Ronald Laskey CBE FRS FMedSci, Vice-President, Academy of Medical Sciences, Dr Robert Parker, Interim Chief Executive, Royal Society of Chemistry, and Professor John Pethica FRS, Physical Secretary and Vice-President, Royal Society.

On 11 May the Committee took evidence from: Tracey Brown, Managing Director, Sense About Science, and Dr Elizabeth Wager, Chair of the Committee on Publication Ethics and Board Member of the UK Research Integrity Office; Mayur Amin, Senior Vice President, Research & Academic Relations, Elsevier, Dr Philip Campbell, Editor-in-Chief, Nature Publishing Group, Robert Campbell, Senior Publisher, Wiley-Blackwell, Dr Fiona Godlee, Editor-in-Chief, BMJ Group, and Dr Andrew Sugden, Deputy Editor & International Managing Editor, Science.

On 23 May the Committee took evidence from: Dr Rebecca Lawrence, Director, New Product Development, Faculty of 1000 Ltd, Dr Mark Patterson, Director of Publishing, Public Library of Science, Dr Malcolm Read OBE, Executive Secretary, JISC, and Dr Michaela Torkar, Editorial Director, Biomed Central; Dr Janet Metcalfe, Chair, Vitae, Professor Teresa Rees CBE, Professor of Social Science and former Pro Vice Chancellor (Research), Cardiff University, and Professor Ian Walmsley, Pro Vice Chancellor, University of Oxford.

A further evidence session is planned for June.

The written evidence received in this inquiry is on the Committee's website. A report is in preparation.

### Practical experiments in school science lessons and science field trips

On 5 April 2011 the Committee announced an inquiry into the practical experiments in school science lessons and science field trips. The Committee invited written submissions by 11 May 2011.

The Committee launched an e-consultation on 9 June 2011 to hear views from students on their school science practicals experiences. There is currently a link to it on the Committee's website. In addition, in June the Committee plans to visit a secondary school and to meet informally with a group of school children in the House of Commons.

The Committee expects to hold further oral evidence sessions in June and July. The written evidence received in this inquiry is on the Committee's website.

### Spending Review 2010

On 24 November 2010 the Committee took evidence from Rt Hon David Willetts MP, Minister for Universities and Science, and Professor Adrian Smith, Director General, Science and Research, Department for Business, Innovation and Skills. On 19 January 2011 the Committee took evidence from a number of Research Councils and from Research Councils UK. On 26 January the Committee invited written submissions on the science and research budget allocations for 2011/12 to 2014/15 by 27 April 2011. The written evidence received is on the Committee's website.

## ORAL EVIDENCE

The transcripts of the evidence sessions described above and below are available on the Science and Technology Committee's website [www.parliament.uk/science].

### Scientific advice and evidence in emergencies: follow-up

On 8 June 2011 the Committee announced that it would take oral evidence following up its report on Scientific advice and evidence in emergencies.

The Committee has also received two Government Responses to its Report (see below).

## REPORTS

### Astronomy and Particle Physics

On 13 May 2011 the Committee published its Fourth Report of Session 2010-12, Astronomy and Particle Physics, HC 806.

### Strategically important metals

On 17 May 2011 the Committee published its Fifth Report of Session 2010-12, Strategically important metals, HC 726.

### UK Centre for Medical Research and Innovation

On 25 May 2011 the Committee published its Sixth Report of Session 2010-12, UK Centre for Medical Research and Innovation, HC 727.

## GOVERNMENT RESPONSES

### Government Response to the Science and Technology Committee report 'The Reviews into the University of East Anglia's Climatic Research Unit's E-mails'

On 6 May 2011, the Committee published the Government's Response to the Committee's Report on The Reviews into the University of East Anglia's Climatic Research Unit's E-mails, HC 496.

### Government Response to the Science and Technology Committee report 'Technology and Innovation Centres'

On 16 May 2011, the Committee published the Government's Response to the Committee's Report on Technology and Innovation Centres, HC 1041.

### Government Response to the Science and Technology Committee report 'Scientific advice and evidence in emergencies'

On 17 May 2011, the Committee published the Government's Response to the Committee's Report on Scientific advice and evidence in emergencies, HC 1042.

## FURTHER INFORMATION

Further information about the work of the Science and Technology Committee or its current inquiries can be obtained from the Clerk of the Committee, Glenn McKee, the Second Clerk, Stephen McGinness, or from the Senior Committee Assistant, Andy Boyd, on 020 7219 8367/2792/2793 respectively; or by writing to: The Clerk of the Committee, Science and Technology Committee, House of Commons, 7 Millbank, London SW1P 3JA. Enquiries can also be e-mailed to scitechcom@parliament.uk. Anyone wishing to be included on the Committee's mailing list should contact the staff of the Committee. Anyone wishing to submit evidence to the Committee is strongly recommended to obtain a copy of the guidance note first. Guidance on the submission of evidence can be found at www.parliament.uk/commons/selcom/witguide.htm. The Committee has a website, www.parliament.uk/science, where all recent publications, terms of reference for all inquiries and press notices are available.

# HOUSE OF COMMONS LIBRARY SCIENCE AND ENVIRONMENT SECTION

The Section produces a series of frequently updated notes on a wide range of topics. Opposite are summaries of some recently updated notes.

The notes can be accessed online at http://www.parliament.uk/topics/Topical-Issues.htm

For further information contact Christopher Barclay Head of Section
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### UK Broadband – Policy and Coverage SN/SC/5970

The UK has one of the highest levels of broadband penetration in the world and one of the highest take-up rates of mobile broadband. However, a third of the country is not commercially attractive for the roll-out of superfast broadband. This tends to be more rural areas with lower population densities and greater distances from local exchanges.

Faster broadband speeds allow the use of a range of "next generation" applications which benefit both business efficiency and effectiveness and an individual's access to Government services, online retailing and social networking. Coalition Government policy is therefore, like the previous Government's policy, currently geared towards ensuring that a digital divide based on broadband speed does not emerge between urban and rural areas. The Government has allocated £530 million to do this with a multi-faceted broadband strategy, Britain's superfast broadband future (December 2010), which seeks to incentivise the deployment of broadband through a variety of technologies with the removal of potential economic and policy barriers.

This note sets out the current situation with regard to broadband access and coverage in the UK and provides an overview of the Government's broadband policy.

### Green Investment Bank SN/SC/5977

This note covers the Government Proposals for a Green Investment Bank which will support renewable and green technologies. There has been debate between departments on the form the Bank will take and the level of finance provided to it.

The Bank will have an initial investment of £3bn and will not be allowed to raise its own capital until at least 2015.

### Biofuels SN/SC/3691

Biofuels can be used as a substitute for fossil fuels to reduce greenhouse gas emissions from transport, to support the rural economy and promote energy security. However, depending on how they are made, some biofuels can lead to greater greenhouse gas emissions than fossil fuels and they can have serious environmental and social impacts. A recent report published by the Nuffield Council on Bioethics indicated that current biofuels policy can be considered "unethical".

Biofuels are supported by both European and UK legislation. Support for biofuels in the UK is mainly through the Renewable Fuel Transport Obligation (RTFO). The EU Renewable Energy Directive requires 10% of transport fuel by 2020 to come from renewable sources – this is expected to be met predominantly with biofuels.

Given concerns about the sustainability of biofuels the Government does not plan to increase biofuel targets in the short term, and it is reviewing biofuel policy. However, "renewable fuel" targets will increase from 2014 to 2020 to meet European targets. The European Commission is considering whether to introduce additional environmental safeguards, and will report in Summer 2011.

### Offshore oil and gas industry SN/SC/5985

The UK offshore oil and gas industry directly supports around 350,000 jobs and also provides around £8 billion annually to the Treasury in taxation. Production levels are in decline. The remaining potential is dependent on the future levels of investment. Industry body Oil & Gas UK estimates that while 39.5 billion boe (barrels of oil equivalent) of oil and gas have so far been recovered from the UKCS, between 15 billion and 24 billion boe still remain.

If offshore oil and gas production is to continue, the industry faces a number of challenges, including making sure that oil and gas companies have access to sufficient finance to invest in the infrastructure needed and the skills needed to support it; giving small companies economically viable access to third party infrastructure, so that smaller and under-developed fields can be further exploited; and making sure that the fiscal regime does not accelerate decommissioning and can make new investment economically viable.

### Why isn't my waste collected weekly? SN/SC/5988

Waste collection can be a contentious issue, particularly when local authorities decide to move away from weekly bin collection to alternate weekly collection (AWC). Over 59% of local authorities now use AWC of household waste – recycling is collected on one week and non-recyclable the next. AWC has been adopted as it can increase recycling rates while reducing the costs associated with managing residual waste. AWC may also lead to a reduction in overall waste generation as residents seek to change shopping habits to reduce waste disposal.

The principal concern raised about AWC is the potential health risk associated with food waste remaining in bins for up to two weeks. However, there is no evidence of increased health risk with AWC, provided common sense precautions are taken.

The Government has said that while it is for local authorities to decide what waste collection system works best for their area, it wants to work with them to collect waste more frequently. If local authorities with AWC revert to weekly bin collections it could cost £530 million.

### Private sewers SN/SC/1514

After a number of consultations the Labour Government announced that approximately 200,000 kilometres of privately owned sewers and lateral drains in England would be transferred to water and sewerage companies from 2011. It also announced the introduction of a mandatory build standard for new sewers, and that new sewers would automatically become the responsibility of water and sewer companies.

The Coalition Government decided to continue with the transfer. On 26 August 2010 a consultation on the plans was published. Draft regulations were laid before the House on 26 April 2011. Private sewers will therefore be transferred from October 2011, subject to parliamentary approval.

### Wild Animals In Circuses SN/SC/5992

This note sets out the Government's decision not to ban wild animals in circuses, but introduce a licensing scheme instead. It also covers debates that followed the announcement, including details of the Austrian case referred to by the Government.

### Religious Slaughter SN/SC/1314

This note deals with the methods of slaughter used by the Jewish and Muslim religions. EU law, like UK law before it, requires farm animals to be stunned before slaughter. However, there is an exception for religious slaughter. The Jewish method of slaughter, Shechita, requires animals not to be stunned before slaughter. Islamic food rules, for Halal meat, can be satisfied with animals stunned before slaughter, but there is no definitive ruling and slaughter without pre-stunning does also take place. Most Halal meat in the UK comes from animals that were stunned before slaughter.

Much of the meat on an animal killed by religious slaughter may not qualify as Kosher or Halal meat. There is no requirement that it should be labelled as meat from an animal killed without pre-stunning. The European Parliament voted in June 2010 to require compulsory labelling for all meat from animals killed without pre-stunning. The Council of Ministers would have to approve that legislation. The Coalition Government does not support it. The Coalition Government has no intention of making Halal or Shechita slaughter illegal, but it is considering welfare labelling of meat.

### Obesity SN/SC/3724

Obesity is defined generally as when a person is carrying too much body fat for their height and sex. The most commonly used measurement of obesity is the body mass index (BMI). In England in 2009, 22% of men and 24% of women were classified as obese (including morbidly obese). Obesity prevalence among boys aged 2-15 in 2009 is estimated to be 16%; among girls, it is 15%. After a period of rapid increase, obesity levels among children are now at similar levels to those observed in 2001.

It is too simplistic to say that obesity is caused simply by energy intake exceeding expenditure. A range of factors that could be causes of obesity include: metabolic and genetic factors; food intake and activity behaviours; habits, beliefs and morals; the living environment; technology; and opportunities for physical activity.

The Coalition Government has set out ways to adapt the previous Labour Government's Change4Life programme, designed to cut levels of obesity, to take a more holistic approach to cover additional factors such as behaviour and mental well-being. The Government has also set out plans for a new integrated public health service – Public Health England – to be created to provide better expertise and responsiveness on public health issues, including obesity.

### Regulation of herbal medicines SN/SC/6002

Herbal remedies for human use have been regarded as medicines under UK legislation, in principle subject to the same extensive licensing procedures as pharmaceuticals. In recognition of a long history of safe use they have historically been exempted from licensing.

The EU Directive on Traditional Herbal Medicinal Products (Directive 2004/24/EC) replaces most existing member state regulations and creates a harmonised licensing system for traditional herbal medicine products (in use for at least 30 years, of which 15 must have been in the EU). The Directive came into full effect on 1 May 2011.

The new Directive applies most directly to manufactured herbal medicines sold over the counter, prohibiting the continued sale of unlicensed products. In the UK, specific exemptions continue to apply to preparations made up by herbal practitioners specifically for individual patients.

The Directive has met with considerable opposition from suppliers and users of herbal medicines. Objections include disproportionate costs of regulatory compliance and unfair treatment of non-European herbal traditions, with a resulting threat to the viability of small and medium-sized businesses and a reduction in consumer choice.

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# HOUSE OF LORDS SCIENCE AND TECHNOLOGY SELECT COMMITTEE

The members of the Committee (appointed 22 June 2010) are Lord Broers, Lord Crickhowell, Lord Cunningham of Felling, Baroness Hilton of Eggardon, Lord Krebs (Chairman), Baroness Neuberger, Lord Patel, Baroness Perry of Southwark, Lord Rees of Ludlow, the Earl of Selborne, Lord Wade of Chorley, Lord Warner, Lord Willis of Knaresborough and Lord Winston. Lord Jenkin of Roding and Lord Oxburgh have been co-opted to the Committee for the purposes of its inquiry into nuclear research and development capabilities. Lord Alderdice, Lord May of Oxford, Baroness O'Neill of Bengarve and Lord Sutherland of Houndwood have been co-opted to Sub-Committee I for the purposes of its inquiry into behaviour change policy interventions.

### Nuclear research and development capabilities

In March 2011, the Science and Technology Committee, under the chairmanship of Lord Krebs, launched a short inquiry to investigate whether the UK's nuclear research and development (R&D) capabilities are sufficient to meet its future nuclear energy requirements to 2050.

The inquiry will examine, amongst other things, the R&D implications of future scenarios up to 2050 and whether the UK has adequate R&D capabilities, including infrastructure, to meet its current and future needs for a safe and secure supply of nuclear energy.

Whilst the Committee decided to undertake the inquiry before the recent events in Japan at the Fukushima Daiichi nuclear plant, health and safety R&D capability is inherent within the scope of the inquiry and the Committee is inviting evidence on these matters.

A call for evidence for the inquiry was released on 17 March 2011 with a deadline for submission of 28 April 2011. The Committee held a workshop with Government officials and key stakeholders on 5 April to start off the inquiry. The Committee will hold public meetings from 10 May 2011 and the report will be published later in 2011.

### Behaviour change policy interventions

In June 2010, the Select Committee appointed a sub-committee under the Chairmanship of Baroness Neuberger to conduct an inquiry into the effectiveness of behaviour change interventions in achieving government policy goals and helping to meet societal challenges.

As governments across the world attempt to meet challenges such as reducing carbon emissions and alleviating the burden on health services caused by smoking, drinking and the rise in obesity, more and more attention is being focused on how behaviour can be influenced using a range of behaviour change interventions that rely on measures other than prohibition or the elimination of choice. The Committee has been considering the current state of knowledge about which behaviour change interventions are effective, whether the Government's current behaviour change interventions are evidence-based and subject to robust evaluation, and how such interventions are coordinated across departments. The Committee has also looked at the role of industry and the voluntary sector in shaping behaviour patterns and the social and ethical issues surrounding behaviour change interventions by government.

As part of its inquiry, the sub-committee has also conducted two case studies. The first has involved looking at behaviour change interventions designed to reduce obesity. The second has focused on travel-mode interventions to reduce car use in towns and cities.

A call for evidence was published on 28 July 2010 with a deadline for submission of 8 October 2010. A second call for evidence on the travel-mode interventions case study was published on 10 December 2010 with a deadline for submission of 21 January 2011. The Committee held a seminar as part of the obesity case study on 19 October 2010 and a second seminar on travel-mode interventions on 26 January 2011. The Committee began taking oral evidence in November 2010 and finished in March 2011. The Committee is due to report in the summer.

### Public procurement as a tool to stimulate innovation

At the end of 2010, the Select Committee, under the chairmanship of Lord Krebs, launched a short inquiry into public procurement as a tool to stimulate innovation within industry. The inquiry focused, in particular, on the Department for Transport and related public bodies, as a working example of the current procurement practices within departments. The inquiry sought to investigate the extent to which the current procurement practices and processes were effective in encouraging innovation within industry and supporting the development and diffusion of innovations. The Committee published its report at the end of May 2011. A Government response is due at the end of August, after which it is anticipated that the report will be debated in the House by the end of the year.

### Disease surveillance and the Forestry Commission

Following the Government's announcement in February 2011 that they were setting up an independent panel to consider forestry policy in England, the Committee wrote to the Department for Environment, Food and Rural Affairs and to the Forestry Commission asking for information about disease surveillance and research. The response of the Forestry Commission will assist the Committee when considering the findings of the independent panel, the report from which is due to be published in Spring 2012.

## OUTSTANDING ACTIVITIES FROM THE PREVIOUS PARLIAMENT

### Setting Priorities for Publicly Funded Research

An inquiry into the setting of science and technology research funding priorities was launched in July 2009. The inquiry was undertaken by the Select Committee under the chairmanship of Lord Sutherland.

Cuts in overall public spending due to the current economic climate will lead to some difficult decisions about how to allocate public funds for science and technology research. Effective mechanisms for allocating funds are vital if the United Kingdom science base is to remain healthy, both now and in the future, and is able to continue to meet societal needs. The Committee investigated a range of issues including how decisions about funding research are made across Government and within Government departments and other public bodies, whether the balance between funding for targeted research and unsolicited response-mode curiosity-driven research is appropriate, and how research is commissioned.

The Committee published its report on 1 April 2010. The Government response to the report was published on 30 July 2010. The report was debated in the House on 8 June 2011.

## FURTHER INFORMATION

The written and oral evidence to the Committee's inquiries mentioned above, as well as the Calls for Evidence and other documents can be found on the Committee's website www.parliament.uk/hlscience. Further information about the work of the Committee can be obtained from Christine Salmon Percival, Committee Clerk, salmonc@parliament.uk or 020 7219 6072. The Committee's email address is hlscience@parliament.uk.

# PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY (POST)

## RECENT POST PUBLICATIONS

### Natural Capital Accounting

*May 2011* *POSTnote 376*

Renewable natural resources are being affected by a range of pressures, such as biodiversity loss and climate change. A minimum level of natural resources is required to maintain the capacity of ecosystems to sustain human well-being at acceptable levels. If governments do not monitor effectively the use and degradation of natural resource systems in national account frameworks ('environmental accounting'), the risks of imposing costs on future economic productivity may be overlooked, with adverse consequences for human wellbeing.

### The Ecosystem Approach

*May 2011* *POSTnote 377*

The ecosystem approach makes explicit the link between the status of natural resource systems and ecosystem services that support human wellbeing. It seeks to maintain the integrity and functioning of ecosystems as a whole to avoid rapid undesirable ecological change. It also recognises that the impacts of human activities are a matter of social choice, and are as integral to ecosystem interactions as ecosystems are to human activities.

### Ecosystem Service Valuation

*May 2011* *POSTnote 378*

Ecosystems in the UK are managed to provide desired levels of specific benefits, such as the provision of food and fibre, to meet human needs. However, other benefits from ecosystems important to human wellbeing do not have a market value. The UK National Ecosystem Assessment has refined methods for placing monetary values on many services provided by the natural environment. It will also demonstrate convincingly that relying on how present markets handle such services will not deliver the best outcomes for society. This POSTnote summarises methodologies for determining reliable values for changes in natural resources and ecosystem services and the policy implications of such valuations.

### Evidence Based Conservation

*June 2011* *POSTnote 379*

Conservation of the natural environment is necessary to protect and enhance the UK's valuable natural resources. The use of scientific evidence to support conservation decisions can increase potential impacts and ensure cost-effectiveness. This POSTnote summarises the benefits of, and issues surrounding, an evidence-based approach to conservation management.

### Landscapes of the Future

*June 2011* *POSTnote 380*

Land underpins the whole economy, through provision of food and other goods and its use for housing, business, transport, energy, tourism and recreation. The UK faces major challenges addressing projected population increases, climate change and economic growth with limited land and natural resources. This POSTnote examines how policy structures, including planning reforms, might deliver land use systems that meet these challenges.

### Mental Capacity and Healthcare

*June 2011* *POSTnote 381*

Adults with learning disabilities or suffering from dementia, brain injuries or mental illness may be unable to make health decisions for themselves. At such times, others will need to decide in their place. The Mental Capacity Act (2005) provides a surrogate decision-making framework. It exists alongside another framework – the Mental Health Act. While the Mental Health Act is restricted to compulsory treatment for mental disorders, the Mental Capacity Act has a broader scope. It applies to welfare, finances, property and research participation as well as to physical and mental health. This POSTnote outlines how the Mental Capacity Act is being interpreted in healthcare and how it works alongside the Mental Health Act.

### Informal STEM Education

*June 2011* *POSTnote 382*

The UK has a diverse informal STEM (Science, Technology, Engineering and Mathematics) education sector. The 2004 STEM Mapping Review, commissioned by the then Department for Education and Skills (DfES), reported over 470 STEM initiatives run by government and external agencies. Further reports have highlighted the importance of informal STEM education, but identified various issues such as the need to improve access, to increase coordination and to measure impact. This POSTnote describes the UK's informal STEM sector, its progress in recent years and debate over its future.

## CURRENT WORK

*Biological Sciences* – Animal Health and Biosecurity, Personal Genomics, Improving Livestock, Clinical Trials, Review of Stem Cell Research, An Ageing Workforce.

*Environment and Energy* – Update to Carbon Footprint of Electricity Generation (POSTnote 268), Energy Security, Invasive Tree Pests and Pathogens, Genetically Modified Crops, Algal Biofuels, Anaerobic Digestion, Marine Spatial Planning, Embedded Water in Products.

*Physical sciences and IT* – Solar Technologies, Clean Water and the Millennium Development Goals, Cybersecurity, Radio Spectrum Update.

*Science Policy* – Science, Technology, Mathematics and Engineering (STEM) Education: 14-19 Year Olds, Science and the Internet

## CONFERENCES AND SEMINARS

### Energy Futures: The Research Councils UK Energy Research Programme

On 11th May, POST and Research Councils UK (RCUK) hosted an interactive exhibition on some of the latest developments in UK energy research. The RCUK Energy Programme is currently investing over £530m in research to help develop secure, low-carbon and affordable energy systems for the future. Leading research groups supported by the Energy Programme were on hand to discuss their work and role in supporting policy development and economic growth. Exhibits included research on renewable energy technologies, nuclear energy, energy efficiency, fuel cells, low-carbon transport and carbon capture and storage. Dr Alan Whitehead MP, Member of the House of Commons Energy and Climate Change Committee and Chair of the Associate Parliamentary Renewable and Sustainable Energy Group, introduced a series of keynote speeches by Professor David McKay, DECC Chief Scientific Adviser, Professor Nigel Brandon, Director of the Energy Futures Laboratory at Imperial College London, and Professor David Delpy, Chief Executive of the Engineering and Physical Sciences Research Council, followed by a question and answer session.

### British Science Association, Science Communication Conference

On 25th May, POST organised a panel debate at this conference. This brought together representatives from the scientific community, policy makers and the media to discuss a number of key issues. The role of scientific advice in policy-making has been in the spotlight in recent years. Events such as the BSE crisis, foot and mouth outbreaks and more recently the dismissal of David Nutt from his position within the Advisory Committee on the Misuse of Drugs have illustrated the sometimes uneasy relationship between government and scientific expert. The result has been a governmental review of the Code of Practice for Scientific Advisory Committees, CoPSAC, due to be finalised in the coming months.

### Landscapes of the Future

On 8th June, POST organised a seminar to discuss the major factors driving landscape change and policy and management options for the future. Many pressures, such as population increase and climate change, will exacerbate competition for land in the next few decades. The UK National Ecosystem Assessment, published in June 2011, is the first assessment of the benefits UK society gains from the natural environment, as well as options to secure delivery into the future. Additionally, the Government published ambitious plans to protect the natural environment at the start of June in the Natural Environment White Paper. Multifunctional landscapes, which balance competing demands for space, can help adaptation and increase resilience to environmental change. This crosses many sectors and policy areas, but in particular land use planning. Barry Gardiner MP, Member of the House of Commons Environment, Food and Rural Affairs Select Committee and Chair of the GLOBE International Commission on Land Use Change & Ecosystems, chaired the seminar at which invited guests heard presentations from Joe Morris, Professor Emeritus, Resource Economics and Management, Cranfield University; Dr Peter Costigan, Science Co-ordinator for the Natural Environment Group in Defra, Val Kirby, Head of Landscape and Geodiversity, Natural England, Howard Davies, Chief Executive of the National Association for Areas of Outstanding Natural Beauty, and Simon Marsh, Acting Head of Sustainable Development, RSPB.

### Staff, Fellows and Interns at POST

*Conventional Fellows (name, institution and sponsoring organisation)*

Emma Ransome, Plymouth University, Natural Environment Research Council

Martina Di Fonzo, Imperial College London, Natural Environment Research Council

Joanna Hepworth, York University, Biotechnology and Biological Sciences Research Council

Jennifer Dodson, York University, Royal Society of Chemistry

Heather Riley, Birmingham University, Biotechnology and Biological Sciences Research Council

Clare Dyer-Smith, Imperial College London, Royal Society of Chemistry

Matthew Mottram, University College London, Science and Technology Facilities Council

Zoe Freeman, Edinburgh University, Biotechnology and Biological Sciences Research Council

Natalie Banner, Kings College London, Wellcome Trust Medical History and Humanities division

*Special Fellow*

Dr Mara Almeida, Medical Research Council, Functional Genomics Unit, Oxford University, on a special Portuguese government one year scholarship to study the functioning of parliamentary science offices.

## INTERNATIONAL ACTIVITIES

### European Parliamentary Technology Assessment Network, annual Directors' Meeting, Karlsruhe, Germany

In early May, the Director represented POST at the annual meeting of directors from the parliamentary science and technology offices of parliaments across Europe. Attendance by directors of all offices, except Italy, with the additional presence of the Chief Scientist of the US Congress' Government Accountability Office, was augmented by the participation of Ms Isabel Millan from the Chilean Parliament. She announced its intention to set up a futures-oriented unit, which will become the first parliamentary horizon-scanning function in a parliament outside Europe or North America.

### POST African Parliaments Programme

POST's programme of work focused on capacity building for handling science and technology issues in parliaments in Africa continues and will run until at least July 2012. The Ugandan Parliament has just reconvened after the elections of February 2011 and most of POST's activities will continue to be focused there. Activities in planning include a third round of MP-scientist pairing, the setting up of a "remote mentoring" scheme for Ugandan parliamentary staff working on scientific issues, and a parliamentary internship scheme for Ugandan scientists. A report, produced with POST's support, on the use of scientific evidence by the Parliament of Uganda, will also be published.

# SELECTED DEBATES

Listed opposite is a selection of Debates on matters of scientific interest which took place in the House of Commons, the House of Lords or Westminster Hall between 26 April and 25 May

## HOUSE OF COMMONS AND WESTMINSTER HALL

| | | |
|---|---|---|
| 26 April | Submarines and Frigates (Plymouth) | HoC 1WH |
| 26 April | UK Oil Refining Industry | HoC 23WH |
| 27 April | Higher Education Policy | HoC 238 |
| 28 April | Variant Creutzfeldt-Jakob Disease | HoC 419 |
| 3 May | Larch Disease | HoC 243WH |
| 3 May | Medical Students | HoC 251WH |
| 4 May | NHS Prescribed Medicines | HoC 282WH |
| 10 May | Ultra Low-Carbon Emission Vehicles | HoC 370WH |
| 12 May | Fisheries | HoC 1405 |
| 12 May | Education Performance | HoC 493WH |
| 17 May | Public Health Observatories | HoC 314 |
| 17 May | Forensic Science Service | HoC 51WH |
| 18 May | Power Line Technology Devices | HoC 467 |
| 18 May | Waste Reduction | HoC 108WH |

## HOUSE OF LORDS

| | | |
|---|---|---|
| 12 May | Agriculture: Global Food Security | HoL 987 |

## PROGRESS OF LEGISLATION BEFORE PARLIAMENT

A comprehensive list of Public Bills before Parliament, giving up-to-date information on their progress, is published regularly when Parliament is sitting in the Weekly Information Bulletin, which can be found at: http://www.publications.parliament.uk/pa/cm/cmwib.htm

# FIRST FEMALE SCIENTIST APPOINTED DEPUTY GOVERNMENT CHEMIST

## Selvarani Elahi takes over the role of Deputy Government Chemist

**On 7th June LGC, the international market leader in analytical, forensic and diagnostic services and reference standards, announced the appointment of Selvarani Elahi as Deputy Government Chemist. She becomes the first female scientist to hold this title in the UK and takes over the role from Ian Lumley, on his retirement. She will now act as deputy for Dr Derek Craston, who has been the UK's Government Chemist since 1 June 2008.**

In addition to her new role, Elahi retains her current position as Head of Consumer Protection Services at LGC. Elahi has over 20 years' experience of the analysis of food and agriculture samples to establish their composition, particularly for contaminants, additives, nutrients and to assess their authenticity for both the private and public sectors.

Discharged on behalf of the UK department for Business, Innovation and Skills, the role of the Government Chemist is a State appointment, agreed under the devolved authorities of Scotland, Wales and Northern Ireland. The Government Chemist title has been in place since 1911, with a remit to discharge the statutory function of referee analyst to resolve disputes over analytical measurements, particularly in relation to food regulatory enforcement. The Government Chemist also takes an active involvement in promoting analytical science and technology, and provides advice to Government and the wider community on policy, standards and regulation.

LGC and the Government Chemist (www.governmentchemist.org.uk) role date back to the establishment of the Laboratory of the Board of Excise in 1842. The UK National Measurement Office now underpins the role by funding a programme of work at LGC, and, with the help of an external working group, ensures that the Government Chemist continues to provide an independent voice for sound analytical measurement science. In recent years, laboratory casework has focused on samples of food and animal feed. The Government Chemist also develops advice on the wide range of science-based policy, standards and regulations affecting the UK.

Under terms agreed when LGC was privatised, the Government Chemist is appointed in open competition by BIS and is required to be a director of LGC, which is contracted to carry out the necessary scientific work in support of the Government Chemist function.

A group of members of the House of Commons Science and Technology Select Committee and the Parliamentary and Scientific Committee, led by Andrew Miller MP, visited LGC on Tuesday 14th June. A report on their visit will be published in the next issue of Science in Parliament.

# SCIENCE DIRECTORY

## DIRECTORY INDEX

**Aerospace and Aviation**
C-Tech Innovation
EPSRC
Institution of Engineering Designers
National Physical Laboratory
Semta

**Agriculture**
BBSRC
CABI
The Food and Environment Research Agency
Institution of Engineering Designers
LGC
PHARMAQ Ltd
Society for Applied Microbiology
Society for General Microbiology
Society of Biology
UFAW

**Animal Health and Welfare, Veterinary Research**
ABPI
Academy of Medical Sciences
The Nutrition Society
PHARMAQ Ltd
Society for Applied Microbiology
Society for General Microbiology
Society of Biology
UFAW

**Astronomy and Space Science**
Institute of Physics
Institution of Engineering Designers
Natural History Museum
STFC

**Atmospheric Sciences, Climate and Weather**
The Geological Society
Natural Environment Research Council
STFC

**Biotechnology**
BBSRC
Biochemical Society
CABI
C-Tech Innovation
Eli Lilly and Company Ltd
Institution of Chemical Engineers
LGC
National Physical Laboratory
Plymouth Marine Sciences Partnership
Royal Society of Chemistry
Semta
Society for Applied Microbiology
Society for General Microbiology
Society of Biology

**Brain Research**
ABPI
Eli Lilly and Company Ltd
MSD
The Physiological Society

**Cancer Research**
ABPI
Eli Lilly and Company Ltd
National Physical Laboratory

**Catalysis**
C-Tech Innovation
Institution of Chemical Engineers
Royal Society of Chemistry

**Chemistry**
C-Tech Innovation
EPSRC
Institution of Chemical Engineers
LGC
London Metropolitan Polymer Centre
Plymouth Marine Sciences Partnership
Royal Institution
Royal Society of Chemistry
STFC

**Colloid Science**
London Metropolitan Polymer Centre
Royal Society of Chemistry

**Construction and Building**
The Geological Society
Institution of Civil Engineers
Institution of Engineering Designers
Institution of Engineering and Technology
London Metropolitan Polymer Centre
National Physical Laboratory

**Cosmetic Science**
Society of Cosmetic Scientists

**Earth Sciences**
The Geological Society
The Linnean Society of London
Natural Environment Research Council
Natural History Museum
Society of Biology

**Ecology, Environment and Biodiversity**
The British Ecological Society
CABI
C-Tech Innovation
Economic and Social Research Council
The Food and Environment Research Agency
Institution of Chemical Engineers
Institution of Civil Engineers
Institution of Mechanical Engineers
LGC
The Linnean Society of London
National Physical Laboratory
Natural Environment Research Council
Natural History Museum
Plymouth Marine Sciences Partnership
Royal Botanic Gardens, Kew
Royal Society of Chemistry
Society for Applied Microbiology
Society for General Microbiology
Society of Biology
Society of Maritime Industries

**Economic and Social Research**
Economic and Social Research Council

**Education, Training and Skills**
ABPI
Academy of Medical Sciences
AIRTO
Biochemical Society
British Science Association
The British Ecological Society
British Nutrition Foundation
British Pharmacological Society
British Society for Antimicrobial Chemotherapy
CABI
Clifton Scientific Trust
C-Tech Innovation
Economic and Social Research Council
EPSRC
EngineeringUK
Institute of Measurement and Control
Institute of Physics
Institution of Chemical Engineers
Institution of Civil Engineers
Institution of Engineering and Technology
Institution of Mechanical Engineers
LGC
London Metropolitan Polymer Centre
NESTA
National Physical Laboratory
Natural History Museum
The Physiological Society
Plymouth Marine Sciences Partnership
Royal Botanic Gardens, Kew
Royal Institution
The Royal Society
Royal Society of Chemistry
Royal Statistical Society
Semta
Society of Biology

**Energy**
CABI
C-Tech Innovation
EPSRC
GAMBICA Association Ltd
Institute of Measurement and Control
Institute of Physics
Institution of Chemical Engineers
Institution of Civil Engineers
Institution of Engineering Designers
Institution of Engineering and Technology
Institution of Mechanical Engineers
Plymouth Marine Sciences Partnership
Royal Society of Chemistry
Society of Maritime Industries
STFC

**Engineering**
C-Tech Innovation
EPSRC
EngineeringUK
GAMBICA Association Ltd
Institute of Measurement and Control
Institution of Chemical Engineers
Institution of Civil Engineers
Institution of Engineering Designers
Institution of Engineering and Technology
Institution of Mechanical Engineers
London Metropolitan Polymer Centre
National Physical Laboratory
Plymouth Marine Sciences Partnership
The Royal Academy of Engineering
Semta
Society of Maritime Industries
STFC

**Fisheries Research**
Plymouth Marine Sciences Partnership
Society of Biology

**Food and Food Technology**
British Nutrition Foundation
CABI
C-Tech Innovation
The Food and Environment Research Agency
Institute of Food Science & Technology
Institution of Chemical Engineers
LGC
The Nutrition Society
Royal Society of Chemistry
Society for Applied Microbiology
Society for General Microbiology
Society of Biology

**Forensics**
Institute of Measurement and Control
LGC
Royal Society of Chemistry

**Genetics**
ABPI
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LGC
Natural History Museum
The Physiological Society
Royal Botanic Gardens, Kew
Society of Biology

**Geology and Geoscience**
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Institution of Civil Engineers
Natural Environment Research Council
Society of Maritime Industries

**Hazard and Risk Mitigation**
The Geological Society
Institute of Measurement and Control
Institution of Chemical Engineers

**Health**
ABPI
Academy of Medical Sciences
Biochemical Society
British Nutrition Foundation
British Pharmacological Society
British Society for Antimicrobial Chemotherapy
Economic and Social Research Council
Eli Lilly and Company Ltd
EPSRC
The Food and Environment Research Agency
GAMBICA Association Ltd
Institute of Physics and Engineering in Medicine
LGC
Medical Research Council
National Physical Laboratory
The Nutrition Society
The Physiological Society
Royal Institution
Royal Society of Chemistry
Society for Applied Microbiology
Society for General Microbiology
Society of Biology

**Heart Research**
ABPI
Eli Lilly and Company Ltd
The Physiological Society

**Hydrocarbons and Petroleum**
The Geological Society

Institution of Chemical Engineers
Natural History Museum
Royal Society of Chemistry

**Industrial Policy and Research**
AIRTO
C-Tech Innovation
Economic and Social Research Council
GAMBICA Association Ltd
Institution of Civil Engineers
Institution of Engineering and Technology
The Royal Academy of Engineering
Semta
STFC

**Information Services**
AIRTO
CABI

**IT, Internet, Telecommunications, Computing and Electronics**
EPSRC
Institution of Civil Engineers
Institution of Engineering and Technology
National Physical Laboratory
STFC

**Intellectual Property**
ABPI
The Chartered Institute of Patent Attorneys
C-Tech Innovation
Eli Lilly and Company Ltd
NESTA

**Large-Scale Research Facilities**
C-Tech Innovation
The Food and Environment Research Agency
London Metropolitan Polymer Centre
National Physical Laboratory
Natural History Museum
STFC

**Lasers**
Institute of Physics
National Physical Laboratory
STFC

**Manufacturing**
ABPI
EPSRC
GAMBICA Association Ltd
Institution of Chemical Engineers
Institution of Engineering Designers
Institution of Engineering and Technology
Institution of Mechanical Engineers
London Metropolitan Polymer Centre
National Physical Laboratory
Semta
Society of Maritime Industries

**Materials**
C-Tech Innovation
Institution of Chemical Engineers
Institution of Engineering Designers
London Metropolitan Polymer Centre
National Physical Laboratory
Royal Society of Chemistry
Semta
STFC

**Medical and Biomedical Research**
ABPI
Academy of Medical Sciences
Biochemical Society
British Pharmacological Society
British Society for Antimicrobial Chemotherapy
CABI
Eli Lilly and Company Ltd
Medical Research Council
MSD
The Physiological Society
Plymouth Marine Sciences Partnership
Royal Institution
Society of Biology
UFAW

**Motor Vehicles**
Institution of Engineering Designers
London Metropolitan Polymer Centre

**Oceanography**
The Geological Society
National Physical Laboratory
Natural Environment Research Council
Plymouth Marine Sciences Partnership
Society of Maritime Industries

**Oil**
The Geological Society
Institution of Chemical Engineers
LGC

**Particle Physics**
Institute of Physics
STFC

**Patents**
The Chartered Institute of Patent Attorneys
NESTA

**Pharmaceuticals**
ABPI
British Pharmacological Society
British Society for Antimicrobial Chemotherapy
C-Tech Innovation
Eli Lilly and Company Ltd
Institution of Chemical Engineers
LGC
MSD
PHARMAQ Ltd
Royal Botanic Gardens, Kew
Royal Society of Chemistry
Society of Biology

**Physical Sciences**
Cavendish Laboratory
C-Tech Innovation
EPSRC
The Geological Society
London Metropolitan Polymer Centre
National Physical Laboratory

**Physics**
Cavendish Laboratory
C-Tech Innovation
Institute of Physics
National Physical Laboratory
STFC

**Pollution and Waste**
ABPI
C-Tech Innovation
The Geological Society
Institution of Chemical Engineers
Institution of Civil Engineers
London Metropolitan Polymer Centre
National Physical Laboratory
Natural Environment Research Council
Plymouth Marine Sciences Partnership
Society of Maritime Industries

**Psychology**
The British Psychological Society
Economic and Social Research Council

**Public Policy**
Biochemical Society
The British Ecological Society
British Nutrition Foundation
British Society for Antimicrobial Chemotherapy
Economic and Social Research Council
EngineeringUK
The Food and Environment Research Agency
Institution of Civil Engineers
Institution of Chemical Engineers
Institution of Engineering and Technology
NESTA
Prospect
Royal Society of Chemistry
Society of Biology

**Quality Management**
GAMBICA Association Ltd
LGC
National Physical Laboratory

**Radiation Hazards**
Institution of Engineering and Technology
LGC

**Science Policy**
ABPI
Academy of Medical Sciences
Biochemical Society
The British Ecological Society
British Nutrition Foundation
British Pharmacological Society
British Science Association
CABI
Clifton Scientific Trust
C-Tech Innovation
Economic and Social Research Council
Eli Lilly and Company Ltd
EPSRC
EngineeringUK
The Food and Environment Research Agency
GAMBICA Association Ltd
Institute of Physics
Institution of Chemical Engineers
Institution of Civil Engineers
Institution of Engineering and Technology
LGC
Medical Research Council
NESTA
National Physical Laboratory
The Physiological Society
Plymouth Marine Sciences Partnership
Prospect
Research Councils UK
The Royal Academy of Engineering
Royal Botanic Gardens, Kew
Royal Institution
The Royal Society
Royal Society of Chemistry
STFC
Society of Biology
UFAW

**Sensors and Transducers**
C-Tech Innovation
GAMBICA Association Ltd
Institute of Measurement and Control
Institution of Engineering and Technology
STFC
Society of Maritime Industries

**SSSIs**
The Geological Society
Royal Botanic Gardens, Kew

**Statistics**
Economic and Social Research Council
EPSRC
EngineeringUK
Royal Statistical Society

**Surface Science**
C-Tech Innovation
STFC

**Sustainability**
The British Ecological Society
CABI
C-Tech Innovation
EPSRC
The Food and Environment Research Agency
The Geological Society
Institution of Chemical Engineers
Institution of Civil Engineers
The Linnean Society of London
London Metropolitan Polymer Centre
Plymouth Marine Sciences Partnership
Royal Botanic Gardens, Kew
Royal Society of Chemistry
Society of Biology

**Technology Transfer**
AIRTO
CABI
C-Tech Innovation
The Food and Environment Research Agency
Institute of Measurement and Control
Institution of Engineering and Technology
LGC
London Metropolitan Polymer Centre
NESTA
National Physical Laboratory
Research Councils UK
Royal Society of Chemistry
STFC

**Tropical Medicine**
Natural History Museum
Royal Botanic Gardens, Kew
Society for Applied Microbiology
Society for General Microbiology

**Viruses**
ABPI
Society for Applied Microbiology
Society for General Microbiology

**Water**
C-Tech Innovation
The Geological Society
Institute of Measurement and Control
Institution of Chemical Engineers
Institution of Civil Engineers
LGC
Plymouth Marine Sciences Partnership
Royal Society of Chemistry
Society for Applied Microbiology
Society for General Microbiology
Society of Biology
Society of Maritime Industries

**Wildlife**
The British Ecological Society
The Food and Environment Research Agency
The Linnean Society of London
Natural History Museum
Royal Botanic Gardens, Kew
Society of Biology
UFAW

## Research Councils UK

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Each year the Research Councils invest around £3 billion in research covering the full spectrum of academic disciplines from the medical and biological sciences to astronomy, physics, chemistry and engineering, social sciences, economics, environmental sciences and the arts and humanities.

Research Councils UK is the strategic partnerships of the seven Research Councils. It aims to:

- increase the collective visibility, leadership and influence of the Research Councils for the benefit of the UK;
- lead in shaping the overall portfolio of research funded by the Research Councils to maximise the excellence and impact of UK research, and help to ensure that the UK gets the best value for money from its investment;
- ensure joined-up operations between the Research Councils to achieve its goals and improve services to the communities it sponsors and works with.

## Biotechnology and Biological Sciences Research Council (BBSRC)

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BBSRC is the UK's principal public funder of research and research training across the biosciences. BBSRC provides institute strategic research grants to eight centres, as well as supporting research and training in universities across the UK. BBSRC's research underpins advances in a wide range of bio-based industries, and contributes knowledge to policy areas which include: food security, climate change, diet and health and healthy ageing.

## Economic and Social Research Council

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Jacky.Clake@esrc.ac.uk
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The ESRC is the UK's leading research and training agency addressing economic and social concerns. We pursue excellence in social science research; work to increase the impact of our research on policy and practice; and provide trained social scientists who meet the needs of users and beneficiaries, thereby contributing to the economic competitiveness of the United Kingdom, the effectiveness of public services and policy, and quality of life. The ESRC is independent, established by Royal Charter in 1965, and funded mainly by government.

## EPSRC

Engineering and Physical Sciences Research Council

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Website:www.epsrc.ac.uk

EPSRC is the UK's main agency for funding research in engineering and physical sciences, investing around £800m a year in research and postgraduate training, to help the nation handle the next generation of technological change.

The areas covered range from information technology to structural engineering, and mathematics to materials science. This research forms the basis for future economic development in the UK and improvements for everyone's health, lifestyle and culture. EPSRC works alongside other Research Councils with responsibility for other areas of research.

## Medical Research Council

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Website: www.mrc.ac.uk

For almost 100 years, the MRC has been improving the health of people in the UK and around the world by supporting the highest quality science on behalf of UK taxpayers. We work closely with the UK's Health Departments, the NHS, medical research charities and industry to ensure our research achieves maximum impact as well as being of excellent scientific quality. MRC-funded scientists have made some of the most significant discoveries in medical science – from the link between smoking and cancer to the invention of therapeutic antibodies – benefiting millions of people.

## Natural Environment Research Council

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Website: www.nerc.ac.uk

The UK's Natural Environment Research Council funds and carries out impartial scientific research in the sciences of the environment. NERC trains the next generation of independent environmental scientists.

NERC funds research in universities and in a network of its own centres, which include:

*British Antarctic Survey, British Geological Survey, Centre for Ecology and Hydrology, and National Oceanography Centre.*

## Science & Technology Facilities Council

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Formed by Royal Charter in 2007, the Science and Technology Facilities Council is one of Europe's largest multidisciplinary research organisations supporting scientists and engineers world-wide. The Council operates world-class, large-scale research facilities and provides strategic advice to the UK Government on their development. The STFC partners in the UK's two National Science and Innovation Campuses. It also manages international research projects in support of a broad cross-section of the UK research community. The Council directs, co-ordinates and funds research, education and training.

## The Academy of Medical Sciences

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The Academy of Medical Sciences promotes advances in medical science and campaigns to ensure these are converted into healthcare benefits for society. The Academy's Fellows are the United Kingdom's leading medical scientists and scholars from hospitals, academia, industry and the public service. The Academy provides independent, authoritative advice on public policy issues in medical science and healthcare.

## Association of the British Pharmaceutical Industry

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Fax: 020 7747 1447
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Website: www.abpi.org.uk

The ABPI is the voice of the innovative pharmaceutical industry, working with Government, regulators and other stakeholders to promote a receptive environment for a strong and progressive industry in the UK, one capable of providing the best medicines to patients.

The ABPI's mission is to represent the pharmaceutical industry operating in the UK in a way that:

- assures patient access to the best available medicine;
- creates a favourable political and economic environment;
- encourages innovative research and development;
- affords fair commercial returns

## AIRTO

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Fax: 020 8614 0470
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AIRTO represents the UK's independent research and technology sector - member organisations employ a combined staff of over 20,000 scientists and engineers with a turnover exceeding £2 billion. Work carried out by members includes research, consultancy, training and global information monitoring. AIRTO promotes their work by building closer links between members and industry, academia, UK government agencies and the European Union.

## Biochemical Society

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The Biochemical Society exists to promote and support the Molecular and Cellular Biosciences. We have nearly 6000 members in the UK and abroad, mostly research bioscientists in Universities or in Industry. The Society is also a major scientific publisher. In addition, we promote Science Policy debate and provide resources, for teachers and pupils, to support the bioscience curriculum in schools. Our membership supports our mission by organizing scientific meetings, sustaining our publications through authorship and peer review and by supporting our educational and policy initiatives.

## British Science Association

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Roland.Jackson@britishscienceassociation.org
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Our vision is a society in which people are able to access science, engage with it and feel a sense of ownership about its direction. In such a society science advances with, and because of, the involvement and active support of the public.

Established in 1831, the British Science Association is a registered charity which organises major initiatives across the UK, including National Science and Engineering Week, the British Science Festival, programmes of regional and local events and the CREST programme for young people in schools and colleges. We provide opportunities for all ages to discuss, investigate, explore and challenge science.

## The British Ecological Society

The British Ecological Society
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British Ecological Society
Charles Darwin House, 12 Roger Street,
London, WC1N 2JU
Tel: 020 7685 2500 Fax : 020 7685 2501
Website: www.BritishEcologicalSociety.org
Ecology into Policy Blog
http://britishecologicalsociety.org/blog/

The British Ecological Society's mission is to advance ecology and make it count. The Society has 4,000 members worldwide. The BES publishes five internationally renowned scientific journals and organises the largest scientific meeting for ecologists in Europe. Through its grants, the BES also supports ecologists in developing countries and the provision of fieldwork in schools. The BES informs and advises Parliament and Government on ecological issues and welcomes requests for assistance from parliamentarians.

## British Nutrition Foundation

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Websites: www.nutrition.org.uk
www.foodafactoflife.org.uk

The British Nutrition Foundation (BNF) was established over 40 years ago and exists to deliver authoritative, evidence-based information on food and nutrition in the context of health and lifestyle. The Foundation's work is conducted and communicated through a unique blend of nutrition science, education and media activities.

## British Pharmacological Society

Today's science, tomorrow's medicines

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Website: www.bps.ac.uk

The British Pharmacological Society has been supporting pharmacology and pharmacologists for over 75 years. Our 2,700+ members, from academia, industry and clinical practice, are trained to study drug action from the laboratory bench to the patient's bedside. Our aim is to improve quality of life by developing new medicines to treat and prevent the diseases and conditions that affect millions of people and animals. Inquiries about drugs and how they work are welcome.

## The British Psychological Society

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The British Psychological Society is an organisation of over 48,000 members governed by Royal Charter. It maintains the Register of Chartered Psychologists, publishes books, 11 primary science Journals and organises conferences. Requests for information about psychology and psychologists from parliamentarians are welcome.

## British Society for Antimicrobial Chemotherapy

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Executive Director
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T: 0121 236 1988
W: www.bsac.org.uk

Founded in 1971, and with 800 members worldwide, the Society exists to facilitate the acquisition and dissemination of knowledge in the field of antimicrobial chemotherapy. The BSAC publishes the *Journal of Antimicrobial Chemotherapy* (JAC), internationally renowned for its scientific excellence, undertakes a range of educational activities, awards grants for research and has active relationships with its peer groups and government.

## CABI

**Science and development organization**

www.cabi.org

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Tel: 01491 829306 Fax: 01491 829100
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Website: www.cabi.org

CABI is an international not-for-profit development organization, specializing in scientific publishing, research and communication. We create, communicate, and apply knowledge in order to improve people's lives by finding sustainable solutions to agricultural and environmental issues.

We work for and with universities, national research and extension institutions, development agencies, the private sector, governments, charities and foundations, farmers, and non-governmental organizations. We also manage one of the world's largest genetic resource collections: the UK's National Collection of Fungus Cultures.

## Cavendish Laboratory

UNIVERSITY OF CAMBRIDGE

The Administrative Secretary, The Cavendish Laboratory,
J J Thomson Avenue, Cambridge CB3 0HE, UK.
E-mail: dhp24@cam.ac.uk
http://www.phy.cam.ac.uk

The Cavendish Laboratory houses the Department of Physics of the University of Cambridge.

The research programme covers the breadth of contemporary physics

**Extreme Universe:** Astrophysics, cosmology and high energy physics

**Quantum Universe:** Cold atoms, condensed matter theory, scientific computing, quantum matter and semiconductor physics

**Materials Universe:** Optoelectronics, nanophotonics, detector physics, thin film magnetism, surface physics and the Winton programme for the physics of sustainability

**Biological Universe:** Physics of medicine, biological systems and soft matter

The Laboratory has world-wide collaborations with other universities and industry

## Chartered Institute of Patent Attorneys

Founded 1882
Royal Charter 1891

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The Chartered Institute of Patent Attorneys
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Tel: 020 7405 9450
Fax: 020 7430 0471
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Website: www.cipa.org.uk

CIPA's members practise in intellectual property, especially patents, trade marks, designs, and copyright, either in private partnerships or industrial companies. Through its new regulatory Board, CIPA maintains the statutory Register. It advises government and international circles on policy issues and provides information services, promoting the benefits to UK industry of obtaining IP protection, and to overseas industry of using British attorneys to obtain international protection.

## Clifton Scientific Trust

CLIFTON SCIENTIFIC Trust

Contact: Dr Eric Albone
Clifton Scientific Trust
49 Northumberland Road, Bristol BS6 7BA
Tel: 0117 924 7664 Fax: 0117 924 7664
E-mail: eric.albone@clifton-scientific.org
Website: www.clifton-scientific.org

**Science for Citizenship and Employability, Science for Life, Science for Real**

We build grass-roots partnerships between school and the wider world of professional science and its applications

- for young people of all ages and abilities
- experiencing science as a creative, questioning, human activity
- bringing school science added meaning and notivation, from primary to post-16
- locally, nationally, internationally (currently between Britain and Japan)

Clifton Scientific Trust Ltd is registered charity 1086933

## C-Tech Innovation Limited

C-Tech Innovation
...advantage through technology

Contact: Paul Radage
Capenhurst Technology Park,
Capenhurst, Chester, Cheshire CH1 6EH
Tel: +44 (0) 151 347 2900
Fax: +44 (0) 151 347 2901
E-mail: paul.radage@ctechinnovation.com
Website: www.ctechinnovation.com

**Leading innovation management and technology development company.**
We help companies, universities, government bodies and non-governmental organisations to benefit and grow through innovation. Vast experience of project and programme management, implementation of novel technologies, contract and collaborative research and technology development, business and technology consultancy, commercialization, IP exploitation, market and sector research. **www.ctechinnovation.com**

## Eli Lilly and Company Ltd

Lilly
Answers That Matter.

Contact: Thom Thorp, Head External Affairs
Tel: 01256 315000
Fax: 01256 775858
Eli Lilly and Company Ltd, Lilly House
Priestley Road, Basingstoke, Hants, RG24 9NL
Email. thorpth@lilly.com
Website: www.lilly.co.uk

Lilly UK is the UK affiliate of a major American pharmaceutical manufacturer, Eli Lilly and Company of Indianapolis. This affiliate is one of the UK's top pharmaceutical companies with significant investment in science and technology including a neuroscience research and development centre and bulk biotechnology manufacturing operations.

Lilly medicines treat schizophrenia, diabetes, cancer, osteoporosis, attention deficit hyperactivity disorder, erectile dysfunction, severe sepsis, depression, bipolar disorder, heart disease and many other diseases.

## EngineeringUK

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PR and Communications Manager
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Website: www.EngineeringUK.com

EngineeringUK is an independent organisation that promotes the vital role of engineers, engineering and technology in our society. EngineeringUK partners business and industry, Government and the wider science and technology community: producing evidence on the state of engineering; sharing knowledge within engineering, and inspiring young people to choose a career in engineering, matching employers' demand for skills.

## The Food and Environment Research Agency

fera
The Food and Environment Research Agency

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The Food and Environment Research Agency
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The Food and Environment Research Agency's over arching purpose is to support and develop a sustainable food chain, a healthy natural environment, and to protect the global community from biological and chemical risks.

Our role within that is to provide robust evidence, rigorous analysis and professional advice to Government, international organisations and the private sector.

## GAMBICA Association Ltd

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21 Broadwall
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GAMBICA Association is the UK trade association for instrumentation, control, automation and laboratory technology. The association seeks to promote the successful development of the industry and assist its member companies through a broad range of services, including technical policy and standards, commercial issues, market data and export services.

## The Geological Society

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The Geological Society is the national learned and professional body for Earth sciences, with 10,000 Fellows (members) worldwide. The Fellowship encompasses those working in industry, academia and government, with a wide range of perspectives and views on policy-relevant science, and the Society is a leading communicator of this science to government bodies and other non-technical audiences.

## Institute of Food Science & Technology

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Website: www.ifst.org

IFST is the independent qualifying body for food professionals in Europe. Membership is drawn from all over the world from backgrounds including industry, universities, government, research and development and food law enforcement.

IFST's activities focus on disseminating knowledge relating to food science and technology and promoting its application. Another important element of our work is to promote and uphold standards amongst food professionals.

## The Institute of Measurement and Control

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Website: www.instmc.org.uk
Reg Charity number: 269815

The Institute of Measurement and Control provides a forum for personal contact amongst practiioners, publishes learned papers and is a professional examining and qualifying organisation able to confer the titles EurIng, CEng, IEng, EngTech; Companies and Universities may apply to become Companions. Headquartered in London, the Institute has a strong regional base with 15 UK, 1 Hong Kong and 1 Malaysia Local Section, a bilateral agreement with the China Instrument Society and other major international links.

## IOP Institute of Physics

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The Institute of Physics is a leading scientific society promoting physics and bringing physicists together for the benefit of all.

It has a worldwide membership of around 40,000 comprising physicists from all sectors, as well as those with an interest in physics. It works to advance physics research, application and education; and engages with policymakers and the public to develop awareness and understanding of physics. Its publishing company, IOP Publishing, is a world leader in professional scientific publishing and the electronic dissemination of physics. Go to www.iop.org

## IPEM Institute of Physics and Engineering in Medicine

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Website: www.ipem.ac.uk

IPEM is a registered, incorporated charity for the advancement, in the public interest, of physics and engineering applied to medicine and biology. It accredits medical physicists, clinical engineers and clinical technologists through its membership register, organises training and CPD for them, and provides opportunities for the dissemination of knowledge through publications and scientific meetings. IPEM is licensed by the Science Council to award CSci and by the Engineering Council to award CEng, IEng and EngTech.

## IChemE

Institution of Chemical Engineers

IChemE is the hub for chemical, biochemical and process engineering professionals worldwide. We are the heart of the process community, promoting competence and a commitment to sustainable development, advancing the discipline for the benefit of society and supporting the professional development of over 32,000 members.

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## Institution of Civil Engineers

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Website: www.ice.org.uk

ICE aims to be a leading voice in infrastructure issues. With over 80,000 members, ICE acts as a knowledge exchange for all aspects of civil engineering. As a Learned Society, the Institution provides expertise, in the form of reports, evidence and comment, on a wide range of subjects including infrastructure, energy generation and supply, climate change and sustainable development.

## Institution of Engineering Designers

support inspire achieve

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The only professional membership body solely for those working in engineering and technological product design. Engineering Council and Chartered Environmentalist registration for suitably qualified members. Membership includes experts on a wide range of engineering and product design disciplines, all of whom practise, manage or educate in design.

IET The Institution of Engineering and Technology

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The IET is a world leading professional organisation, sharing and advancing knowledge to promote science, engineering and technology across the world. Dating back to 1871, the IET has 150,000 members in 127 countries with offices in Europe, North America, and Asia-Pacific.

## Institution of Mechanical Engineers

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The Institution provides politicians and civil servants with information, expertise and advice on a diverse range of subjects, focusing on manufacturing, energy, environment, transport and education policy. We regularly publish policy statements and host political briefings and policy events to establish a working relationship between the engineering profession and parliament.

## LGC

*Setting standards in analytical science*

Queens Road, Teddington
Middlesex, TW11 0LY
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Website: www.lgcgroup.com

LGC is an international science-based company and market leader in the provision of analytical, forensic and diagnostic services and reference standards to customers in the public and private sectors.

Under the Government Chemist function, LGC fulfils specific statutory duties as the referee analyst and provides advice for Government and the wider analytical community on the implications of analytical chemistry for matters of policy, standards and regulation. LGC is also the UK's designated National Measurement Institute for chemical and biochemical analysis.

With headquarters in Teddington, South West London, LGC has 29 laboratories and centres across Europe and at sites in China, Brazil, India and the US.

The LINNEAN SOCIETY of London

The Linnean Society of London
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The Linnean Society of London is the world's oldest active biological society. Founded in 1788, the Society takes its name from the Swedish naturalist Carl Linnaeus whose botanical, zoological and library collections have been in its keeping since 1829. The Society continues to play a central role in the documentation of the world's flora and fauna, recognising the continuing importance of such work to many scientific issues.

## London Metropolitan Polymer Centre

Sir John Cass Faculty of Art, Media & Design

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The London Metropolitan Polymer Centre provides training, consultancy and applied research to the UK polymer (plastics & rubber) industry. LMPC is one of the departments within the Sir John Cass Faculty of Art, Media & Design (JCAMD) and provides a broad perspective of materials science and technology for the manufacturing and creative industries. JCAMD contains Met Works, a unique Digital Manufacturing Centre, providing new technology for rapid prototyping and manufacture. The Faculty will offer short courses in a range of polymer, rapid prototyping and practical areas.

## MSD

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www.merck.com

MSD is a tradename of Merck & Co., Inc., with headquarters in Whitehouse Station, N.J., U.S.A.

MSD is an innovative, global health care leader that is committed to improving health and well-being around the world. MSD discovers, develops, manufactures, and markets vaccines, medicines, and consumer and animal health products designed to help save and improve lives.

## The National Endowment for Science, Technology and the Arts

NESTA Making Innovation Flourish

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Website: www.nesta.org.uk

NESTA is the National Endowment for Science, Technology and the Arts – an independent organisation with a mission to make the UK more innovative. It operates in three main ways: by investing in early-stage companies; informing and shaping policy; and delivering practical programmes that inspire others to solve the big challenges of the future. NESTA's expertise in this field makes it uniquely qualified to understand how the application of innovative approaches can help the UK to tackle two of the biggest challenges it faces: the economic downturn and the radical reform of public services.

## National Physical Laboratory

NPL National Physical Laboratory

Contact: Fiona Auty
National Physical Laboratory
Hampton Road, Teddington
Middlesex TW11 0LW
Tel: 020 8977 3222
Website: www.npl.co.uk/contact-us

The National Physical Laboratory (NPL) is the United Kingdom's national measurement institute, an internationally respected and independent centre of excellence in research, development and knowledge transfer in measurement and materials science. For more than a century, NPL has developed and maintained the nation's primary measurement standards - the heart of an infrastructure designed to ensure accuracy, consistency and innovation in physical measurement.

## Natural History Museum

NATURAL HISTORY MUSEUM The Science of Nature

Contact: Joe Baker
Directorate
Natural History Museum
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Website: www.nhm.ac.uk

We maintain and develop the collections we care for and use them to promote the discovery, understanding, responsible use and enjoyment of the natural world.

We are part of the UK's science base as a major science infrastructure which is used by our scientists and others from across the UK and the globe working together to enhance knowledge on the diversity of the natural world.

Our value to society is vested in our research responses to challenges facing the natural world today, in engaging our visitors in the science of nature, in inspiring and training the next generation of scientists and in being a major cultural tourist destination.

## The Nutrition Society

Contact: Frederick Wentworth-Bowyer,
Chief Executive, The Nutrition Society,
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London W6 7NJ
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www.nutritionsociety.org

Founded in 1941, The Nutrition Society is the premier scientific body dedicated to advance the scientific study of nutrition and its application to the maintenance of human and animal health.

Highly regarded by the scientific community, the Society is the largest learned society for nutrition in Europe. Membership is worldwide and is open to those with a genuine interest in the science of human or animal nutrition. Principal activities include:

1. Disseminating scientific information through its programme of scientific meetings and publications
2. Publishing internationally renowned scientific learned journals, and textbooks
3. Promoting the education and training of nutritionists
4. Engaging with external organisations and the public to promote good nutritional science

## PHARMAQ Ltd

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Website: www.pharmaq.no
Web shop: www.pharmaqwebshop.co.uk/shop

PHARMAQ is the only global pharmaceutical company with a primary focus on aquaculture. Specialising in the supply of veterinary pharmaceuticals for the salmon and trout farming industries including vaccines, anaesthetics, antibiotics and sea lice treatments. In the UK we also support an extensive range of biocides and cage and aviary products.

## The Physiological Society

Contact: Dr Philip Wright
Chief Executive
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London WC1X 8LZ

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Website: www.physoc.org

Physiology is the science of how humans and other animals function in an integrated way and is the basis for many biological and clinical sciences. Founded in 1876, The Physiological Society is a learned society with over 2,900 Members drawn from over 60 countries. The majority of Members are engaged in research, in universities or industry, into how the body works.

## Plymouth Marine Sciences Partnership

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The Plymouth Marine Sciences Partnership comprises seven leading marine science and technology institutions, representing one of the largest regional clusters of expertise in marine sciences, education, engineering and technology in Europe. The mission of PMSP is to deliver world-class marine research and teaching, to advance knowledge, technology and understanding of the seas. PMSP research addresses the fundamental understanding of marine ecosystems and processes that must be applied in support and development of policy, marine and maritime industry and marine biotechnology.

## Prospect

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Prospect is an independent, thriving and forward-looking trade union with 122,000 members across the private and public sectors and a diverse range of occupations. We represent scientists, technologists and other professions in the civil service, research councils and private sector.

Prospect's collective voice champions the interests of the engineering and scientific community to key opinion-formers and policy makers. With negotiating rights with over 300 employers, we seek to secure a better life at work by putting members' pay, conditions and careers first.

## The Royal Academy of Engineering

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Founded in 1976, The Royal Academy of Engineering promotes the engineering and technological welfare of the country. Our activities – led by the UK's most eminent engineers – develop the links between engineering, technology, and the quality of life. As a national academy, we provide impartial advice to Government; work to secure the next generation of engineers; and provide a voice for Britain's engineering community.

## Royal Botanic Gardens, Kew

Kew
PLANTS PEOPLE POSSIBILITIES

RBG Kew is a centre of global expertise in plant and fungal diversity, conservation and sustainable use housed in two world-class gardens. Kew receives approximately half of its funding from government through Defra. Kew's Breathing Planet Programme has seven key priorities:

- Accelerating discovery and global access to plant and fungal diversity information
- Mapping and prioritising habitats most at risk
- Conserving what remains
- Sustainable local use
- Banking 25% of plant species in the Millennium Seed Bank Partnership
- Restoration ecology
- Inspiring through botanic gardens

Contact: The Director's Office
Tel: 020 8332 5112
Fax: 020 8332 5109
Email: director@kew.org
Website: www.kew.org

*Inspiring and delivering science-based plant conservation worldwide, enhancing the quality of life*

## The Royal Institution

The Royal Institution of Great Britain

Contact: Dr Gail Cardew
Head of Programmes
The Royal Institution
21 Albemarle Street, London W1S 4BS
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E-mail: gail@ri.ac.uk
Website: www.rigb.org
Twitter: rigb_science

The core activities of the Royal Institution centre around four main themes: science education, science communication, research and heritage. It is perhaps best known for the Ri Christmas Lectures, but it also has a major Public Events Programme designed to connect people to the world of science, as well as a UK-wide Young People's Programme of science and mathematics enrichment activities. Internationally recognised research programmes in bio- and nanomagnetism take place in the Davy Faraday Research Laboratory.

## The Royal Society

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Website: www.royalsociety.org

The Royal Society is the UK academy of science comprising 1400 outstanding individuals representing the sciences, engineering and medicine. The strategic priorities for our work at national and international levels are to:

- Invest in future scientific leaders and in innovation
- Influence policymaking with the best scientific advice
- Invigorate science and mathematics education
- Increase access to the best science internationally
- Inspire an interest in the joy, wonder and excitement of scientific discovery.

## The Royal Society of Chemistry

RSC | Advancing the Chemical Sciences

Contact: Dr Stephen Benn
Parliamentary Affairs
The Royal Society of Chemistry
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Tel: 020 7437 8656 Fax: 020 7734 1227
E-mail: benns@rsc.org or parliament@rsc.org
Website: http://www.rsc.org
http://www.chemsoc.org

The Royal Society of Chemistry is a learned, professional and scientific body of over 46,000 members with a duty under its Royal Charter "to serve the public interest". It is active in the areas of education and qualifications, science policy, publishing, Europe, information and internet services, media relations, public understanding of science, advice and assistance to Parliament and Government.

## The Royal Statistical Society

ROYAL STATISTICAL SOCIETY

Contact: Mr Andrew Garratt
Press and Public Affairs Manager
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Website: www.rss.org.uk

The Royal Statistical Society is a leading source of independent advice, comment and discussion on statistical issues. It promotes public understanding of statistics and acts as an advocate for the interests of statisticians and users of statistics. The Society actively contributes to government consultations, Royal Commissions, parliamentary select committee inquiries, and to the legislative process. In 2009, the RSS celebrated 175 years since its foundation in 1834.

## Semta

**the Sector Skills Council for Science, Engineering and Manufacturing Technologies**

semta – The Sector Skills Council for Science, Engineering and Manufacturing Technologies

Contact: Customer Services
14 Upton Road
Watford
WD18 0JT
Tel: 0845 643 9001
Fax: 01923 256086
E-mail: customerservices@semta.org.uk
Website: www.semta.org.uk

**Semta's skills service for UK science, engineering and manufacturing employers**

- Training needs assessment against a company's business objectives.
- Quality programmes from The National Skills Academy for Manufacturing
- A training management service.
- Access to available funding and accredited training providers.
- Research into training needs to influence governments' support for skills strategies

## Society for Applied Microbiology

society for applied sfam microbiology

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Society for Applied Microbiology
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E-mail: pfwheat@sfam.org.uk
Website: www.sfam.org.uk

S*f*AM is the oldest UK microbiological society and aims to advance, for the benefit of the public, the science of microbiology in its application to the environment, human and animal health, agriculture and industry.

S*f*AM is the voice of applied microbiology with members across the globe and works in partnership with sister organisations to exert influence on policy-makers world-wide.

## Society for General Microbiology

Contact: Dariel Burdass
Marlborough House, Basingstoke Road,
Spencers Wood, Reading RG7 1AG.
Tel: 0118 988 1802 Fax: 0118 988 5656
E-mail: pa@sgm.ac.uk
Website: www.sgm.ac.uk

SGM is the largest microbiological society in Europe. The Society publishes four journals of international standing, and organises regular scientific meetings.

SGM also promotes education and careers in microbiology, and it is committed to represent microbiology to government, the media and the public.

An information service on microbiological issues concerning aspects of medicine, agriculture, food safety, biotechnology and the environment is available on request.

## Society of Biology

SOCIETY OF Biology

Contact: Dr Mark Downs
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Charles Darwin House
12 Roger Street
London WC1N 2JU
Tel: 020 7685 2550

The Society of Biology is a single unified voice for biology: advising Government and influencing policy; advancing education and professional development; supporting our members, and engaging and encouraging public interest in the life sciences. The Society represents a diverse membership of over 80,000 - including, students, practising scientists and interested non-professionals - as individuals, or through learned societies and other organisations.

## Society of Cosmetic Scientists

SOCIETY OF COSMETIC SCIENTISTS – SCS

Contact: Gem Bektas,
Secretary General
Society of Cosmetic Scientists
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Website: www.scs.org.uk

Advancing the science of cosmetics is the primary objective of the SCS. Cosmetic science covers a wide range of disciplines from organic and physical chemistry to biology and photo-biology, dermatology, microbiology, physical sciences and psychology.

Members are scientists and the SCS helps them progress their careers and the science of cosmetics ethically and responsibly. Services include publications, educational courses and scientific meetings.

## Society of Maritime Industries

Society of Maritime Industries

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London EC2R 8AY
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Website: www.maritimeindustries.org

The Society of Maritime Industries is the voice of the UK's maritime engineering and business sector promoting and supporting companies which design, build, refit and modernise ships, and supply equipment and services for all types of commercial and naval ships, ports and terminals infrastructure, offshore oil & gas, maritime security & safety, marine science and technology and marine renewable energy.

## Universities Federation for Animal Welfare

UFAW Established 1926

Contact: Dr James Kirkwood
Chief Executive and Scientific Director
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Tel: 01582 831818. Fax: 01582 831414.
Email: ufaw@ufaw.org.uk
Website: www.ufaw.org.uk
Registered in England Charity No: 207996

UFAW is an international, independent scientific and educational animal welfare charity. It works to improve animal lives by:

- supporting animal welfare research.
- educating and raising awareness of welfare issues in the UK and overseas.
- producing the leading journal Animal Welfare and other high-quality publications on animal care and welfare.
- providing expert advice to government departments and other concerned bodies.

# SCIENCE DIARY

## THE PARLIAMENTARY AND SCIENTIFIC COMMITTEE

Contact: Annabel Lloyd
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parliamentaryandscientificcommittee@hotmail.org.uk
www.scienceinparliament.org.uk

Tuesday 18 October 17.30
Discussion Meeting
**Wetter, Warmer, Windier … will the UK's Infrastructure cope?**
Speakers to be confirmed

Tuesday 22 November 17.30
Discussion Meeting
**Scientific Freedom**
Speakers: Professor Don Braben, Honorary Professor in Earth Sciences, University College London
Professor James Ladyman, Professor of Philosophy, University of Bristol
Professor Ben Davis, Department of Chemistry, University of Oxford

Tuesday 13 December 17.30
Discussion Meeting
**What is the Public Understanding of Risk?**
Speakers to be confirmed

## THE ROYAL SOCIETY

Website: royalsociety.org
The Royal Society hosts a series of free events, including evening lectures and conferences, covering the whole breadth of science, engineering and technology for public, policy and scientific audiences. Events are held at the Royal Society's offices in London, at the Kavli Royal Society International Centre at Chicheley Hall, Buckinghamshire.

Highlights in the next few months include the following. Details of all of these plus many more events can be found on our website at royalsociety.org/events:

Exhibition open until November 2011
**Arabick Roots**
The Royal Society, London
The exhibition is accessed through free guided tours, bookable via our website.

Thursday 8 September 18.00-19.00
**Greater Glory: Science and the Race To The Pole 100 Years Later**
The Royal Society, London

Monday 12 and Tuesday 13 September
**The new science of oxide interfaces**
The Royal Society, London
Scientific discussion meeting exploring the exciting new science, including properties such as magnetism and superconductivity, present in functional properties of certain oxide interfaces.

Monday 19 and Tuesday 20 September
**Non-protein-coding RNAs - the DNA–RNA dialogue in shaping the transcriptome**
Kavli Royal Society International Centre
A Theo Murphy International Scientific Meeting focusing on the role of RNA in the transmission of genetic information, and the impact this has on human disease.

Saturday 1 and Sunday 2 October
**One Culture – The Royal Society Festival of Literature and the Arts**
The Royal Society, London
Celebrating 350 years of the library of the Royal Society, a weekend of talks, events, debates and readings celebrating the many connections between science and the written word.

Monday 10 and Tuesday 11 October
**Warm climates of the past - a lesson for the future?**
The Royal Society, London
In several periods in Earth's history, climate has been significantly warmer than present. This scientific discussion meeting asks what lessons about the future can be learnt from past warm periods? An associated satellite meeting at the Kavli Royal Society International Centre immediately following the meeting will be held on "Reconstructing and understanding $CO_2$ variability in the past".

Thursday 13 October 18.30-19.30
**The Royal Society Clifford Paterson Lecture**
The Royal Society, London
The Royal Society Clifford Paterson Lecture for 2011 will be given by Professor S Ravi P Silva of the University of Surrey. The prize lecture is awarded for excellence in the field of engineering.

Friday 14 October 13.00-14.00
**Niépce in England**
The Royal Society, London
Philippa Wright, National Media Museum, speaks about Joseph Nicéphore Niépce, an early pioneer of photography, and new research that places Niépce in his rightful place within the history of photography.

Details of these, and further events in press, will be available on our website at royalsociety.org/events

## THE ROYAL INSTITUTION

21 Albemarle Street
London W1S 4BS.

All events take place at the Royal Institution.

For information and to book tickets visit www.rigb.org

## THE ROYAL ACADEMY OF ENGINEERING

3 Carlton House Terrace
London SW1Y 5DG
www.raeng.org.uk/events or
events@raeng.org.uk

020 7766 0600

## THE ROYAL SOCIETY OF CHEMISTRY

For details please contact Dr Stephen Benn
benns@rsc.org

## ROYAL SOCIETY OF EDINBURGH

22-26 George Street
Edinburgh EH2 2PQ
Tel: 0131 240 5000
events@royalsoced.org.uk
www.royalsoced.org.uk

Monday 5 September 18.00
Public Lecture at the RSE
**Radiation and Reason: Straight and Open Thinking about Choosing Nuclear**
Professor Wade Allison, Emeritus Fellow, Keble College, Oxford

Monday 26 September 18.00
Discussion Forum at the RSE
**Facing up to Climate Change**
The Rt Hon Lord Adair Turner, HonFRSE, Chairman of the Financial Services Authority, and Professor David Sugden FRSE, Professor of Geography, University of Edinburgh and Chair, RSE Climate Change Inquiry.

Young People's events
Contact: Maggie Twomey
mtwomey@royalsoced.org.uk or 0131 2405035
RSE@ schools talks (dates to be confirmed)

Autumn Science Masterclasses (dates to be confirmed).

## BRITISH SCIENCE ASSOCIATION

Saturday 10 – Thursday 15 September
**British Science Festival 2011**
**Venue: Bradford**
**Theme: Exploring new worlds**
With over 250 events, activities, exhibitions and trips taking place over the week, the programme of events offers something for everyone with activities for families and schools groups, adults looking for entertainment and stimulating debate or professionals interested in the latest research. For more information please visit; www.britishsciencefestival.org

## ROYAL PHARMACEUTICAL SOCIETY

events@rpharms.com
Tel: 0845 257 2570
www.rpharms.com

Thursday 13 October
**Modern methods of drug analysis in biological materials: analysis of drugs for the London 2012 Olympics**
By the Joint Pharmaceutical Analysis Group
At the Royal Pharmaceutical Society

Thursday 10 November
**Blue pill pink pill? Does gender matter?**
A joint conference from the Royal Pharmaceutical Society, National Association of Women Pharmacists and the Medical Women's Federation
At the Royal Pharmaceutical Society

## THE LINNEAN SOCIETY OF LONDON

Burlington House
Piccadilly
London W1J 0BF
Tel: +44 (0)20 7434 4479 ext 11
www.linnean.org
Unless otherwise stated events are held at the Linnean Society of London

Thursday 8 September 09.00-19.30
**The Role of Behaviour in Evolution** – "organisms can be proud to have been their own designers" supported by The Royal Entomological Society, the British Ecological society and the Natural History Museum.

Registration fee £45, download booking form from www.linnean.org.

Thursday 27 October 10.30-16.30
**Insect conservation and biological pest control –** ecological issues of small population, joint meeting with the Entomological Club.

Registration fee £30, download booking form from www.linnean.org

## OFFICERS OF THE PARLIAMENTARY & SCIENTIFIC COMMITTEE




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