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Is Britain nurturing SciTech innovation?

How innovation and knowledge exchange are essential for growth

The Journal of the Parliamentary and Scientific Committee

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BIVDA

The Age of Diagnostics:

Making a real difference to 21st Century Healthcare

Seventy percent of clinical decisions are based on an *in vitro* diagnostic (IVD) test. These have an increasing role to play to deliver cost effective healthcare and improve outcomes for patients.

However, to fully realise these patient benefits and cost efficiencies we need the Government to:

- Encourage increased access to point of care diagnostics in the community – allowing more rapid treatment of patients in a setting convenient for their daily lives
- Address the way money flows within the NHS to reduce perverse incentives which block the use of new tests or better use of existing tests
- Recognise the value companion diagnostics bring to targeting drug treatment

About BIVDA

BIVDA is the national industry association for the manufacturers and distributors of IVD products in the UK. We currently represent more than 90% of the industry and over a hundred organisations ranging from British start-up companies to UK subsidiaries of multinational corporations. BIVDA members employ over 8,000 people in this country including in manufacturing and R&D, with a total industry turnover of approximately £900 million of direct sales.

Please don't hesitate to contact the Chief Executive, Doris-Ann Williams if you would like any further information about any of the aspects of this issue or about *in vitro* diagnostics in general. She is always more than willing to visit you in Westminster.

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A year or so ago many punters thought that "fracking" was a term not to be used before the 9.00pm watershed on television, or possibly articulated by Wayne Rooney after missing an opportunity to score away from home! No longer is that the case because attempting to increase the UK supplies of fossil fuels has led to a very small earthquake off Blackpool.

When one reflects that the Leaning Tower of Pisa attracts ten times more tourists than Blackpool's tower, maybe it would be economically beneficial for a bigger quake to occur but that is most unlikely and certainly won't be caused by fracking.

Our discussion on 28th February on Ground Engineering looked at such matters, as well as landslips, tunnels and embankments. An account will be found on pages 36 to 44.

Since that meeting both the coalition and opposition have published important policy positions on the exploitation of shale gas. Tom Greatrex MP set out in simple terms a position that I think could be adopted across Parliament when he said, "….decisions in the UK should be taken on the basis of evidence, assessing the risks involved and on an informed basis."

We are seeing the beginnings of a technology in the UK that could assist our very worrying energy shortfall and I hope political agreement can be reached on the way forward.

Turning to another subject, I am increasingly concerned about the proposed changes to the rules on charitable giving. Having encouraged hospitals, schools, universities and scientific research to depend increasingly on benefactions from prosperous donors, the recent shift of the goal posts at short notice is likely to impact seriously on important areas of research.

I hope that the Government watch this matter with great care and have the courage to reverse the rules if my fears are correct.

Andrew Miller MP
Chairman, Parliamentary and Scientific Committee

SCIENCE IN PARLIAMENT

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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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THE IMPORTANCE OF EMBRACING A NEW ERA FOR MANUFACTURING

Iain Gray
Chief Executive,
Technology Strategy Board

Manufacturing has certainly found itself the subject of ever increasing scrutiny and attention in recent months with a never ending stream of suggestions as to the solutions for developing this precious industry in the UK.

Manufacturing remains one of the key sectors with the capacity to enable the UK to achieve economic growth. Manufacturing still accounts for 12 per cent of our economy – and 75 per cent of all business R and D in the UK is in the manufacturing sector. Working with partners and businesses, since 2007 the Technology Strategy Board has invested more than £2.5bn in UK innovation, including around 200 collaborative R and D manufacturing projects involving almost 400 companies – 50 per cent of which are SMEs. It is important to remember that the reason the manufacturing sector needs to survive is not just because it is important in its own right, but because it supports many businesses and services within its supply chains.

As the industry adapts to a changing landscape, where emerging technologies will be the drivers of success, our role, as an organisation seeking to inspire the next generation of innovation, is to consider the most effective ways we can to deliver new technologies that will place UK companies at the forefront of new markets.

The Technology Strategy Board helps companies seeking to break down the barriers to innovation though a number of different support mechanisms. We sit at a unique pivot point between research, academia and businesses and co-ordinate great ideas. If the UK is to realise its potential in high value manufacturing then continued Government support for R and D is vital.

The role of the Technology Strategy Board is to create impact beyond the initial R and D phase – it is about helping to *commercialise* the technology that has the potential to deliver new products, processes and services to UK industry that will ultimately be what defines our true success. Manufacturing is a perfect example of how scale changes can take many years to be introduced and filter down through different sectors. In the 1960s scientists and companies in the UK first realised the high potential of carbon fibres. It is only recently that we have started to see their wider application in commercial and civilian aircraft, recreational, industrial and transport markets.

In 1969 there was a House of Commons Select Committee enquiry into the ability of British industry to make the best of this scientific breakthrough. There was concern that this invention would be exploited more successfully overseas. Sadly, this was ultimately the case.

It is almost ironic that we face a similar exciting and world leading opportunity with the discovery of Graphene. This has become one of the hottest topics in the materials science arena since its discovery eight years ago. I speak for the majority in the manufacturing world when I urge us to do all we can, not just to develop the science base, but also to create the right environment to manufacture this material at scale, to ensure that it is cost effective, commercially viable and lives up to its potential. We need Graphene to build on the reputation that the UK has for a diverse, well managed and innovative range of products with international appeal.

One of the keys to manufacturing success in the UK is that good ideas and initiatives need to be effectively co-ordinated – cutting edge university R and D facilities are only an advantage if they can attract commercial customers and engage with innovative businesses. Along with my fellow colleagues at the Technology Strategy Board I spend a lot of time 'cheerleading' the UK's innovation capabilities. We have to be bold about correcting negative perceptions that while the UK has moved away from labour intensive, mass production manufacturing, we have entered a bold and sophisticated new era where we are producing hi-tech products at the point of use disrupting traditional supply chains.

. . . Manufacturing still accounts for 12 per cent of our economy . . .

In a report by Price Waterhouse Coopers in 2008 offering an outlook on how to create a sustainable UK manufacturing 'championing your industry' was one of the top five recommendations. 'Talk up your achievements and make sure the widest possible audience knows what you have done and what you can do..' this might sound like a simple marketing philosophy but it is critical – and not just for commercial reasons. The report highlighted that young people will not train for a career in engineering or manufacturing if they believe there is no future for them – and retaining the best young minds in the UK will be essential to attracting continued investment in UK companies.

changing. Many refer to this as the 'knowledge economy' but labels aside, for me this is the sense that services and manufacturing are truly starting to come together. The days when a single company developed a new product or service and brought it to market in a reasonable time scale are over. The UK's new and emerging industries are built around interdependent services and products, spanning many sectors, involving a range of skills and large and small companies. There is no simple or single recipe for success so collaboration takes on an increasingly important focus. This is where the UK can play to its strength by focusing on the areas where it has the skills, technology capability and experience. Being a leading

. . . UK plc must be known and respected as a brand that represents quality, innovation and dynamism. . .

As an organisation we have learned not to underestimate the value of communicating and networking. Being the UK's main innovation agency is an important role and our input will have a positive impact on the companies we work with.

UK plc must be known and respected as a brand that represents quality, innovation and dynamism. We lead where others follow and identify the new materials and processes of the future. British manufacturing is starting to adapt to this new 'niche' genre – and is now being recognised for its specialists who have a track record of best practice in development and continuous improvement.

The way in which we use our intellectual and technological capability as a nation is also

player in all sectors is not realistic but being a leader in selected chosen areas of expertise is the way forward.

In a report we recently commissioned by the Cambridge Institute for Manufacturing to look at the future of high value manufacturing we sought to pinpoint those areas where the UK has the best chance of economic success including low carbon technologies, integrated products and services and ICT. A full copy of the report can be accessed at: http://www.innovateuk.org/_assets/pdf/publications/TSB_IfM_HighValueManufacturingT12-009%20FINAL.PDF

This report has consolidated our decision to open a Catapult Centre for high value manufacturing which has been operational since last autumn. Catapult Centres were announced as a £200m investment programme by the Government in October 2010, and since then the Technology Strategy Board has been co-ordinating the key stakeholders to deliver these strategically important platforms that will take innovation forward in the UK.

Catapult Centres provide a network to support business in areas that will be economically significant for the UK. They will create a critical mass for business and research innovation by focusing on a specific technology and will be an integral part of the UK's innovation system, making a major long-term contribution to UK economic growth. Catapult Centres will allow businesses to access equipment and expertise that would otherwise be out of reach, as well as conducting their own in-house R&D. They will also help businesses access new funding streams and point them towards the potential of emerging technologies.

Catapult sectors complement and link with other programmes that the Technology Strategy Board manages to promote collaboration between universities and business, and drive innovation and find commercial opportunities for new technology and ideas.

One of our key aims is to shorten the journey between concept and commercialisation. We believe that the targeted focus of Catapults in areas like High Value Manufacturing will deliver tangible commercial opportunities out of Britain's world-class research base. We want the HVM catapult to play a key role in moving the UK's HVM agenda forward.

An example of this is that through our High Value Manufacturing Catapult Centre there is an exciting opportunity to access strong synergy benefits. We have already identified three areas where the greatest potential for this lies – Applications of Plastic Electronics; Simulation and Modelling and Advanced Metrology – and already we have a number of collaborative Cross Centre Projects taking shape. As technology barriers continue to break down and we develop even more sophisticated and unconstrained manufacturing processes this will inevitably bring designers closer to the point of use or consumption and so create a greater understanding between these communities is critical.

As economies in China, India and Russia continue to attract opportunities away from the UK, timing has been of the essence for us as an organisation and we have moved quickly to implement measures that build on the feeling that things may be getting better at last. I referred to manufacturing as being one of the few sectors with the capacity to drive economic growth and we will continue to drive our efforts in this rebalancing of the economy – where we can attract both foreign and inward investment and export to the rest of the world. As demand for technological change and innovation drives the future economy, we have a central role to play in the recovery of the UK as a new powerhouse of global innovative manufacturing.

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INTERDEPENDENT AND INCREASINGLY VULNERABLE – How the world is responding to environmental change

Professor Julia Slingo
Met Office Chief Scientist

Recent natural hazards around the world have raised awareness of society's vulnerability to environmental change; challenged scientists' understanding of the role of weather and climate in environmental change; and questioned society's ability to predict and prepare for such events.

Four key influences combine to increase society's vulnerability to environmental change: where people live, how people live, what they use, and climate change. It is a blend that Professor Sir John Beddington, Government Chief Scientific Adviser, has described as the 'perfect storm'.

Our planet's population is increasing, causing our cities to grow, often along coastlines. Here, people are not only more exposed to rises in sea-level and storm surges, many cities are built in zones where tropical cyclones regularly make landfall. Pakistan has a rapidly growing population with millions of people living along the Indus Valley. The floods that devastated the region in 2010 were not unprecedented – there was a similar level of flooding in 1929 – but the impacts in 2010 were far more serious: nearly 1,800 people lost their lives while 2 million were displaced; it destroyed 23% of the national crop and wiped $5 billion off expected growth.

Our world is much more interdependent than it was. We rely on global telecommunications systems; source food from around the world; and depend on efficient transport systems and a constant supply of energy and water. The way we live and the technology we exploit are exposing us to natural hazards that would have had very little impact in the past. This was brought home by the eruption of Eyjafjallajökull in Iceland in April 2010. While it wasn't a major volcanic eruption, it was the first of any significance since the growth in air travel over the last 50 years. Coupled with unfriendly weather, its impact on UK air travel and therefore on our economy was profound.

Due to population growth, we are now drawing more and more resources from the natural environment; particularly water for domestic use and agriculture, and land for food production. In the UK, for example, the population of southern England has grown significantly in the last 20–30 years while the use of water per capita has, for some time, been above the replenishment rate from rainfall. As a result, we are now faced with drought which could have an impact on agricultural production and prices.

The additional pressure of climate change creates a unique set of circumstances. While the sea surrounding the UK buffers us from some of the most serious effects of global warming, we are not immune to the impacts of climate variability and change in other parts of the world. Due to global interdependency, a changing climate has genuine consequences for the UK economy and lifestyle.

THE ROLE OF WEATHER AND CLIMATE

The importance of the weather in our vulnerability to environmental change and forecasting what it may do next, have long been understood. Last year, the Met Office celebrated 150 years since the first public weather forecast; and, over that time, weather forecasting and its influence on the UK economy and our daily life has become part of our culture. Often the weather can be the instigator of a natural hazard but other parts of the Earth's geophysical system come into play, so we can no longer look at the weather in isolation. For example, the 2007 floods in the UK were both meteorological

and hydrological and cost the country over £3 billion in insured losses.

Having had an influence on nearly all of the natural hazards we've witnessed around the world recently, it is clear that the weather and climate are drivers of environmental change. As the climate changes the rate of change is likely to be greater than at any other time in our planet's history. This will impose huge stresses on the environment; and highlights the importance of models that represent the way the environment will change in all its aspects for telling us about the future, because these will be absolutely critical in decision-making.

HOW SCIENCE CAN HELP IMPROVE RESILIENCE

The UK leads the world in many areas of environmental science. Met Office science and forecasting is envied around the world and there's increasing interest from other countries in using our modelling systems in their own operations. Advances in science have allowed us to improve weather forecasting accuracy so that a five-day forecast is as accurate as a one-day forecast was 40 years ago. In terms of being better prepared and more resilient, the impacts of this are huge; particularly when estimating the lives saved and costs avoided by knowing in advance that hazardous weather is on the way.

Take the Cockermouth floods in November 2009. The Met Office had just introduced a new high resolution 1.5 km model for the UK. This level of detail proved invaluable in allowing us to issue warnings 24 hours in advance of what would be exceptional and unprecedented levels of rainfall over the Cumbrian Fells. A red alert triggered a Cabinet Office Briefing Room meeting and emergency responders took the necessary steps to protect life and property.

Society's increasing vulnerability to variations in weather and climate presents the Met Office with complex scientific challenges in order to provide reliable predictions on regional and local scales, spanning timescales from hours to decades ahead. We are in a unique position to succeed in meeting them, with weather forecasting and climate prediction under the same roof, using the same science and modelling systems. Having built up several decades' experience in weather forecasting and communicating that intelligence for decision-making, we are now developing the same capability in climate prediction.

TURNING SCIENCE INTO SERVICES

We have an understanding of our customers' needs across the public and private sectors and around the world. We supply everything from underpinning science to sophisticated bespoke products and services. It is our job to look at the impacts of environmental change to enable others to make informed decisions.

A unique aspect of the Met Office is the closeness of our weather and climate science to services, so the time between advances in science and the help it offers is short. 80% of our science has a direct and attributable benefit on our operational performance – unlike any other scientific discipline.

But as the latest Science and Technology Select Committee reported in February 2012, there is a lot more science "ready and waiting" at the Met Office. At the moment, we currently lack the supercomputing power to take it through to the delivery of better services.

An area of predictive capability to have emerged at the Met Office over the last ten years is seasonal forecasting. In parts of the developing world, where our seasonal forecasts are increasingly accurate, they have a profound influence in helping societies to better prepare for events such as prolonged drought or food shortages.

We are also getting much more skilful and confident in making longer range predictions out to several decades, which is often the timescale for investment in major infrastructure. The Met Office has been doing detailed work on flood risk in the Thames Estuary, for example, looking at whether the Thames Barrier will hold fast and continue to protect London and the estuary communities.

WORKING IN PARTNERSHIP

The challenges posed by environmental change involve a greater breadth of science than the Met Office can cover on its own. We recognise this and have started building partnerships across environmental science and with those government departments for whom this information is critical to decision-making.

We are working with DfID on a major programme called the Climate Science Research Partnership. This involves capacity building in different African countries to look at ways of improving the accuracy and utility of climate predictions.

We've also initiated the Met Office Academic Partnership, currently with three leading universities – Leeds, Reading and Exeter – to align our research and extract maximum value from UK's investment in science. Our partnership with academia complements the Met Office–NERC Joint Weather and Climate Research Programme concerned with maintaining and developing the UK's national capability in science, observations and modelling.

At an operational level, the Pitt Review of the summer 2007 floods was the catalyst for a joint Met Office–Environment Agency Flood Forecasting Centre that brings together meteorologists and hydrologists from each organisation to deliver critical joined-up advice and flood warnings to the civil contingency community.

THE FUTURE FORECAST

We've since extended this way of working to consider other natural hazards such as volcanic ash, space weather and health. We initiated the development of the Natural Hazard Partnership (NHP) – a multi-agency programme that brings together government bodies, science institutes and research councils to provide an authoritative voice and a consistent message when natural hazards strike. The NHP was recently asked to review the National Risk Register to make sure it took a consistent view of risks relating to the environment – not just weather and climate.

Beyond this, we have established an Environmental Science to Service Partnership to look at how we bring different aspects of environmental science into a broader range of products, services and advice for different customers. With the experience and infrastructure needed to run a 24/7 operational service, the Met Office has a key role to play here. We are very well placed to be a conduit of science into services to provide better advice to the UK and the world. This is critical at a time when society's vulnerability to environmental change has never been greater.

SCI-TECH INNOVATION – The key to addressing global challenges

Professor Sa'ad Medhat FIKE
CEO, New Engineering Foundation and Institute of Innovation and Knowledge Exchange

The NEF Institute of Innovation and Knowledge Transfer (IKE) www.IKEInstitute.org, has been established to develop a body of knowledge that enables members to evolve their thinking and practice, build new values through intelligent behaviours, inspire opportunities for economic growth, support innovative leadership and improve social well-being. The Institute's programmes help organisations large and small identify new market insights and create sustainable opportunities for growth. Guided by its Innovation Council, IKE brings together business and educational leaders, financiers, entrepreneurs, inventors, thinkers, researchers and policy makers to improve capability to stimulate innovation, fostering a spirit of openness to new ideas and promoting active horizon-scanning.

That 'innovation' is a word and a concept being used increasingly in politics and the media is to be welcomed. But, argues Professor Sa'ad Medhat, words need to be supported by actions to create an environment where innovation can solve our biggest challenges.

Many business and political leaders would argue that for the UK to rebalance its economy, a move must be made away from consumption, and imports financed by borrowing, and a focus made to increase exports of manufactured goods and services. Today's challenges of weak output growth, increased unemployment and continued public debt frequently claim the news headlines. Other symptomatic challenges such as a declining and ageing working population, coupled with the diminishing returns on investment in physical capital to strengthen long-term growth, call for an alternative approach to transform our economy and society. Innovation is a key instrument to achieve such a transformation. Innovation generally, and science and technology innovation (SciTech Innovation) particularly, enhances competitiveness, helps to diversify the economy, and pushes countries towards high value-added activities.

It is easy to speak about innovation. President Obama cited 'innovation' six times in his State of the Union address; the UK Chancellor of the Exchequer in his 2012 Budget Statement put innovation and entrepreneurship at the top of the Government's agenda for growth. Everyone wants to be seen as innovative. As any business leader will know, changing focus mid-stream (or even diverting energies to consider something new) is not an easy action to take. Many organisations don't even know where to start.

THE NEED TO INNOVATE

Translating science and technology innovation into socially responsible action requires creative leadership and a shared commitment by both public and private sector organisations. This is greatly needed, for by 2050, nine billion people will inhabit the world. Societies will be faced with unprecedented demands for energy, food, goods and services and housing against a back-drop of diminishing natural resources, a commitment to raise people from poverty and to protect the environment. A sustainable future will need to balance economic stability and growth. Finding solutions to overcome today's problems presents a challenge, but also an opportunity, and one that will be afforded through innovation.

The Emerging Markets in the East have become the world's innovation hotbed, producing breakthroughs in all elements of modern business, from R&D and systems of production through to marketing, pricing and supply-chain management. They not only significantly reduce cost; they redesign entire business processes to do things better and faster than their rivals in the West. For Britain to compete, new models for business, policy and education are needed to invigorate innovation within our society. They are needed to inspire creativity and enable leaders and decision-makers to be visionaries, challenging the status quo and seeking new answers.

There are many types of innovation relevant to an organisation's growth; and in some cases their ability to thrive. Changing the business model to drive innovation brings much higher risk due to the potential for internal disturbance. However, for large organisations, recognising and managing this kind of transition can be critical to long-term survival. For Kodak, it was not a lack of fresh ideas that caused them to file for bankruptcy in January 2012, (indeed, they were among the first to take out patents on digital photography in the 1970s), it was a failure to manage these ideas into successful reality.

The rise of ubiquitous broadband and the move to everything digital resulted in many organisations having to reposition rapidly and move away from trusted business models. Innovation became the clarion call and the only way to maintain business. Organisations had to be 'innovative by design', and the endgame had to be radical transformation.

For example, Lateral Group CEO Jason Cromack, FIKE, says: "The increasing volume of data

generated through multiple channels, including social media and online trading, has transformed our business. In order to adapt to this changing environment, Lateral have to manage these data, by creating strategic innovative solutions. This required big thinking, driven by insight, using a combination of the right technology and expertise."

MODELS OF INNOVATION

Most innovation undertaken in organisations is incremental, involving 'tweaks' to an existing feature of a product or process to make it better. It doesn't involve ground breaking exploration. Product development is regarded as incremental innovation when technology enhancements are used to improve performance or reduce production cost. Strategic innovation is the form most associated with research and development (including new product development), and is linked to long term business planning and investment. This form of innovation is tightly controlled and often requires long development cycles. Given the need for return on investment, staff are under constant pressure to deliver on R & D targets.

A much talked about form is disruptive innovation, which creates a significant step change in market behaviour through the introduction of a new science or technology. A familiar example is the Apple iPhone and associated mobile applications which have impacted hugely on professional and personal communications.

Looking closer to home, additive manufacturing (3D printing) is another disruptive innovation. Renishaw PLC produces rapid, waste-free complex components that could never be made conventionally. "Whilst widely used in prototyping, additive manufacturing is transforming industries such as restorative dentistry, where it is replacing manually intensive investment casting. Other possibilities are in the aerospace sector, where the weight savings achieved in optimising complex components yield enormous fuel savings" says Renishaw Director Marc Saunders, FIKE.

Start-up businesses have an advantage since they can iterate and adapt their business model rapidly to respond to changing market dynamics and take advantage of new technologies or practices. This suggests why many disruptive innovations come from start-up businesses. For example, Celbius is a start-up company that combines two specialised technologies: ultrasonication and biocatalysis. Celbius Co-Founder, Dr Graham Ruecroft FIKE, says: "By bringing these two technologies together, chemicals can be made at lower cost. Any bioprocess is a potential candidate for improvement by this technology."

Often for innovation to happen, organisations need to engage in 'creative destruction', a literal tearing down of what has been and a building of something fresh and new. People need to change mind-set and 'unlearn' what has been done in the past to instil the 'creative habit'. In SciTech Innovation, such sacking of past citadels of success is a natural process to advance new scientific and technological breakthroughs.

CREATING THE ENVIRONMENT FOR INNOVATION

Innovation can be applied at many levels and across a myriad of situations whether in the creation of new products, innovative approaches to health care and education or in providing solutions to support sustainability. However, we need to create a better understanding of the role of innovation, how to apply it to our day-to-day lives and make it core to an individual's thinking processes through continued education. At the same time, exploitation of innovation can only really be achieved through the exchange of knowledge at all levels, in education, through industry and government.

Creating the environment for innovation is essential. Giving people freedom and the latitude to think and explore is critical if an organisation wants to embrace an innovative culture. If an idea doesn't work, 'fail fast and move on' behaviours should be encouraged. In the UK, unlike the US for example, 'not succeeding first' is akin to 'losing altogether', but how many famous entrepreneurs have had to go through idea after idea before they hit pay dirt? Driving out old preconceptions requires radical thinking and development of new structures that take advantage of the interconnectedness of the world, and build opportunity through knowledge exchange.

NEW STRUCTURES

Some organisational structures defer more naturally towards innovation. For example, the SME working in high-tech or emerging-tech areas has immediate affinity with innovation through necessity. Research has shown[1] that a new type of organisational model is evolving which is known as the Micro-Multi National Company (Micro-MNC) – an entity that is small, nimble, highly connected and global in its outlook. Market sectors such as biotech, financial services and gaming have seen a rise in Micro MNC type behaviour.

Another new structure used to innovate is clustering, in itself not new having been used by universities and their research partners. The new aspect is the approach used today, which brings together supply chains, customers, adjacent markets, researchers and even competitors to form clusters to address specific issues facing their sector. New product development in SciTech companies is not only driven by internal experiment and discovery; clusters that include supply partners and key customers have resulted in breakthroughs in new product innovations. An example is Aquamarine Power's Oyster wave power technology. Aquamarine CEO, Martin McAdam FIKE, says: "We have successfully raised over £70 million to date towards the commercialisation of Oyster technology capitalising, on the multi-billion pound wave energy market."

A PROFESSIONAL BODY FOR INNOVATION

IKE's Chair, Dr Rosie Bryson, of BASF says: "Fresh thinking and innovation is vital to business, education and policy. A professional body which encourages the development of innovation and provides a voice to those putting innovation at the heart of our economy is a major step in the right direction".

Reference

1 Transformation: Dig for Realism. ISRS 2012.

HOW MEASUREMENT IS DEVELOPING THE UK'S LOW CARBON ECONOMY

Jane Burston

Jane Burston, Head of the Centre for Carbon Measurement, explains why the development of measurement infrastructure is vital to advancing low carbon technologies and informing policy response to climate change.

In 2008 the UK became the first country in the world to set legally binding carbon targets in the Climate Change Act. The Act set goals for emission reductions of 34 per cent by 2020 and 80 per cent by 2050. Accurate measurement will play a critical part in enabling the UK's transition to a low carbon economy and will benefit government, business and the wider society.

Advancing carbon measurement practices will reduce uncertainties in climate data and provide the confidence that is required to account for, price and trade carbon emissions. It will also help accelerate the development and adoption of low carbon technologies.

Businesses need incentives to reduce emissions and make low carbon investments. If heavy industry is to reduce emissions through carbon capture and storage, they need to be able to prove the effectiveness and safety of the processes and technologies being used. The government needs to have faith that the resulting investments will deliver our carbon targets, and the public needs to know that low carbon products do what they say.

Getting this right will help us develop an environmental goods and services sector that can deliver nationally and internationally. It will allow the UK to lead the world as the financial centre of the global carbon market (projected to be over $1 trillion by 2020) and will secure the UK's position as a leader in growth and innovation as well as emission reduction.

All of this requires the development of a measurement infrastructure – not only in the UK but internationally. The National Physical Laboratory (NPL) has launched the Centre for Carbon Measurement – a world-first facility that will provide just that.

THE CENTRE FOR CARBON MEASUREMENT

NPL occupies a unique position as the UK's National Measurement Institute and sits at the intersection between scientific discovery and application. Our expertise and research make a huge impact in areas such as security, healthcare, defence and energy.

Recently launched at our London headquarters, the Centre for Carbon Measurement will supply the necessary measurement infrastructure to support the UK's transition to a low carbon economy and provide capabilities to test instrumentation, develop low carbon technologies, and provide confidence in data used to model the potential impact of climate change.

The Centre has consulted stakeholders from across government, academia and business to inform the focus of our projects. These stakeholders, which include the National Grid, E.ON, the Department for Energy and Climate Change and the National Centre for Earth Observation, endorse the three areas of our work: reporting and reducing uncertainties in climate data used to monitor and model climate change; supporting existing and emerging tax, trade and regulatory instruments for carbon pricing and reporting; and accelerating the development of, and validating, the performance of low carbon technologies.

REPORTING AND REDUCING UNCERTAINTIES IN CLIMATE DATA

One area where measurement is becoming increasingly vital is predicting the impact of climate change. Work to date enables us to say with a degree of confidence that our climate is changing due to man-made emissions. What the data and climate models do not yet allow us to predict, with the certainty we need, is the future impact of climate change and how quickly and where the impacts will be felt.

We need to improve the accuracy of climate change data in order better to inform government policy regarding mitigation and adaptation programmes, and the areas in which our resources would have the biggest impact. Should we be scaling up wind farms, developing the Thames Barrier or moving populations away from low-lying and coastal areas?

Improving the accuracy and reliability of climate data through data auditing and setting standards is a difficult task. We are making measurements of small signals against a noisy background using instruments across the globe, in a way that is internationally consistent and can be relied upon for decades.

The Centre will develop standards and validate the sensors used in satellites so that accurate, laboratory-quality measurements of climate parameters can be made from space – essentially launching National Measurement Institutes into orbit.

These data will allow modelling of climate change to understand its impact; enabling international agreements and

national policies for climate change mitigation and adaptation to be placed on a firm footing.

SUPPORTING CARBON TRADING AND PRICING

Our second focus is to support the infrastructure for carbon trading, pricing and reporting.

Countries which have agreed to cap their carbon emissions often purchase carbon credits to help meet their allocated quantity. These 'offset' credits are produced by emission-reduction projects in developing countries such as avoided deforestation. The validity of offset projects is reliant on accurate measurement to validate the extent of carbon dioxide mitigation and sustain a viable carbon trading system.

NPL is a world leader in atmospheric measurements and, with industry partners, has developed a range of technologies that could be adapted to measure carbon dioxide emissions. One of these is NPL's unique Differential Absorption Lidar (DIAL) which generates a 3D map of emissions and calculates the concentrations, providing rapid, accurate measurements of airborne emissions up to 3km away.

Heavy industries that emit carbon dioxide have to purchase carbon credits to help mitigate their effect on climate change. Under the existing EU Emission Trading Scheme (ETS), organisations must purchase one 'allowance' for every tonne of carbon emitted. As well as creating costly outgoings, the supply of allowances is limited, incentivising organisations to reduce their carbon emissions.

Pumping carbon dioxide underground would avoid emissions entering the atmosphere and so reduce the number of allowances companies have to buy. Demonstrating that the process is effective and safe – and that captured carbon dioxide is not leaking back into the atmosphere – will require reliable measurement.

Carbon Capture and Storage (CCS) is likely to be in depleted oil and gas reservoirs, which are often under the seabed. These offshore sites could use acoustic techniques to monitor and measure potential leaks. Gas bubbles created by carbon dioxide scatter sound strongly and may be detected using imaging or sonar techniques. Geo-acoustic sensors could be positioned on the sea-floor to detect movement and provide early warning of the changes in sea-bed composition. The Centre for Carbon Measurement has the relevant facilities for testing marine acoustics, allowing underwater acoustic measurements for CCS to be developed.

As the international community seeks to develop more sophisticated and coordinated policies, it will become increasingly important that the underpinning measurement infrastructure keeps in step. The work of the Centre for Carbon Measurement will enable regulation, ensure fair and stable carbon markets, support businesses in reporting and managing emissions, and provide confidence to establish and meet international agreements.

ACCELERATING DEVELOPMENT OF LOW CARBON TECHNOLOGIES

Our final focus area is supporting the development of low carbon technologies. The Centre provides access to the best measurement techniques for developers of low carbon products and clean technologies, which will allow validation of their performance.

> . . . Pumping carbon dioxide underground would avoid emissions entering the atmosphere. . .

This will provide the confidence to secure investment to develop and commercialise the product, ensure regulations are met and reassure customers that the claims about the product are valid. Such support is key to the delivery of policies such as the Green Deal, and to commercialising advances in areas such as building energy efficiency, fuel cells, renewables and smart devices.

The measurement challenges faced by developers and users of low carbon technologies are often best solved in real-world situations rather than in a lab setting. Part of the Centre's work will build on an existing NPL facility – the 'hotbox' – which measures energy performance of large building sections and materials such as solid wall insulation to evaluate the thermal performance. We aim to develop this capability for use on full, occupied buildings in order to determine how such products perform in real-world settings.

THE IMPACT ON THE UK SKILLS-BASE AND THE ECONOMY

The development of a National Measurement Infrastructure to meet these carbon challenges supports many of the individual activities set out in the Department for Energy and Climate Change's Carbon Plan. In addition, the Centre will aim to support the up-skilling of the UK workforce for a low carbon future, provide significant direct economic benefit and ensure the UK continues to be a leader in the effort to address climate change.

Launched in March 2012, the first year of activity for the Centre of Carbon Measurement will bring together existing expertise and build new capabilities along with partners. We are looking for those with an interest in this area – from business, government and academia – to work with us to expand the capabilities of the Centre and to take advantage of our expertise to advance their own low carbon practices, technologies and research.

Without a robust measurement infrastructure, it is difficult to know the scale of the climate problem or the adequacy of the solutions – whether those are policies, projects or technologies. NPL's existing work has helped solve some of the most pressing issues. With the introduction of the Centre for Carbon Measurement at a world leading centre of excellence in measurement science, NPL and its partners will be able to make a profound and global difference.

http://www.npl.co.uk/carbon-measurement/

ABOUT NPL

The National Physical Laboratory (NPL) is one of the UK's leading science facilities and research centres. It is a world-leading centre of excellence in developing and applying the most accurate standards, science and technology available.

THE AGE OF DIAGNOSTICS:
The increasing role of in vitro diagnostics in modern healthcare

Doris-Ann Williams MBE
Chief Executive, British In Vitro Diagnostics Association (BIVDA)

BIVDA

"...the upcoming years may well be known as the age of diagnostics"

Janet Woodcock MD Director of the Centre for Drug Research & Evaluation, US FDA

In vitro diagnostics (IVDs) are an integral part of the investigative journey any clinician must embark upon for a patient. Blood, fluids or tissue are examples of the human samples required to perform such tests. They are the clues required to flesh out the clinical picture of what is happening inside a patient's body. Yet, despite their name, IVDs are not just used to diagnose. IVDs are used to test the safety of blood supplies by determining the blood group, they are used to screen for infectious agents and rule out possible causes of disease. The role of IVDs in monitoring conditions and treatment is increasingly important. Tests can be utilised to catch changes in health for patients managing long term conditions – hypoglycaemia in patients with diabetes, for example – and they can also be used to determine whether a treatment is working or failing. Whichever situation warrants their use, IVDs generate the information required to decide on an appropriate course of action.

Previously, diagnostic testing always occurred in the hospital. A GP would refer a patient to a hospital specialist if they required a test. The specialists were effectively the gatekeepers of hospital resources. We have now seen a shift in how diagnostic tests are administered. By 1990 semi-automated analysers appeared, making tests simpler and faster. Rapid manual tests (the most familiar example of this format being the pregnancy test) or miniaturised instrumentation allow tests to be performed to lab standards at the 'point of care' (POC). This means a GP can rule out Chlamydia or HIV with a swab or drop of salvia, while the presence of drugs can be detected in the emergency room. Appropriate action can be decided upon in minutes.

Across London, a successful 'direct access' diagnostic scheme is in place. Mobile, fixed or community-based facilities enable GPs to make direct referrals for tests without the need to visit a hospital specialist. This reduces the need for hospital outpatient appointments and reduces time between the presentation of symptoms and diagnosis: saving both money and lives.

POC tests are not the only way in which tests are creeping out of the lab and closer to the patient. While in acute care, there are a number of routine tests which are performed in order to measure the patient's metabolic processes. Blood sodium and gas levels are routine but essential much in the same way as a GP taking your blood pressure or temperature. These can now be performed on the ward or even at the bedside. The value of bringing IVDs closer to the patient is in not having to wait for referrals, then for results to come back from labs. For many patients, the most value can be found in minutes. Also, more intrusive tests can be avoided and money can be saved.

The future, then, sees diagnostics in the homes of patients managing and self monitoring long term conditions from the home – while using

. . . The role of IVDs in monitoring conditions and treatment is increasingly important. . .

technology to share data with clinicians. Patients with diabetes are already monitoring their blood glucose levels in order to adjust their diet and lifestyle accordingly, keeping them out of hospital. It will soon be a reality for HIV patients to monitor the effectiveness of their antiretroviral drugs from home, making sure that time consuming visits to clinics only occur when they are truly necessary. In a time when efficiency is so important for the NHS, keeping patients out of hospital beds as much as possible is incredibly important. IVDs look set to have a huge role in this essential paradigm shift in modern healthcare.

Diagnostics also look set to predict the likelihood of a patient developing a disease. By identifying the biomarker neutrophil gelatinase-associated lipocalin (NGAL), diagnostic tests can predict the likelihood of the development of kidney disease after cardiac surgery. Cancer has been the main focus of this kind of research for quite some time, with researchers working towards genetic cancer predictions from small tissue samples.

If we look again into the future – perhaps to BIVDA's 40th anniversary – we see diagnostics coupled with drugs. Rather than merely making the initial diagnosis, which leads to the prescription of drugs, the diagnostics will be working out the best kinds of drugs for patient sub-populations. We call these 'companion diagnostics' and they will eventually be used to predict the effectiveness of a specific drug. The Technology Strategy Board (TSB) is currently researching which groups of patients will benefit from generic drugs such as Metformin. Metformin (for people with diabetes) has a high success rate when prescribed to the correct patient sub-population, but it produces severe side effects for others. The vision for research such as that by TSB is that one day, with a prick of the finger, doctors will know which patients they can prescribe to. The benefit for patients is obvious and the cost savings to the NHS will be significant too.

So in the age of diagnostics, IVDs are no longer behind the scenes. They are the GP's first port of call and part of the day-to-day routine in the home. The white goods next to a hospital patient's bed are not washing machines but blood gas analysers. They are also at the heart of R&D, making sure that tumours are genetically predictable and pharmaceuticals specifically targeted. Bringing diagnostics further forward in the patient pathway saves precious minutes and money. The sooner a patient is diagnosed, the sooner clinicians can start to think about what will make them better and if they can be kept out of hospital then the resources of our healthcare institutions can breathe a sigh of relief. These are pressing issues in a time when our population is ageing and efficiency savings must be made. In the age of diagnostics it will be diagnostics that help us to decide what will make the difference.

. . . with a prick of the finger, doctors will know which patients they can prescribe to. . .

STRATEGICALLY IMPORTANT METALS

Mark Tyrer and Alan Gibbon present their views a year after the Science and Technology Committee report

Mark Tyrer (Geochemist)

Research Manager with MIRO. Originally a geology and materials graduate, he further studied radiochemistry and completed a PhD in cements chemistry. Previously, Mark has worked for the British Geological Survey, WS Atkins and with Imperial and University Colleges in London, where he maintains strong links.

Alan Gibbon (Precious metals metallurgist)

Development Director with MIRO. Graduated from the University of Birmingham as a Mineral Processor but has spent over 30 years in the platinum and precious metal refining business. Prior to joining MIRO in 1993, Alan worked for Johnson Matthey Plc and now specialises in precious metal treatments, mineral wastes, pyrometallurgy, process modelling and environmental issues.

MIRO – The Mineral Industry Research Organisation is a not for profit limited company owned by its members and based in the UK.

In May 2011, the Parliamentary and Scientific Committee discussed strategically important metals. At that time, the findings of Science and Technology Committee had just been published (HC 726), to which the formal government response was issued in September (HC 1479). These and the many commissioned studies considering this topic, form a substantial body of work which describe our reliance on certain elements, their supply chains, applications and recovery. In the year which has passed, we consider some of the recommendations of this work and look at how they might be implemented.

The issue is that for many technologies, reliance on a limited number of chemical elements is absolute, or almost so; in that no alternative approaches have yet been developed which would displace them. There are many examples, prominent amongst which are the use of the rare earth elements (REE, lanthanides) dysprosium, terbium and especially neodymium in modern 'super' magnets and the use of lanthanum in battery technology. Beyond REE metals, many other examples exist, such as phosphorous and fluorine for the chemicals and allied industries, indium in computer displays and the platinum group metals. For example, applications for ruthenium have burgeoned in recent years, owing to its incorporation in electronics (hard disk drives, on-chip resistors) and in display technology. In recent years, the supply of many strategic metals has been controlled by China, whose reserve of rare earths eclipses the rest of the world. Understandably, it is of greater benefit to China to export value-added products rather than raw materials and this is the underlying driving force of the debate.

In looking for alternative sources of supply, world attention has focused on Australia, South Africa and the United States, all of which have capacity to expand their production, and are in the process of doing so now the global demand (and price) of scarce materials has risen. The *Mountain Pass* mine in south east California is expected to regain its full production capacity later this year and other countries are responding to growing demand, estimated at between 8 and 11% per annum.

We might ask what resources are available to us in the UK; do we have reserves of REE and other minerals which we might exploit? The S&T report cites written evidence from the Mineralogical Society and the Royal Society of Chemistry which states that the UK mineral reserves are incompletely known, referring to the *Mineral Reconnaissance Programme* led by the British Geological Survey (BGS) which has identified unexploited deposits of various strategic metals, such as the platinum group metals and gold, in the UK. Through support from the Natural Environment Research Council (NERC) BGS compile and publish 'World Mineral Production', as well as production and trade data for Europe. In addition, BGS publish the 'Mineral Commodity Profiles' which include strategic metals such as REEs, tungsten and PGMs – a new one on Li will be published later this year. The NERC Knowledge Exchange Grant is funding a new 'Critical Metals Handbook' from BGS which is expected at the end of the year. Written evidence from the Geological Society discusses resource recovery from secondary mineral sources such as burnt oil shale waste, fly ash and metallurgical slags, which has attracted considerable attention. Andrew Miller MP, Chaiman of the S&T Committee, said *"There is significant potential for the UK to improve its efficiency of metal use, and we heard evidence of effective methods for materials recovery. It is vital that the Government explores these options without delay."*

As to what government actions are being undertaken as a result of the debate, DEFRA and BIS summarise new initiatives in their recent 'Resource Security Action Plan' (March 2012) as follows:

- Innovation Challenge: Defra will fund an Innovation Challenge Fund for local economy closed-loop projects under the co-ordination of the TSB. The

idea is that local businesses will be helped to extract value from domestic and commercial waste streams, through partnerships between business, local authorities and local communities.

- The government (through BIS) will investigate the feasibility of applying the principle of Individual Producer Responsibility (IPR) more generally to the Waste Electrical and Electronic Equipment (WEEE).
- Similarly through BIS, the government will work to support UK businesses by extending data capture of waste electrical and electronic equipment being treated by waste management companies and other players outside the current 'WEEE system'.
- The Environmental Sustainability Knowledge Transfer Network (ES KTN) together with the British Geological Survey and other partners including the Waste and Resources Action Programme (WRAP), BIS, and Defra will develop and test a 'critical resources dashboard'. This will seek to provide companies with better information to take more informed decisions on the resource risks to their operations, and will be launched by the end of January 2013.
- WRAP will develop a high level critical materials flow analysis in key WEEE product categories (initially for WEE 'hotspots').
- A new industry-led consortium, convened by the Green Alliance, will bring together interested businesses and business groups to provide a mechanism to develop further links between government, business and other organisations to address resource opportunities and concerns, to disseminate leadership thinking and best practice and to provide a forum for policy innovation.

Whilst each of these initiatives is to be applauded, there seems to much fundamental work still to be done. High on the list would be to prepare for growth in strategic metals recycling.

Although some of these elements are not especially rare, rich ores of these elements are very scarce and many commercial deposits are in a few, fairly remote locations. To compound this, relatively small quantities are in current use, of which only a small fraction is in products close to the end of their service lives. Consequently, recycling of these metals is in its infancy. Compare this situation with that of lithium, which although more abundant, is not yet recycled effectively. On a recent visit to the lithium operations of *Umicore*, in Olen, Belgium recently, our host asked a simple question – *"What have you done with your old mobile phone?"* Without exception, the visitors admitted that they were in a drawer with several others! This is a key hurdle which we must overcome and the solution is not a simple one. There is a considerable time lag between acquiring technology containing scarce resources and our willingness to recycle them and the same is likely to be true of other rare metals. It seems likely that many expensive devices will be stored at the end of their lives – 'just in case they are needed – before they enter the recycling circuit. To impose a tax on new electronic devices to be refunded upon recycling seems a draconian measure, but surely, some incentive is needed to promote resource efficiency.

One of the difficulties of dealing with the lanthanides is that they exhibit such similar chemistries. This makes their chemical separation notoriously difficult and expensive, which has resulted in renewed interest in separative technology such as electro-winning of the metals from molten salts. Fundamental to this is our incomplete understanding of the chemical thermodynamics of these elements and their compounds, without which, industrial optimisation of process chemistry becomes a rather slow and vague process. The National Physical Laboratory has recently launched a 'Rare Earths Club' as a way of drawing together expertise in this field. An ability to predict the optimum conditions for metal separation would put the UK at the forefront of REE recycling.

The Research Councils have a key role to play in developing this technology. The Engineering and Physical Sciences Research Council (EPSRC) are building on their recent projects on REE recycling with a transatlantic call for proposals with the (US) National Science Foundation. Specifically, one task seeks proposals in *"New chemistry to recycle economically chemicals that cannot be replaced, such as phosphorus and the rare earth elements".* The Natural Environment Research Council (NERC) has launched two recent programmes: *'Mineral resources: Science to sustain security of supply in a changing environment' (£7m, contributes to sustainable use of natural resources theme).* This recognises the need for rapid advances in science to understand how strategic minerals are mobilised and concentrated in the earth's crust and the technologies required for their location and efficient recovery.

It is very encouraging to read of the NERC companion programme *"Resource recovery from waste (£6m, Contributes to sustainable use of natural resources and environment, pollution & human health themes)".* Recycling research impinges on the activities of both EPSRC and NERC and it is heartening to see this activity embraced directly. This programme seeks *'to lead the delivery of the strategic science needed to accomplish a paradigm shift in the recovery of resources from waste, driven by environmental benefits integrated across air, soil and water resources and for human health, and not by economics. Further, the programme will forge new thinking that goes "beyond carbon" to understand waste as a resource from the perspective of ecological not carbon outcomes.'*

Hear! Hear! So often we see technological developments hampered by the economic constraints of immediate financial return. The nation needs to invest in generating knowledge and understanding before planning commercial developments. Our traditional approach of good at 'R' but less so at 'D' need not persist. In the case of REE recycling, wealth generation may reasonably follow knowledge generation, if we manage our knowledge resources with care.

This subject needs a champion. The activities reported here are an excellent start, but they need to be focused on the national need if momentum is to be maintained. Perhaps the S&T committee will revisit this subject in a couple of years time, to show the real advances made from this strong start.

PEER REVIEW: NO ALTERNATIVE TO EXPERT JUDGEMENT

Sir Mark Walport
Director, The Wellcome Trust

Peer review is an integral part of the scientific enterprise. Misconceptions around peer review abound, and it is seen in some quarters as an opaque and slightly mysterious process. But the concept behind it is really very straightforward – simply that of review by experts.

Peer review is important because science involves many tough choices. Research funders need to decide how to allocate limited public and charitable funds between the many competing grant proposals they receive. Scientific journals need to decide which research papers are worthy of publication and which are not. And commercial enterprises and investors need to decide which scientific innovations will have the greatest potential to reach application and generate returns.

Peer review ensures that these key decisions are informed by the views of experts in their field, based on a robust and independent appraisal of the underlying science. Whatever the limitations and challenges of peer review may be, the alternative – effectively, that such decisions do not involve the input of genuine experts – is surely far worse.

PEER REVIEW AT THE WELLCOME TRUST

As a global research charity dedicated to achieving extraordinary improvements in human and animal health, the Wellcome Trust is committed to ensuring that we use the funds we have to support the very best researchers with the brightest ideas. We want to identify those researchers who, based on their track record and research vision, have the potential to make real breakthroughs in advancing knowledge and its application to improve health. We believe that it is practising scientists who are best placed to make such appraisals, based on their experience and expert judgement.

As such, peer review lies at the very heart of our decision making processes. Grant applications are assessed by independent committees made up of leading scientists from around the world. Their deliberations are informed by the comments of external referees who are experts in the subject areas covered by a particular grant application.

Careful selection of reviewers is absolutely key to the success of peer review. At the Wellcome Trust, we put considerable effort into ensuring that we get the right mix of reviewers for a particular grant application. Because the field of possible reviewers in some areas is quite small, we will often try to include some reviewers with a broader perspective in addition to those with specialist expertise in the specific area covered by the application. We also have robust conflict of interest policies to mitigate risks that reviewers will be subject to undue influences in their appraisals.

No one is under the illusion that peer review is a perfect system. In particular, the quality of review will only ever be as good as those who undertake it. It depends crucially on their rigour, generosity, fairness, expertise and sound judgement. Several recent high-profile cases have illustrated that when peer review is done badly, the consequences can be highly damaging and can erode public trust in science. All of us in the scientific community have a key obligation to uphold the integrity of peer review, and to be open and transparent in communicating its importance and its limitations to the wider public.

THE COST OF PEER REVIEW

Perhaps the most pressing challenge associated with peer review is the burden it places on the academic research community. The Wellcome Trust alone makes between 15,000 and 17,000 approaches to potential referees each year, and on average around 45 per cent of these approaches will result in a review being submitted. We consider this to be a good hit rate. However, with the mounting volume of requests for reviews being generated by research funders and journals and the pressures that exist on researchers' time, there is a risk of increasing 'review fatigue'. This will result in falling response rates and could ultimately compromise the quality of reviews.

At present, peer review is a service that researchers usually

provide on an unpaid basis, and which many conduct in their own time – fitting it around their research and teaching duties, often in the evenings or at weekends. Most do not resent the time they invest, and view their contribution as crucial to the successful operation of the wider scientific enterprise of which they are part. In addition, peer review can provide genuine benefits for their professional development and helps them to keep abreast of advances at the cutting-edge of their field.

Nonetheless, the current situation does raise important questions. At present, it is funders and publishers who benefit from the use of peer review, but it is the researchers themselves and their employing institutions who bear almost all of the cost. Ultimately this situation will probably have to change. Peer review is a professional service, and it seems appropriate to recognise properly this activity as part of a researcher's role. At the Wellcome Trust, we are developing plans for a peer review college to cover our major funding programmes, which would reimburse referees for the reviews that they provide.

The longer-term sustainability of peer review will depend critically on a continued pipeline of quality reviewers. Developing the skills necessary to conduct reviews is a key part of a young scientist's development, and is already fostered through informal mechanisms in academic departments, such as journal clubs. Nevertheless, there is a strong case for ensuring that formal training is also available; this is something that we would encourage research institutions to develop as part of their training and professional development activities.

ADDRESSING THE CHALLENGES

While the system is definitely not at the point of collapse, there is a pressing need for both funders and publishers to explore actively innovative ways of reducing the burden of review, whilst upholding its quality.

As a funder we adopt a combination of different approaches to peer review, which we endeavour to apply in a judicial manner at the appropriate stages of the application process. In particular, the use of methods such as triage can help to reduce the number of requests to external reviewers, without compromising the rigour of the overall process.

An excellent example is our Investigator Awards. These Awards provide outstanding early-career and established senior scientists with long-term flexible funding to pursue their research visions. Preliminary applications for these awards are first triaged by subject-based expert review groups, and only those that are successful are sent to international referees for review. Candidates are then interviewed by an Interview Committee, again consisting of international external experts, who make a final decision, based on the outcome of the interview and the comments of the referees.

INNOVATION IN PUBLISHING

There is also considerable scope for innovation in the publishing sector to address some of the challenges associated with peer review. This has been enabled in part by the rapid growth of the open access publishing movement over the last decade, which ensures that the published outputs of research papers are freely available to all at the point of use. A popular myth persists that open access equates to less rigorous peer review – but this is simply not the case, proper peer review is as integral to open access publishing as it is to traditional scientific publishing.

Indeed, open access publishers have been responsible for some of the most exciting innovations in this area. The model pioneered by *PLOS One* – where review focuses solely on whether the findings are justified by the results and methodology presented, rather than on assessment of the relative importance of the research – has both reduced the burden on reviewers and the time it takes to get a paper published. Open access publishers have also led the way in the development of more sophisticated metrics to measure the impact of individual research papers, taking us beyond the blunt tool that is the journal impact factor.

Recognising the opportunities for transformative change in this area, the Wellcome Trust has joined with the Howard Hughes Medical Institute and the Max Planck Society to establish *eLife* – a new top tier, open access e-journal. *eLife* will place scientists at the heart of the publication process, ensuring rapid, transparent and scientifically-based editorial decisions. It will adopt innovative approaches to accelerate peer review and to maximise the potential of online technologies to enhance access to scientific information.

In pursuing such opportunities, it will be important to recognise that different scientific disciplines have very different cultures and ways of working, and there will never be a one size fits all approach for peer review. For example, whilst pre-publication review works well in the high-energy physics field, it would not be appropriate for the medical sciences – where the publication of results ahead of expert scrutiny can sometimes carry significant risks for public health.

DEBUNKING THE MYTHS

There are a number of myths which have permeated the debate on peer review. These merit challenge. First, there is a widespread view that peer review serves to promulgate conservatism and inhibits ideas that challenge established norms. While this may happen on occasion, it is our experience that the vast majority of reviewers we work with genuinely wish to embrace innovative, cutting-edge research and to take risks where the underlying science is sound.

It is also widely claimed that peer review disadvantages research that cuts across disciplinary boundaries. This does not necessarily reflect our experience in practice as a funder, which is that most reviewers are very receptive and wish to enable such research.

A FINAL WORD

It is our strong belief that peer review remains critical to the process of science. Whilst it is by no means a perfect system, the decisions we make in science have major implications and need to be based on the judgement of experts. There is simply no viable alternative.

Should we actively embrace innovation to address the challenges and burdens associated with peer review? Of course we should. Is peer review broken? Emphatically not.

PEER REVIEW AND THE PUBLIC INTEREST

Tracey Brown
Sense about Science

Peer review is not just the esoteric concern of scientific researchers. It is a system of independent scientific scrutiny that helps to safeguard the public interest in sound science, and as such we should pay it a lot of attention.

Sense About Science is a UK based charity to help people make sense of science and evidence. We work with over 5000 scientists and hundreds of organisations from science and civil society to respond to questions about scientific issues and to chase up misleading claims.

Our trust was born in 2002, one of many responses to the troubled relationships between science and society, troubles which had been elaborated in the House of Lords Science and Technology Committee's report of 2000.

It was a baptism of fire. The newspaper front pages raged with headlines and horror stories about cloning, stem cell research, genetic modification, mobile phone radiation, the Measles Mumps and Rubella vaccine and nuclear waste disposal. Many stories were being generated by claims, often apparently conflicting, about what was shown by scientific research. Contradictory accounts of evidence were not just the product of the news media. They often arose in statements from advocacy groups, policy makers, advertisers and from the rapidly multiplying public relations activities of institutions. At the same time, the Internet had given new life to single issue campaigners, product promotion and self-styled gurus offering theories about the causes and cures for disease, many of which were purporting to be based on cutting edge scientific research and techniques, such as stem cell implantation.

. . . Peer review seemed to be a well kept secret of the research community. . .

This was the landscape in which we had to intervene to encourage people – policy makers, media, organisations and the public at large – to consider scientific evidence. One of the first things that stood out was how little attention was being paid to the quality or status of research findings, and in particular to whether they had been subjected to any kind of peer review.

Peer review seemed to be a well kept secret of the research community. In no other area of life do people systematically volunteer their life's work to be critically evaluated by others in their field. Can you imagine a Government Minister's press releases being submitted for approval to MPs before publication?

Our Working Group on Peer Review, established in 2004 and chaired by Professor Sir Brian Heap FRS, concluded that it was a process little understood by many who interacted with the findings of research. For them, and the public at large, insights into how research had been evaluated were valuable. The Working Group resolved that greater effort was needed by research institutions, journals, publishers and others to share the workings of these processes.

However, many in the scientific community were sceptical about the public's interest in peer review. This might in part have been the result of defensiveness about those times when the system broke down – incidents which accounted for what little publicity there was about the peer review process at that time. Concerns about bias, frustrating experiences, bad behaviour by reviewers or authors, eclipsed consideration of a system that delivered 1.3 million papers a year and that was used to select research for funding and to develop critical evaluation post-publication. There were also reservations about putting information about the system into the hands of the public, for fear that it would be misunderstood. For example, 'it's peer reviewed' might be taken to mean 'it's true'.

When we published the resulting public guide to peer

review, *I Don't Know What to Believe,* I am afraid that we took these comments rather too much on board. The guide explains how research findings are reviewed for validity, significance and originality. It also gives a brief summary of how editors select reviewers and discusses the importance of ensuring that papers refer to previous work and provide information so that others in the field can see how the research was conducted. We printed just 10,000 copies.

It was to our surprise that the publication of the guide immediately generated public discussion, ranging from national radio and papers to the specialist publications serving voluntary bodies and public information services. Peer review seemed to be newsworthy. The guide began flying out of the door and the electronic link to it appeared across the Web.

Here we are today, some 500,000 copies and 10 reprints later, looking at a much improved situation. The guide is used by many people and organisations who respond to the public's questions about research claims, such as patient helpline operators who handle calls about the validity of stories in the news about the causes of Alzheimer's disease, for example. Our peer review work is now backed by library services, publishers and editors. Information about whether findings have been peer reviewed is sought by journalists, and details of the scientific publication are regularly included in institutions' press releases and in news reports, though it has to be said, not yet regularly enough.

In policy too the picture is better. Back in the early 2000s, there had been a rapid growth in Government's use of consultations, especially on contentious policy issues. This appeared to have been accompanied by a rather literal weighing of research claims in Whitehall. So we saw situations where two consultation submissions giving opposite views about research were counted thus: one for, one against. Never mind that one might summarise and evaluate the entire peer-reviewed, published body of research and the other be based on the press release of an unpublished survey by a campaign group.

Now there is a greater awareness of the need to ask questions about the status of research being fed into policy making. Information about peer review is included in training for senior civil servants. Revised guidelines about the Government's use of scientific advice include more explicit reference to the extent to which results have been reviewed and, where appropriate, repeated. Our campaigning mantra has been, and continues to be, that the status of findings is as *important* as the findings themselves.

> . . . Something must select what we pay attention to from the sea of research out there. . .

Contrary to the fears of some researchers, the public seem quite able to understand that peer review is an indicator of scrutiny rather than the final word. Perhaps that should not be surprising. When we buy a microwave it has a kitemark. We know this means that it has passed some safety and operating standards. We also know that the microwave won't work forever and, in fact, that the kite mark doesn't guarantee it won't break down the day we get it home. But we know that the kitemark is important all the same.

> . . . Peer review is more than just having to settle for 'the best we've got'. It is the best. . .

The importance of the status of findings shows up in the kinds of questions that the public ask us about research. When we analysed our call logs, we found that many enquiries were very similar: should we worry about these findings? Is it a scare story or real science? What do scientists actually know? Is it a proper study? How can I tell? What do other scientists say about it?

Having helped to promote a focus on questions about the ways that research is scrutinised, at Sense About Science we became concerned a few years ago about growing talk of 'a crisis in peer review'. This crisis talk seemed to refer variously to the global expansion of scholarly research, to particular incidents of flawed papers making it into print (the Wakefield paper on MMR and autism in the *Lancet* for example), to reaction to the UEA email exchange about trying to stop publication of some climate research, and to the mounting pressures on researchers to get grants and publish papers, leaving little time to review papers. Was the global peer review system about to collapse under this weight? Did the relatively small number of problems in how papers were handled threaten to become a much bigger number?

In 2009 we conducted a survey of authors and reviewers about these issues, using the template of a Publishing Research Consortium survey 2007, and adding questions about the role of the peer review system and how well it was understood. We asked about the time spent reviewing papers and motivations for reviewing. The Peer Review Survey 2009 turned out to be the largest ever global survey of authors and reviewers. The preliminary findings were published in the journal Serials; the full data are online at our website and the final paper on these will be published this spring.

The biggest surprise was that overall satisfaction with peer review was very high. Only 9% of authors and reviewers said that they were dissatisfied with the system. There was some confusion among respondents about the purpose of the system. While, as expected, "improves the quality of the paper" ranked high in both what the system does and what it *should* do, a surprising number thought that peer review does and should be able to detect plagiarism and fraud. This might tell us that the peer review system is seen by researchers as bound up with other things that journals do, such as running software to help pick up plagiarism. While improvements to peer review were strongly supported, talk of crisis was clearly much exaggerated.

Motivations to review were altruistic. Reasons such as "playing my part as a member of the academic community" and being able to improve a

paper ranked much higher (90% and 85%) than gaining personal recognition or enhancing one's career (34% and 46%). Sir Mark Walport has discussed the question of paying reviewers. We should tread very carefully here, where there is a risk of undermining these values by putting a price on them.

I want to tackle a few things that people often conclude when we discuss the challenges of peer review. Some argue that we need alternatives to peer review. But why should we leap from individual failures in the system to dismiss the bigger principles at stake? We don't do that in other systems which fall short of their principles. Lawyers will regale you about court delays and inadmissible evidence. But we don't say we need an alternative to justice. We ask how the system can deliver it better.

Let's be clear too about the 'alternatives'. There is just one. Something must select what we pay attention to from the sea of research out there. If it is not a system that aims for independence and objectivity, then it will be researchers with the clubbiest contacts and institutions with well-funded public relations. You can dress this up in talk of online technologies and social media networks, but it remains what it was in the time of the Medicis – patronage.

Peer review is more than just having to settle for 'the best we've got'. It is the best. It might struggle with the weaknesses of human judgement, but that is because it has all the strengths of human judgement. It's a flexible system, which can reflect movement within a field in a way that no tick-box approval system can. It has the ability to spot something good and bring it to the attention of researchers and research users more quickly. If it falls short, it is because our aspirations to objectivity are high. For the public and for the research community, we should keep them that way and improve the system.

PEER REVIEW – IS IT WORKING?

PEER REVIEW IN A CHANGING AND DISRUPTED PUBLISHING LANDSCAPE

Dr Irene Hames
Editorial Advisor and Consultant

Peer review is often the subject of intense debate, and never more so than now when we are at a critical juncture in scholarly publishing. A number of interlinked areas, including peer review, are impacting one another and will affect how research output is going to be communicated, accessed and evaluated in the future. The time is ripe for innovation and it is likely that new models and new players will enter the arena.

Peer review in journal scholarly publishing (known as 'editorial' peer review, to distinguish it from funding review) is, quite simply, "the process by which research output is subjected to scrutiny and critical assessment by individuals who are experts in those areas"[1]. It traditionally takes place before publication, ie a 'filter, then publish' approach, but there have been suggestions that everything should be published and only then evaluated, ie 'publish, then filter'. Many, however, are concerned that this approach would not only release incorrect material, which in some disciplines could be harmful or misleading, but readers, particularly non-specialists, would find it difficult to know what to trust. Indeed, one of the conclusions of the 2011 House of Commons Science and Technology Committee inquiry into peer review was that "Peer review in scholarly publishing, in one form or another, is crucial to the reputation and reliability of scientific research"[2].

It is important to stress that quality of peer review is independent of journal business model. It does not matter whether it is subscription based, open access with author-side payment, or has a hybrid arrangement with elements of both. Sweeping statements shouldn't be made by any group to denigrate another (as has sometimes happened against open-access journals); there are good and bad examples of peer review in all the models. Criticisms of peer review itself have, however, been around for a very long time – that it is slow, expensive, unreliable, idiosyncratic, conservative, and open to abuse and bias. These are certainly potential problem areas, ones that most researchers have experienced in their careers. Peer review isn't

infallible. It can and does go wrong, just as any other human activity. The peer-review process looks deceptively simple, for example when described in a flow chart. In reality it's complex and sophisticated, and at its best and in the right hands a powerful tool. The role of the Editor is absolutely critical. A common misconception is that it is reviewers who 'accept' or 'reject' manuscripts. They don't. They assess, advise and make recommendations, and it is Editors who makes the decision whether or not to publish. Good and skilful Editors are ones who exercise sound and fair critical judgement, acting as more than just vote counters, deciding whether reviewers' criticisms and requests are justified, whether additional work is or is not needed. They help create and maintain a sound scholarly record. Bad and inept Editors bring the system into disrepute. Good peer review helps improve not only manuscripts, but often the science behind them.

. . . A common misconception is that it is reviewers who 'accept' or 'reject' manuscripts. They don't. . .

Researchers are being put under increasing pressure to publish in high Impact Factor journals. Despite the criticisms levelled at the use of journal Impact Factor as a proxy measure of research and researcher quality, it still plays an important role in the careers and funding prospects of researchers. Over 20 years ago, Stephen Lock, *BMJ* Editor 1975-1991, voiced the concern:

"… And underlying these worries was yet another: that scientific articles have been hijacked away from their primary role of communicating scientific discovery to one of demonstrating academic activity." [3]

This is even more applicable today, with greatly increased submissions to journals making publication highly competitive. Competition is also becoming keener because of the increasing numbers (and quality) of submissions from newly emerging scientific nations such as China and India. Editorial and reviewing loads are becoming heavier, and this has led to speculation that "the peer review system is breaking down and will soon be in crisis" [4]. There is currently some geographical imbalance in submission and reviewing activity which may be partly responsible for this, with researchers in the USA, for example, carrying a higher reviewing burden, producing about 20% of papers globally but conducting about 32% of the reviews, and those in China producing 12-15% of the papers but doing only 4-5% of the reviews [5]. The situation is likely to become better balanced as researchers from the emerging nations become more established, gain international reputations, and name-disambiguation schemes currently being developed make it easier to identify people correctly.

The scale of the total reviewing effort needed is enormous – about 1.5 million articles are published globally in around 26,000 peer-reviewed journals each year. This equates to at least 3 million reviews, probably many more, because articles that are rejected from one journal go on in most cases to be submitted to other journals in turn until accepted somewhere. This 'wastage' of reviews is of concern to many, and has led to various 'cascading' initiatives – both within publishers (eg Nature Publishing Group, BioMed Central, Institute of Physics Publishing, Royal Society of Chemistry) and between them (eg Neuroscience Peer Review Consortium) – where rejected manuscripts and their reviews can, if authors choose, be passed on to other journals for consideration. Reviewing is a reciprocal 'give and take' activity, as authors and reviewers are mostly the same community. So reviewers get valuable feedback on their manuscripts when they are authors. Increasingly it is felt that there should also be more formalised recognition of reviewing, and training available for early-career researchers.

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Two events – one a few years ago, one just a few months ago – have resulted in seismic shifts in the scholarly publishing landscape, and the traditional publishing industry now faces the threat of disruption. These shifts have, however, also brought opportunities to move forward with the scientific research community and provide new value-added services.

In December 2006, a new open-access journal, *PLoS ONE*, was launched in which the two functions of peer review – assessment of rigour and selection for interest and novelty – were for the first time separated. The journal's review process would concentrate only on assessment of scientific and ethical soundness and not make any judgement on novelty, interest or potential impact. That would be left for the post-publication phase. *PLoS ONE* has grown extremely rapidly and is now often referred to as the largest journal in the world. In terms of annual output it is: in 2011 it published around 14,000 articles, representing about 1.5% of the total world scientific output. The journal is a true 'game changer', partly because it has proved itself to have a sustainable business model. Indeed, many publishers have rushed to launch similar repository-type or 'mega' journals. With this model, researchers no longer have to go from journal to journal to get research published, thus avoiding delays in getting sound work out and available to others to use and build on and allowing them to concentrate on their research rather than chasing publication. Many, understandably, like this, and *PLoS ONE's* respectable Impact Factor (4.411) has led to a steep rise in submissions.

The second seismic event began on 16 December 2011. On that day, the Research Works Act (RWA) bill (HR 3699) was introduced into the US House of

. . . The blogosphere and Twitterverse are becoming increasingly important. . .

Representatives. The RWA would, if passed, effectively reverse the NIH (National Institutes of Health) Public Access Policy of 2008, which requires NIH-funded researchers to deposit all final peer-reviewed manuscripts resulting from that funding in PubMed Central (NIH's National Library of Medicine free archive of biomedical and life sciences journal literature) and to be publicly accessible no later than 12 months after publication. It would also prohibit any further open-access mandates for federally funded research. Support of the bill by the Association of American Publishers (although a number of member publishers dissociated themselves from this) and the actions of certain publishers acted as a trigger, releasing latent unrest amongst the academic community. An acrimonious battle has since broken out and is being played out in the blogosphere. There has been a 'call to arms', which is having a direct effect on peer review – researchers are being asked to refuse to review, submit and carry out editorial duties for certain commercial publishers as a protest against support of the RWA and other measures to restrict free exchange of information, the prices of journal subscriptions, the level of some publisher profits, and reluctance to move to open access as the basis of research publishing. For example, The Cost of Knowledge web site http://thecostofknowledge.com/was started at the end of January (originally for mathematicians, but it now encompasses various sciences, medicine and social sciences) and at the beginning of March has nearly 8000 signatures. Template letters for review refusal are circulating on the internet, along with negative, sometimes vicious, comments about publishers. A major problem seems to be a lack of understanding and engagement by the two sides. Publishers cannot afford to ignore what is being said. All partners in the funding and communication of science need to get together to find ways to move forward for the benefit of science. On 27 February, the controversial RWA was very suddenly abandoned. The unrest in the research community, however, continues.

Peer review doesn't stop at publication. Many feel that this is actually when real peer review starts, as researchers begin to scrutinise, repeat and build on published work and the self-correcting nature of science starts. Post-publication review and evaluation can take a number of forms and the internet and technological advances have brought increasing opportunities for experimentation and innovation. There are a number of challenges, including how to get people to participate (the level of engagement is in many cases very low), how to aggregate opinions, evaluations, blog posts and other contributions in a meaningful way, and knowing who to trust. A number of projects are already under way, but there is again plenty of space for innovators to create new services. With the increasing number of journals adopting the *PLoS ONE* model, there is a real need for evaluation, sorting and analysis of all the work being published. The blogosphere and Twitterverse are becoming increasingly important in this respect, especially as adoption of social tools by researchers grows, allowing scientific interaction outside of journal articles. They also provide the means to alert communities rapidly about problems with published work, for example as happened with a paper published in the journal *Science* in December 2010[6]. When researchers reported that they'd found a bacterium that could grow on arsenic and incorporate arsenate in place of phosphate into its DNA, experts in the field started to post criticisms of the methodology and interpretation online within a day or two. The story came to be known by its Twitter hashtag, #arseniclife[7]. The online community knew about the problems with the paper straight after publication, readers of the journal article wouldn't have known about them until a number of commentaries on the article appeared 6 months after its publication.

So, is peer review working? Yes, but it's facing many challenges. As the publishing landscape evolves, so will the diversity of peer-review models. It's possible that new organisations will be set up to offer peer-review services. A recent example is *Peerage of Science* (http://www.peerageofscience.org/), a Finnish company founded, owned and governed by scientists. There is the potential for considerable disruption in the scholarly publishing sector. To maintain a central position, publishers will need both to convince researchers of the value they bring and to innovate in ways that will help them be more productive, providing the tools they need to do this. Research funder-publisher partnerships will also be critical, and publishers need to be prepared for funders to require the work they fund to be publicly available. Publishers have to ask themselves the brutal questions: Can researchers survive without publishers? Can publishers survive without researchers?

. . . Can researchers survive without publishers? Can publishers survive without researchers? . . .

References

1 Hames I (2012) Peer review in a rapidly evolving publishing landscape, Chapter 2, *Academic and Professional Publishing,* Eds R Campbell, E Pentz and I Borthwick, Chandos Publishing (in production)

2 UK House of Commons Science and Technology Committee (2011) Peer review in scientific publications. Eighth Report of Session 2010-12, HC 856, The Stationery Office Limited, London. http://www.publications.parliament.uk/pa/cm201012/cmselect/cmsctech/856/856.pdf (Para 277)

3 Lock S (1985) *A Difficult Balance. Editorial peer review in medicine*, Introduction to third impression 1991, *BMJ* London, p.xi.

4 Fox J and Petchey O L (2010) Pubcreds: Fixing the Peer Review Process by "Privatizing" the Reviewer Commons. *Bulletin of the Ecological Society of America* **91**,325–333.

5 Elsevier (2011) Evidence given by Mayur Amin to the UK House of Commons Science and Technology Committee Inquiry into Peer Review, 11 May 2001. Transcript of oral evidence, HC 856, Q127. http://www.publications.parliament.uk/pa/cm201012/cmselect/cmsctech/856/856.pdf

6 Wolfe-Simon F, Blum J S, Kulp T R, et al. (2011) A bacterium that can grow by using arsenic instead of phosphorus. *Science* **332**, 1163-66.

7 Zimmer C (2011) The discovery of arsenic-based Twitter. How #arseniclife changed science. *Slate*, May 27, 2011. http://www.slate.com/id/2295724/

MATHEMATICS MATTERS – A CRUCIAL CONTRIBUTION TO THE COUNTRY'S ECONOMY

National Science and Engineering Week Seminar on Thursday 15th March

THE MATHEMATICAL SCIENCES LANDSCAPE IN THE UK

Professor Sir Adrian Smith
Director General, Knowledge and Innovation, Department of Business Innovation and Skills

As a mathematician in Government, I want to use my contribution to the P&SC *Mathematics Matters* seminar to highlight the Government's commitment to the subject (which is inseparable from its wider support for science and research). I also wanted to fly the flag for UK mathematical excellence – at the same time I sounded some warnings about the challenge to maintain this in the context of international developments and competition.

The evidence is there that Government as a whole gets the importance of mathematics and science: look at the Spending Review settlement and successive announcements of further capital funding since (Budgets, Autumn Statements etc). Neither is moral support for the growth of the subject lacking. In a recent speech at a British Academy conference on quantitative skills David Willetts stressed not only the increasing importance of statistical literacy for those studying non-STEM disciplines but also the value of mathematics to every one of us in our daily lives.

There are other reasons to be cheerful. We have seen a steady rise in the take-up of mathematics over the last 10 years at A Level – linked to which has been a corresponding growth in B plus grades. Entrants to final degrees show a similar trajectory.

These figures evidence the benefits of a sustained Government commitment to the subject but they also reflect another fact, borne out by the other speakers at this event and my own experience in teaching the subject for thirty years: in the fields of mathematics and science… *Britain Has Talent*.

Note our national research standing. With 3.9% of World Researchers and 3.0% of World Gross Expenditure on R&D (GERD) the UK delivers 6.4% of articles. These articles have 9.4% of article usage, gain 10.9% of citations and comprise 14.0% of the top 1% highly-cited articles. In terms international citation of UK articles on mathematics we vie with the US as a world leader and consistently surpass the lands of Descartes and Gauss.

But the same figures are both 'sweet and sour', revealing as they do in a context of increasing international competition that China is coming up fast.

When I was doing my PhD in statistics it was most unusual to see a Chinese name on a research paper; now it is most unusual to see a statistics journal without Chinese names, sometimes in the majority.

Yes, we ***can*** compete but I also believe that International co-operation is one way of responding to competition, forming partnerships with a global talent pool. It is happening already: 46% of UK papers in 2010 had an international co-author; higher than any other G8 or BRIC country except France. Papers with an international co-author achieve twice as many citations as those produced within a single institution, showing that collaboration drives up both quality and impact.

Mathematics is vital to the formation and operation of policy across Government, from health and education to defence and national security. While the climate of increasing competition and tight public funding means we must prioritise within our research portfolio, the importance of mathematics is assured.

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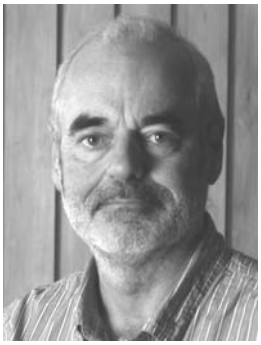
ASSESSING AND COMMUNICATING RISKS AND UNCERTAINTY



Professor David Spiegelhalter
Winton Professor of the Public Understanding of Risk, University of Cambridge

Every day we get exposed with messages about risk – the media love a good scare story. At our website understandinguncertainty.org we try to take apart some of these stories using maths. For example, a few weeks ago a study from Harvard on the dangers of eating red and processed meat got a lot of attention, with the Daily Express reporting that if we ate less meat *"10% of all death could be avoided"* – a truly remarkable claim revealing they had no idea what the study actually said. This was that a daily portion of red meat was associated with an increase in the *annual* risk of death by 13% over the period of the study. But even if this number were true – which can be disputed – what would this mean for life-long meat-eaters? Would it mean a 13% shorter life?

To check this we need to consult the life-tables produced by the Government Actuary and apply the 13% extra risk for each year of eating meat. This uses the mathematical statistical technique of 'survival analysis', and reveals that a 40 year-old man who eats a quarter-pounder burger for his working lunch each day can expect, on average, to live to 79, while his mate who avoids the burger can expect to live to 80.

Put this way, the lost year associated with the burger-stuffing does not sound too bad if, in the classic words of Kingsley Amis, self-denial means an extra year in a nursing home in Weston-super-Mare. But we can reframe the message in a more alarming way: over a lifetime habit, each daily portion of red meat is associated with about 30 minutes off your life expectancy – more than the time it takes to eat it – and around the same as 2 cigarettes or each day of being 5 Kg overweight. This idea of accelerating your daily ageing may be more persuasive to change behaviours.

Mathematical risk models are very widely used: in insurance and pensions, finance and economics, individualised risk assessments for heart attacks, health policy by NICE and for epidemics, weather and climate and associated hazards of flooding and so on. The National Risk Register produced by the Cabinet Office has become increasingly sophisticated and now publicly communicates the assessed numerical chances (except for security events) of various extreme scenarios over the next 5 years, such as severe space weather and Icelandic volcanic eruptions.

Making such assessments is tricky, and the NERC is now funding the PURE initiative that brings together mathematicians, statisticians and environmental scientists to develop risk models for natural hazards as well as appropriate means to communicate the results. One attractive metaphor for communication involves the idea of "possible futures", which can be based on *Monte Carlo* methods in which large numbers of possible future 'worlds' are simulated under slightly different conditions, and the proportion in which a particular extreme event happens reflects the chances of the event occurring. These techniques started in the US hydrogen bomb project, and the UK is now world-leading in theory, software and applications, including the use of 'ensembles' for weather forecasting. Unfortunately there is still a reluctance to communicate publicly the chances of different weather patterns, although in the US 'possible paths' of hurricanes are routinely shown on public news broadcasts.

The Bank of England is an organisation that has fully embraced the open communication of uncertainty about its forecasts, with its 'Fan Charts' expressing what might be expected *"If economic circumstances identical to today's were to prevail on 100 occasions …Consequently, GDP growth is expected to lie somewhere within the entire fan on 90 out of 100 occasions."* A central prediction line is deliberately not given for a week after the initial release of the fans, much to the annoyance of the press, who are prevented from declaring a single 'prediction' for growth and inflation.

All science is hedged with uncertainty, and when difficult policy decisions have to be made it is a tricky balance to be both upfront about uncertainty and retain trust. Nevertheless, when the Commons Science and Technology Select Committee examined *Scientific Advice and Evidence in Emergencies,* David Willetts – Minister for Universities and Science – said that *"Communicating the intrinsic uncertainties in scientific advice is something that we probably need to do better".*

Mathematical risk models are a vital tool in this process, but the financial crisis has shown that they should be accompanied by a warning: there are serious dangers if fancy mathematical tools are used by people who do not understand their limitations. The solution is both to invest in mathematics, and to make full use of the great expertise we have this in this country.

MATHEMATICS IN SECURITY AND INTELLIGENCE

Malcolm MacCallum
Director, Heilbronn Institute for Mathematical Research, Bristol

As the successor to the famous Bletchley Park, Government Communications Headquarters' (GCHQ) mission relates to national security, the economic wellbeing of the UK and support of the prevention or detection of serious crime, as set out in the Intelligence Services Act 1994.

The Heilbronn Institute is a partnership between GCHQ and Bristol University. It continues part of the Bletchley tradition – exploiting the skills of top-class UK academic mathematicians in GCHQ's service.

Part of GCHQ's role is providing advice and assistance about cryptography and other matters to protect UK information and other material (ie communications and data) from those who might wish to eavesdrop, steal, corrupt or deny access to it. Such security has become urgent with the 'cyber-security' challenge, arising from the global internet. The Foreign Secretary has spoken publicly about this, most recently at the London conference on cyberspace last year.

I can only use historical examples, but there are good modern parallels – indeed surprisingly many.

Secure transmission of financial information to websites (those starting with https://) relies on 'public key cryptography', first discovered at GCHQ. Its conceptual framework was due to James Ellis and the first implementation to Clifford Cocks, a new recruit from a postgraduate mathematics degree course, who invented the key idea in about 30 minutes. This was possible because of his good knowledge of relevant mathematics: the security depends on the quantifiable difficulty of factoring a product of two very large prime numbers. The transmission of your credit card details to secure web sites is made safe by mathematics (though this protection does not extend to other types of fraud).

The second example comes from Bletchley. Colossus, the first computer, was built to decode teleprinter messages between German Army HQs encrypted by Lorenz machines, codenamed Tunny. Tunny added a "key" to the unencoded input. From a 'depth' (two messages with related content and the same key) Colonel John Tiltman extracted 3976 characters of key. He gave it in autumn 1941 to Bill Tutte to analyse. Tutte was a Cambridge postgraduate chemist with an interest in mathematics and trained in cryptography. From the key, Tutte inferred the structure of the Tunny machine, although, unlike the famous Enigma, it had never been captured or seen.

This information was enough to enable much codebreaking. The mathematician Max Newman saw that mechanised methods were needed to do better. Tutte's second major invention was a statistical method of finding Tunny wheel settings directly from the coded message, and Newman had Colossus built to do this: Colossus was a special purpose cryptographic device, rather than a general purpose computer. The design, by Tommy Flowers of the Post Office, incorporated several novel features.

Tunny decryption was very important, although it gave many fewer messages than Enigma. It allowed us to forewarn the Russians of the German attack around Kursk in July 1943, decrypt messages direct from Hitler himself in 1944, know the German dispositions before D-Day, and assess the value of the Italian campaign in tying down German forces. The work of Tutte and Flowers was arguably an even greater achievement than that on Enigma.

Such work, then and now, depends on a vibrant research culture in mathematics in UK universities.

GCHQ applies the skills people bring: Turing, Newman, Tutte, Flowers and Cocks provide examples.

UK mathematics, especially pure mathematics, makes a major contribution to UK security and intelligence.

My colleagues and I intend to ensure this is considered in the forthcoming Research Excellence Framework.

It is the experience of solving mathematical research problems, being able to adapt that experience to new questions, and work in teams, which we need, and we exploit the variety and geographic spread of UK expertise. We therefore want to ensure that the difficulties highlighted in the article by Professors Glendinning and Brown (Science in Parliament 68 (4), 30) are overcome.

GCHQ and HIMR each put resources into supporting the desired UK research culture. For example, we part-sponsor various undergraduate and postgraduate events; employ undergraduate and postgraduate interns; fund targeted postgraduate studentships and postdoctoral fellowships; and sponsor academic workshops and conferences.

We want to enable talented UK students to progress into academia. Concerns include the impact of future funding structures, making UK postgraduate training rigorous enough to compete with the EU and US, and ensuring sufficient postdoctoral positions (which provide the vital bridge between postgraduate study and an academic career).

Ending by putting on my hat as President of the International Society on General Relativity and Gravitation, I was recently fascinated to see, on a Kent cereal farm, expensive equipment whose accurate use depended on the corrections from general relativity to the GPS (Satnav) system. Einstein in 1915 could not have foreseen this impact of mathematical physics, another area with endangered funding, on farming.

MATHEMATICS MATTERS

COUNTING CASES:
How does mathematics help us control infectious diseases?

Déirdre Hollingsworth
Junior Research Fellow, MRC Centre for Outbreak Analysis and Modelling, Department of Infectious Disease Epidemiology, Imperial College London

Infectious disease transmission is a dynamic process, resulting from a sequence of chance events. Infectious people make contact with people who are susceptible to the disease, whether through sharing a bus, making conversation or through more intimate contacts, and transmission occurs with a certain probability. The outbreak grows as more people become infected until eventually the number of people who haven't been infected becomes small and the epidemic runs out of steam. But how do we know how many cases to expect? How many people do we need to vaccinate to prevent an outbreak? If we can't prevent an outbreak, how should we use our resources to prevent the hospitals becoming overwhelmed? These crucial public health questions can only be addressed using mathematical methods and analyses.

Mathematical models are a way of rigorising our thoughts about infectious disease transmission, expressing the transmission process in a formal language. The development and analysis of models is ideally an interaction between clinicians, biologists, policy makers, statisticians and mathematicians. We can inform these models with the available data, using modern statistical methods, and extrapolate our insights to designing 'what-if' scenarios for policy.

Simple, yet powerful, insights can emerge from these mathematical constructs. For example, many core results in infectious disease epidemiology come from the concept of the basic reproductive number (R0), which is the mean number of new infections caused by a single infected individual in a wholly susceptible population (see figure). If individuals at the start of an epidemic infect on average more than one person ($R0>1$), then the epidemic will grow.

How does this help with designing control measures? In the case of vaccination, vaccinated individuals cannot be infected, and so the effective reproductive number in the presence of vaccination is lower than without vaccination (see figure). In fact, if p is the proportion of the population who are vaccinated, then on average the number of new infections which can be caused by a single infected individual is $(1-p)R0$. If the aim of the policy is to prevent an outbreak by vaccinating the population then the average new infections needs to be less than one, $(1-p)R0<1$. We can rearrange this expression to get the critical vaccination proportion $p_c>1-1/R0$. If the average number of new infections in an unvaccinated population is large, then the critical vaccination proportion is high (eg measles, which has an $R0>10$ and so more than 90% of the population need to be vaccinated to prevent transmission), whereas the critical fraction is smaller for a disease like smallpox with a $R0\sim4$, which facilitated the eradication of smallpox by vaccination. The most important insight in this analysis (most famously outlined by Karl Dietz in 1975) is that the whole population does not have to be vaccinated to control an outbreak of an infectious disease – ie the critical vaccination proportion is not 100%. This is because those who are unvaccinated are protected by the vaccination status of their contacts, which prevent infections which would otherwise be amongst their contacts (so called 'herd immunity').

Vaccination strategies are, of course, based on a more nuanced understanding of disease transmission and vaccine uptake than this scenario suggests. For example, an important consideration for a childhood vaccination programme is the likely impact on transmission between children and adults. More complex models, together with high quality data, are used to inform the details of policy in particular diseases.

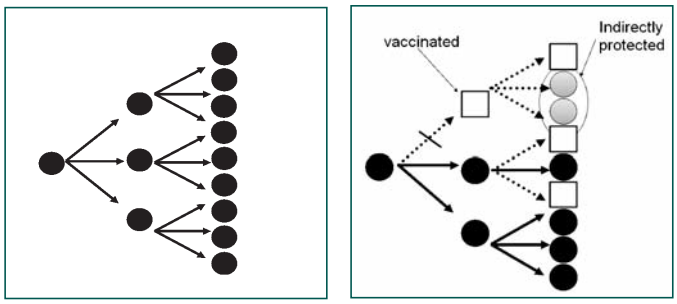


Figure legend
Infectious disease transmission occurs in a chain, with each infected individual infecting a number of others (in this schematic exactly 3 others, left figure, black circles). If vaccination is introduced (right figure, white squares) the average number of new infections drops (here the average is 2 when $4/13\sim\sim1/3$ of the population is vaccinated). The vaccinated people are not the only ones who are protected, there is indirect protection for a proportion of the population. This means that not everyone needs to be vaccinated to eradicate a disease (see text for more details).

There are many other forms of complexity which can be introduced. For diseases like malaria, which are spread by mosquitoes, our models take account of rainfall and ecology in local areas to estimate the impact of the use of bed-nets on transmission. For sexually transmitted diseases, explicit modelling of sexual contact networks may be required. Since the problems addressed within this field are so varied, the methodology we use comes from a number of mathematical research areas including probability, statistics, mechanics, ecology, network theory, enzyme kinetics and computation, from both long-standing results and current areas of active research.

All models have their limitations and the mathematicians who use them are all too aware of these frailties. The impact of uncertainties within the model and the data depends on the question being asked. Models can therefore rarely be used 'off-the-shelf' when addressing a new policy question without some understanding of these limitations and so expert users are required.

The UK is a world leader in the field of infectious disease modelling and in the interaction between modelling and public health policy. In recognition of this, the Medical Research Council Centre for Outbreak Analysis and Modelling, led by Professor Neil Ferguson OBE, has recently been designated the first World Health Organisation Collaborating Centre for infectious disease modelling. The success of the UK in this field is based on a history of using the most appropriate mathematical or statistical tool for the problem at hand, and as such is reliant on a rich supply of novel mathematical research.

MATHEMATICS MATTERS

MATHEMATICS OF INFORMATION

Professor Jared Tanner
Professor of Mathematics of Information, University of Edinburgh

The proliferation of computing and data processing has influenced the past two decades so fundamentally as to inspire the term 'Information Age'. Although collecting and analysing data has served for centuries as the bedrock of the scientific method, it is the introduction of computers that has elevated the scale of the data to that which we commonly process today. Mathematics, and in particular statistics, has always played a central role in the collection and analysis of data, with foundations laid by leading UK researchers such as Bayes, Pearson, and Fisher. The prevalence of large data sets and the great need for algorithms which can extract meaningful information has resulted in a resurgence of seemingly pure mathematics research engaging with statistical questions. Two such exemplary novel topics are compressed sensing and matrix completion.

The ease with which we digitally store multitudes of documents, as well as capture and transmit images and video, relies on the expectation that the data we are interested in can, in some way, be compressed to a much smaller representation. For instance, most documents are composed of relatively few different words, and most images are composed of few objects, each of which can normally be approximated by slowly varying colours. Nonetheless, we usually treat compression as a secondary process, to be performed only after painstakingly acquiring very detailed information, such as high-precision images. It is, obviously, highly inefficient to first carefully acquire information when it is known beforehand that only a compressed version will be retained as it contains the essential information. This suggests the question: can we acquire the desired essential information more efficiently by including compression into the measurement process? If so, such a method should allow for dramatically more efficient sensors of all sorts.

Remarkably, seemingly pure mathematics informs us that this is indeed possible, generating a paradigm shift in data acquisition. For instance, it is common in medical imaging that there is limited ability to acquire information; limitations range from the inability to hold one's breath longer than a short time during an MRI scan to limiting radiation exposure. Incorporating compression into the data acquisition process – known as compressed sensing – has resulted in seven times faster MRI scan rates. Mathematics has both inspired this approach and has proven its effectiveness.

Similar notions are also being applied to questions in the digital economy. The extraordinary quantity of information available has made search and recommendation software essential. For example, the success of online video rental companies is driven not just by the quantity of films available by a company, but also their ability to make recommendations to their customers. Mathematically this task corresponds to having a large spreadsheet of different customers and their film choices; however, the spreadsheet is largely empty as most customers have seen a tiny fraction of existing films. The company is tasked with predicting how customers would rank unseen films, and then using this information to make recommendations. This process is referred to as "matrix completion", and is closely connected to compressed sensing. Again, the success of this approach relies on the information having an underlying structure that is simple, which might correspond to there being relatively few types of film watching preferences.

The underpinning mathematical theory of compressed sensing and matrix completion follows directly from the following, apparently abstract, question. Consider a triangle with sides of equal length, a cube with all sides equal, or the object one gets when adjoining the bases of two pyramids; these are

examples of two and three dimensional objects known as Platonic solids. Mathematics allows us to define similar objects in an arbitrarily large dimension. However, only these three objects retain their structure in arbitrary dimensions, making them fundamental to the study of geometry. These objects have undergone intense investigation, including asking questions about which of their properties remain when these objects are 'randomly flattened'. These retained properties in this last question make possible the seven-fold faster MRI scan rates mentioned previously. Much of the foundational theory was developed in the UK, by geometers including: P McMullen, H Ruben, and G Shephard. These, and other, researchers developed the theory of randomly projected objects, and the formulae necessary to calculate when the needed properties would be retained, which now allow engineers to design the next generation of imaging protocols. Even more abstract, nonlinear, geometric questions underlying matrix completion are currently under intense investigation by UK mathematicians. Application inspired interactions bridging mathematics, informatics and statistics portend a wealth of new technological advances.

Presentation to Peter Simpson
Immediately after the Seminar Andrew Miller MP made a presentation to Peter Simpson who stood down as Scientific Secretary and Editor of Science in Parliament on 31st March. Andrew expressed the Committee's gratitude to Peter for all his hard work over the years.
Courtesy of Jonathan Tickner and the Council for the Mathematical Sciences

RECOGNISING THE ROLE OF TECHNICIANS

Jon Poole, Chief Executive IFST

The day-to-day running of the UK, as elsewhere in the world, is increasingly reliant on technology. The changing economic landscape, and increasingly global marketplace, has added even sharper focus to the critical role technical skills play in supporting all business sectors ... and it is no longer only an issue confined to engineering, manufacturing and science industries. Surprisingly, the largest growth in demand for technological skills is now seen in media & publishing, public administration, service and defence sectors.[1]

Although demand for technical skills in the UK is rapidly increasing, recruitment of people into technical roles is failing to keep pace. Today it is calculated that some 2 million people are employed in technician-based roles across all sectors of the economy within the UK.

For the UK to keep pace with demand and hold its competitive position, it is essential to recruit, train and retain technicians in greater numbers than in the past. We need around three pupils out of every senior school class opting for a career in technology. Not only that, there is also a need to encourage more women into technician-based roles.

Against this backdrop, in 2010, Lord Sainsbury brought together a group of interested parties to consider outputs from two White Papers[2] which considered the future needs for scientific and engineering skills. Following on from this, a new body – the Technician Council – was formed to address the underlying issues behind the skills shortage and to look into how a common framework for professional recognition could be provided across science, engineering, IT and health sectors.

This body, Chaired by Stephen Holliday, CEO of National Grid, was constituted of representatives from a wide range of stakeholders including the Science Council; Engineering Council; EngineeringUK; the National Apprenticeship Service; representatives from a number of individual professional bodies as well as key SET employers including Ministry of Defence; Microsoft; Lonza Biologics and BAE Systems.

The challenges facing the Technician Council and its constituent members were complex. Quantifying the numbers employed in technician-based roles was far from straightforward. Science and engineering companies employ many non-technical people and conversely, many technicians work in non-engineering or science based sectors such as food and retailing. Job titles themselves provide no help with the term 'technician' used indiscriminately – ironically often to add status to relatively non-technical roles.

A further challenge facing the Technician Council was the gender imbalance. Women make up 49% of the economically active workforce in the UK, however they remain significantly under-represented at every level in SET employment (Science, Engineering & Technology) – and in higher levels of STEM

education (Science, Technology, Engineering & Maths).[3]

Providing job mobility for technicians across all sectors was one of the key principles which the Technician Council needed to incorporate. More people will be attracted to technical roles if they can see that the roles can bring with them flexibility and the potential for transferability. If employers are able to recognise those with the requisite technical and softer skills (which are often very transferable) through professional recognition they will have more confidence when employing technicians.

Research conducted by the Science Council[4] highlighted that many technicians feel that while they do have a professional identity, this identity is not well developed – indeed, most would not describe themselves as 'professionals'. The same research also identified that a formal framework for professional recognition was desirable, firstly in terms of gaining respect from other work colleagues, but also because of the clearer career opportunities and pathways that such recognition might provide.

March 26 saw the first phase of work by the Technician Council culminate in a high profile launch event, attended by senior people from industry, science and technology, Government officials and the media. At this event, the Technician Council unveiled the results of its 18 month review into the gap in technical skills provision in the UK, and presented their recommendations.

The problems relating to the professional recognition of technicians may be complex but the potential benefits are expected to be significant.

Employers benefit from recruiting and retaining more highly skilled and motivated technical people. They will also find there is greater transparency in the recruitment process given that professional recognition of technicians is expected to become a 'shorthand' for high quality skilled practitioners.

Technicians themselves clearly benefit from greater respect; the opportunity for more focused development and the prospect of enhanced career mobility and prospects.

The UK economy will benefit because providing professional recognition for people working in technical roles raises their standing; can provide clearer career paths and will so attract talent into these much-needed technical roles.

What has become clear is that there is already a great appetite from significant numbers of employers, educational-based organisations and other interested bodies such as Sector Skills Councils, unions and trade bodies for the proper recognition of technicians.

In the case of my own sector, the food sector, the Institute of Food Science & Technology (IFST) recognises the huge potential presented through professional recognition of technicians. The food sector, from farm to fork, employs around 117,000 skilled individuals who use some element of science within their roles – whether in quality assurance; food inspection and safety; plant or animal breeding or further along the food production chain within retailing and logistics.

IFST is pleased to have been granted a licence from the Science Council along with six other pilot bodies to offer Registered Science Technician (RSciTech) registration. We believe that offering this new form of professional status can encourage food technicians to focus on enhancing their skills through continuing professional development, and so improve the quality and safety of food produced in the UK.

The launch by the Technician Council is merely the end of the first phase. The next phase will see the translation of the initial groundwork into a viable and vibrant form of recognition.

The Technician Council has been 'signing up' employers and other supporting bodies who are prepared to commit formally and publicly to support the future vision for technicians. Those institutions looking to open their doors to professional recognition of technicians are also looking carefully at the future support and services that they need to provide those involved in technical roles to ensure that they are truly relevant to the next generation of technicians.

What is needed now is for everyone who can provide support – whether in Government, education, academe, but especially employers, to acknowledge and celebrate the contribution technicians make to their businesses and to the UK economy.

To find out more about professional recognition for technicians, the future plans for the Technician Council and to see how you can support this important programme, please visit the website:

www.techniciancouncil.org

References

1 ONS Labour Force Survey 2009

2 Skills for Growth: The National Skills Strategy (BIS 2009) and Skills for Sustainable Growth (BIS 2010).

3 UKRC's Guide (2010)

4 Science Council, Science Technicians in the Workforce, 2011

A GLIMPSE OF THE FUTURE?

This article is based on a Cumberland initiative working paper and is published in a similar form elsewhere. The simulation in Figure 1 was performed under MATCH, funded by the EPSRC.

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It's Friday evening at the Emergency Department – the ED – in the city centre, and things are getting busy. At the heart of the hive are a dozen comfortable cubicles surrounding the nerve centre, a place to which ED staff return repeatedly throughout the evening, updating notes, putting up new names or removing the names of patients who have been discharged or admitted to the main hospital.

And each of them glances from time to time at the wall-mounted display showing a set of predictions. Unlike the ubiquitous satnav predicting arrival time, this system keeps estimating how long the patients will be in the Department tonight. Back in the noughties, before such systems were popular, a wait of more than four hours meant the ED had breached the metrics. Now, the display goes amber as soon as the average predicted stay exceeds 90 minutes, and red highlights identify patients who are heading for the two hour mark. Later this evening it will go amber again, and the Consultant in charge will spend five minutes running three pre-set scenarios through the model, including the option of redirecting some of the anticipated demand, before choosing how best to manage the crisis that will not happen tonight. It has been six months since any patient stayed for more than 2½ hours.

Smooth throughput needs to be blockage-free, so tonight patients will not wait for a bed. As each arrived, a sophisticated software system was already sifting through records and GP-generated predictions, capturing the provisional diagnoses of the consultant-led front-of-Department team and feeding this information into the model that drove the prediction-display on the wall. But the system also uses this knowledge to signal forward to the wards, and, sometimes, to other care services, about the likely admissions and discharges over the next few hours. These systems cannot say exactly who will be admitted tonight, but they have become uncannily good at getting the averages right.

The GP-generated predictions have also been a great success. Two hours ago, every feeder practice submitted its estimate of how many people in its catchment were likely to pitch up as emergency admissions every day for the next nine days. To begin with, these estimates had been haphazard, but it had not taken long for the main risks to be pinned down – the weather forecast (especially cold snaps), the demographics (the very young and the very elderly are higher users of services), diseases such as diabetes (with its associated morbidity), and risk factors such as alcohol consumption (with its link to violence) – and now EDs have been planning with confidence for a decade. Together with a few sports injuries and other accidents, there was now a robust map of what the evening might look like. Again, there were always exceptions, but now there was more resource left over to manage those carefully.

In fact, everywhere you look this Friday evening, predictors buried deep in the system are gathering data and signalling silently to other parts of the system. Seemingly magically, resources have been ready when needed – 98.7% of the time, according to the display on the wall this evening. Wards are estimating the length of patient stays to the hour, and scheduling transport services, alerting social services and managers of intermediate care to emerging demand, and texting friends and relatives with updates on when to expect people home.

Two decades ago, people had been really worried about the European Working Time Directive and the loss of resource it represented as Junior Doctors and others had to cut their on-call hours. Today, in 2030, the NHS delivers more and better care than ever before, and the number of staff has stabilised well below 2010 levels. As well as cutting costs dramatically, the NHS has more well-paid jobs and three-quarters of the workforce now choose their working hours through an on-line negotiating service.

Will it take until 2030 to deliver such a service? Well, by 2030, care will have to look very different – we simply will not have the staff to manage burgeoning demand. Most of the indicators are that we are travelling in the direction of using data intelligently to predict and manage demand – the key question is how fast? Can we bring the clock forward and have most of this in place before 2020?

The answer is that almost all the technology needed has already been developed in some form and has been used successfully somewhere. Figure 1, for instance, came from a simulation performed in our group by Dr Julie Eatock. It shows admissions to an urban ED (blue) averaged over 4 weeks. In red is the likelihood of breaching the 4-hour limit – until recently a national standard – estimated as each new patient arrives. Such a model, if implemented in real time, would give staff up to 4 hours to avoid breaching.

Increasingly, doctors, nurses and healthcare managers are turning to models and simulations to get a handle on care management. Stockport PCT noted a rise in GP referrals to hospital after the introduction of the new 'free choice' system for patients. Scenario Generator, a modelling package, was used to trace and analyse the routes – or pathways – patients were choosing and the management team found a way to ensure that 97% of patients received an appointment within 28 days and

that nobody waited for more than 37 (mashnet.info/case study/stockport-pct-%e2%80%93-understanding-demand capacity-and-waiting-times/).

Meanwhile, Dr Julie Hankin, a Consultant Psychiatrist and Clinical Director for service improvement, writes, "Mental health is affected by education, the criminal justice system, by employment and a host of other factors. If one can build these variables into models of mental health care, then one can performance-manage outcomes and not simply simulate service delivery. More practically, in the short term, modelling allows you to look across health and social services and see the impact of different commitments at various points in the patient pathway. It can really help us to optimise the positioning of resources and see, in advance, the knock-on effects of the changes we want to make. This is not a pipe dream. Lots of businesses use modelling very effectively. There is no reason why we cannot make it work for mental health services" (http://www.cumberland-initiative.org/2012/02/21/planning-mental-health-services-using-simulation-and-modelling/).

While not yet connected to patient notes, great strides are being taken to risk-stratify patients, especially those with long-term conditions, such as diabetes or physical impairment.

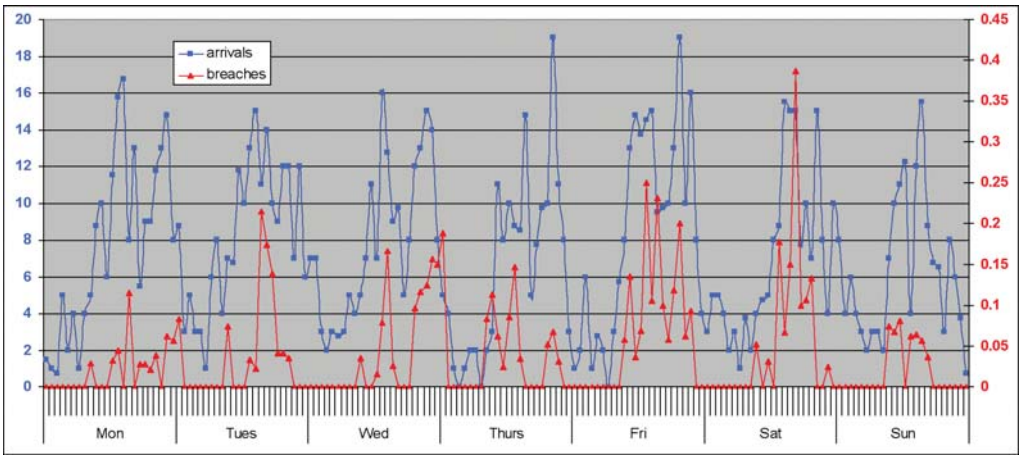


Figure 1 Simulation of arrivals and breaches at an ED

The SHIP cluster (http://hampshire.nhs.uk/component/content/article/60-corporate/780-ship-pct-cluster-takes-shape) will need to commission nearly £3 billion of care each year. To do this, it has brought together a range of tools from sources as diverse as the Johns Hopkins Bloomberg School of Public Health, McKesson and Experian, to predict and then procure the care that is needed.

Figure 2 shows a control room in Tan Tock Seng Hospital, Singapore, a concept that is starting to catch on in large hospital Trusts here. The big question is, what are the knowledge systems that will manage the flows behind the displays?

These examples establish a direction and there is a new generation of doctors coming through who will re-wire their world. What is needed now to help them is a systematic push to integrate this together and apply it across the nation. This will mean drawing our knowledge companies into healthcare in a new way. In a sense, the Connecting for Health debacle may unfortunately have inoculated the NHS against the information disease. Everyone has had just enough of IT-driven change to build up the antibodies. But what if we caught the 'knowledge' disease in the NHS big time?


Figure 2 Photograph provided by Professor Sally Brailsford, Southampton University

Of course, it is not just about scaling up. We know that adding extra lanes to our motorways rarely eases congestion and often makes it worse. The reason is that the motorway is only a part of a complex social system of people and work and families and school and home and football and weddings, and funerals and shopping, and ... the list is endless. Changing one part of that system changes the choices we have and we adjust our behaviour accordingly. Often the net effect is to take things back to where they were, sometimes to make things worse. In the past half century, we have come to understand quite a lot about systems and the perplexing responses we get to the changes we implement. Jay Forrester, a seminal thinker in this field, pointed out that when things become very complex, you must either try to hold all the variables in your mind – a mental model – or you need to find a computational way to manage the problems. Models and computer simulation are a way of managing the complexity when our ability to foresee all the unintended consequences runs out.

Other sectors have used these methods to great advantage. We now make better cars more profitably – and more of them – than ever before. The grocery giants have shown what can be done by detailed analysis of their supply chains – fresher food, more choice, and, of course, a vastly more profitable sector.

The Cumberland Initiative (www.cumberland-initiative.org) is an attempt by a group of research academics with strong healthcare credentials, working with clinicians and knowledge companies, to bring this vision into reality. We understand that the vision is almost too great to be taken seriously. We also know that, in time, the system will get there on its own.

So what is it worth to bring the future a decade closer? And what is the biggest barrier to this level of change? Well, it is us. As Henry Ford is reported to have said "Whether you think that you can, or that you can't, you are usually right."

INSPIRING STUDENTS INTO STEM CAREERS

Dr Gordon Mizner
Chief Executive, EDT

Writing in the Autumn 2011 edition of Science in Parliament Andrew Miller MP, Chairman of the Parliamentary and Scientific Committee, highlighted the danger of future shortages of qualified scientists and noted the need for school students to get practical experience of science subjects if the UK is to supply the anticipated need. Dr Gordon Mizner, Chief Executive of education charity EDT backs up this thought by recommending that properly resourced education/business links is the solution to future shortages of scientists and engineers.

THE DEMOGRAPHIC PROBLEM

Andrew Miller highlighted the findings of the Science Council that there are 5.8 million people (20% of the UK workforce) employed in science based roles. To keep pace with the needs of industry this needs to rise to 7.1 million people by 2030. This means that we will need many more people with these skills and qualifications coming into the workforce, over and above those required to replace those leaving through retirement or changes in careers. There is a similar situation in the engineering industries. At the EDT we hold discussions with numerous companies and other organisations in the science and engineering industries. It is already clear that there are skills shortages in many disciplines.

The demographics of the UK make this even more of a challenge as the age profile of the population means that large numbers of skilled workers are nearing retirement age. At the same time the number of 18 year olds leaving school will decline over the next ten years. This means that we need a significant increase in the proportion of school leavers pursuing science and engineering careers to meet the needs of the UK's core industries.

THE PERCEPTION PROBLEM

EDT is deeply rooted in encouraging science, technology, engineering, and maths (STEM) subjects in schools. A large part of the problem in getting more young people interested in STEM subjects, and then following through into STEM related jobs, relates to perceptions developed early. These perceptions may derive from parents, teachers, friends or exposure to media stereotypes. They are well established early in a school career. As a general rule, young people going into secondary education have poor perceptions about engineering and applied sciences as a job or career, and an even poorer understanding of the actual jobs and careers undertaken in modern business.

This lack of knowledge and associated adverse perceptions militates against the increases in uptake which are required to fill the vacancies in these sectors. This means that students are not being prepared to match the jobs that are going to be available. It also means that our core industries will not be able to source the talent they require in the UK so that there is a risk that these industries will be forced to base themselves elsewhere. A double negative for the UK economy.

EDT undertakes research into perceptions of pupils aged between 12 and 14, and their understanding of particular jobs is enlightening. When asked to nominate 5 attributes of a particular role the pupils' responses centred on ideas that Engineers – have dirty hands (41%) repair cars (43%) and wear overalls (34%). Scientists – are clever (73%) wear white coats (42%) and wear glasses (19%). Students have a perception which fits into a stereotype of these jobs without any real idea of what the roles involve.

Our observations have recently been supported by the Education and Employers Task Force in research they have published into the career prospects and aspirations of children at school. The research concluded that there was "strong evidence that there is a misalignment between the career aspirations of many young people and real job prospects". The report pointed to research into the occupational preferences of Year 7 pupils mapped against actual jobs by sector in the UK which shows that "nearly one half of respondents aspired to occupations actually undertaken by one in twenty of the working population."

There is a serious problem with the perceptions and aspirations of pupils as they come into secondary education. Interventions need to be found which will guide pupils into viable careers. From the point of

view of the future health of our core science, technology and engineering industries it is important that these interventions guide a significant proportion into STEM careers.

CHANGING PERCEPTIONS

Fortunately there is evidence that the perception of students can be changed. EDT's perception research is taken before and after an experience of a business-related science or engineering project experience. The figures quoted above are 'before'. The 'after' figures show a much better understanding of the realities of the role.

The research by the Education and Employers Task Force shows "compelling evidence that young people are especially attentive and trusting of first-hand information about jobs and career pathways received from employers". They also note that "countries with greatest success in dealing with youth unemployment typically include extensive workplace exposure within education programmes".

All the evidence suggests that if caught at an early stage it is quite possible without too much resource to improve significantly a secondary school student's perceptions of science and engineering careers by engaging them with a real business problem or environment and giving them exposure to role models who can inform them of the reality of STEM jobs and careers. It is important that such intervention comes early in their school careers because GCSE (or Scottish equivalent) choices are often the point at which many students wave goodbye to the option of a STEM career without even having considered it properly.

In order to achieve widened participation we have to do more to inspire and generate interest among those who would not naturally seek out information about STEM opportunities. This means providing events and activities that enable real experiences and contact with role models; 'seeing it in action', 'hands on'. Finding the time and resource within schools for this to take place is crucial, and encouragement to make this time and resource available will need to come from government.

PROVIDING EXPERIENCES

However, including enrichment activities in the school curriculum is only one half of the problem. The other half is providing the experiences; provision of the projects that engage and the role models that inspire. Organisations like EDT can provide the infrastructure to co-ordinate the work, but the real contact can only be provided by the STEM industries themselves, committing resources of manpower and finance to inspire the next generation of scientists and engineers which will be their workforce.

We have found that enlightened companies are willing to put resource into partnering with EDT to deliver enrichment experiences that inform and inspire school students into a STEM career. We work with industry leaders such as Rolls Royce, Eon, BP, and Astra Zeneca and many others in delivering such experiences.

We tailor a partnership to the needs of the companies. Typical is our relationship with SELEX Galileo, a leader in defence electronics. SELEX Galileo recognises the importance of an outreach programme to assist in recruitment. It works with EDT to take a dynamic approach to engaging with the schools in its local areas. As well as the benefits to the schools and students outlined above, SELEX Galileo has found that providing mentoring activity for the students is important to staff development. The EDT schemes provide the opportunity for new graduate recruits and apprentices to mentor the school teams, giving them excellent CPD experiences and developing their confidence.

SELEX Galileo is one of many committed companies and EDT is currently providing STEM enrichment experiences for upwards of 25,000 students each year. However, there is much more to do. We are making progress on increasing the proportion of girls on the programmes but there is a wider task in engaging the 'harder to reach' schools. This is a resource challenge because sustaining relationships with such schools is difficult, but there is enormous scope to include many more schools.

THE CHALLENGE AND THE SOLUTION

The challenge we face is stark. Unless significant effort is made to inform and inspire students into STEM careers early in their secondary school careers, we will not have sufficient qualified people to supply the jobs in STEM industries which the UK can provide. The flip side of this is that, if we don't inform and inspire students into STEM jobs, a proportion are likely to end up with qualifications which don't fit the available job market, leaving them unemployed and disillusioned.

The good news is that we know the solution to this challenge. Exposing students to real work problems and environments and enabling them to engage with appropriate role models will modify their false perceptions and inspire them to engage in STEM careers with jobs that are needed and well rewarded.

We can see the challenge, we know the solution – what is needed is for government and industry to work out how best to implement that solution. There is little time for procrastination.

SET FOR BRITAIN

On Monday 12th March SET for BRITAIN 2012 was held in the House of Commons Terrace Marquee. Andrew Miller MP, Chairman of the Parliamentary and Scientific Committee, acted as host to 180 early-career researchers who brought their posters to Westminster to take part in the competition and to show their research to Members of both Houses of Parliament, 90 of whom attended.

The competition was divided into three sections: Biological and Biomedical Sciences, Physical Sciences (Chemistry and Physics) and Engineering. The posters in each section were judged by panels of experts from the Society of Biology, The Physiological Society, the Royal Society of Chemistry, the Institute of Physics and the Royal Academy of Engineering.

Medals were awarded to the winners of each session, together with Gold, Silver and Bronze Awards of cash prizes. These awards were made possible by generous donations from BP, EADS, Airbus, AgChemAccess, the Institution of Engineering and Technology, the Institute of Biomedical Science, Oxford Instruments, GE Hitachi and the Wellcome Trust.

The final award was the Westminster Medal, donated by the SCI in memory of Dr Eric Wharton, who founded SET for BRITAIN and, with his wife Sue, ran the events for many years. The winners of the four Gold awards were judged on the strength of their skill in communicating the scientific concept in their poster by Sir John Beddington, Government Chief Scientific Adviser, Lord Krebs and Andrew Miller MP, Chairmen of the Science and Technology Select Committees in both Houses of Parliament.

PRIZE WINNERS

Biological and Biomedical Sciences

Gold Award: £3,000 and the GW Mendel Medal: **Mr Nicholas Love**, Faculty of Life Sciences, University of Manchester: HYDROGEN PEROXIDE AS A NOVEL AND NECESSARY REGULATOR OF APPENDAGE REGENERATION

Silver Award: £2,000: **Miss Renata Gomes**, Physiology, Anatomy and Genetics, University of Oxford: NANOPARTICLES FOR SIMULTANEOUS MRI TRACKING AND MICRORNA DELIVERY

Biology Prizewinners
Prizewinners in the Biology session with Dr Philip Wright, The Physiological Society, Dr Stephen Benn and Dr Mark Downs, Society of Biology, Andrew Miller MP and Jill Rodney, Institute of Biomedical Science.

Engineering Gold
Jeannette Heiligers, winner of the Engineering Gold award, with Neil Scott, Airbus, and Sir John Parker, Royal Academy of Engineering.

Engineering Silver
Dr Simon Leigh with Ben Rudd, Institution of Engineering and Technology, and Sir John Parker, Royal Academy of Engineering.

Engineering Bronze
Jonathan Dewsbury with David Powell, GE Hitachi, and Sir John Parker, Royal Academy of Engineering.

Physical Sciences Group Winners
Winners in the Physical Sciences session with Lynn Shepherd, Oxford Instruments, Gary Phillips, AgChemAccess, Dr Stephen Benn, Andrew Miller MP, Professor Sir Peter Knight, Institute of Physics, Dr Ellen Williams, BP, and Professor David Phillips, Royal Society of Chemistry.

Bronze Award: £1,000: **Dr Christopher Burt**, Disease and Stress Biology, John Innes Centre, Norwich: EYESPOT DISEASE OF WHEAT: PROBLEM SOLVED?

Physical Sciences (Chemistry and Physics)

Chemistry

Gold Award: £3,000 and Roscoe Medal: **Dr Matthew Powner**, Department of Chemistry, University College London: THE CHEMICAL ORIGINS OF LIFE

Silver Award: £2,000: **Miss Laura Davies**, School of Chemistry, Newcastle University: TAMING A FUNCTIONAL GROUP: THE FIRST AIR-STABLE FLUORESCENT PRIMARY PHOSPHINES AND THEIR APPLICATIONS IN DISEASE IMAGING

Bronze Award: £1,000: **Mr Alessandro Poma**, Cranfield Biotechnology Centre, Cranfield University: SOLID-PHASE SYNTHESIS OF MOLECULARLY IMPRINTED NANOPARTICLES ("PLASTIC ANTIBODIES")

Physics

Gold Award: £3,000 and Cavendish Medal: **Dr Kevin O'Keeffe**, Department of Physics, University of Oxford: QUASI-PHASE-MATCHED HIGH HARMONIC GENERATION

Silver Award: £2,000: **Miss Hannah Arnold**, Department of Physics, University of Oxford: RELIABLY PREDICTING UNCERTAINTY IN WEATHER AND CLIMATE FORECASTS

Bronze Award: £1,000: **Dr Daniel Elford**, Department of Physics, Loughborough University: NOVEL NOISE BARRIER TECHNOLOGY

Engineering

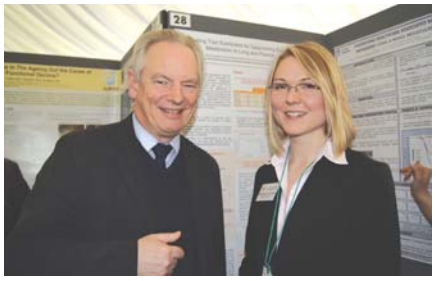
Gold Award: £3,000 and Engineering Medal: **Miss Jeannette Heiligers**, Mechanical and Aerospace Engineering, University of Strathclyde: POLE-SITTER SPACECRAFT FOR EARTH OBSERVATION

Silver Award: £2,000: **Dr Simon Leigh**, School of Engineering, University of Warwick: 'CLICK TO MANUFACTURE' SENSORS AND ELECTRONICS

Bronze Award: £1,000: **Mr Jonathan Dewsbury**, Ground Engineering, Buro Happold Ltd Bath/University of Southampton: RE-USING FOUNDATIONS

Westminster Medal in memory of Dr Eric Wharton (overall winner):

Mr Nicholas Love, Faculty of Life Sciences, University of Manchester: HYDROGEN PEROXIDE AS A NOVEL AND NECESSARY REGULATOR OF APPENDAGE REGENERATION

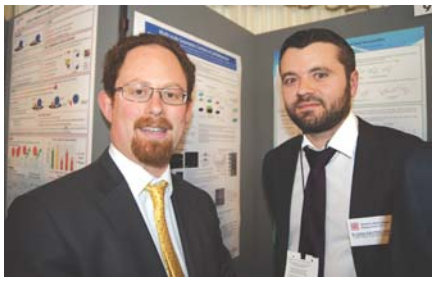


Francis Maude MP and Eleanor Knight

Julie Hilling MP, Thomas Benians & Hilary Benn MP

Mark Field MP & Dan Credgington

Lilian Greenwood MP, Kim Hardie, Dina Lary



Julian Huppert with Julien Gautrot

Sue Wharton presenting the Westminster medal to Nicholas Love

Chi Onwura MP & Alexander Nicholson

Gold award winners from all sections with the Westminster Medal judges, winners in the Engineering section, Sue Wharton and other members of the organising team.

THE QUEEN ELIZABETH PRIZE FOR ENGINEERING

Anji Hunter, QE Prize Director

From large-scale power and water infrastructure to the nanotechnology and bioengineering that are beginning to enhance our daily lives, the products of engineering are ubiquitous in modern society. This makes it a subject of huge importance to the economy, and to humanity as a whole. Yet, we take much of this for granted. It is time engineering is acknowledged not only for its contributions to improving our quality of life but the contribution that investment in technology and engineering projects makes to growth. In 2009, UK industry contributed 21% of the country's GDP. UK engineering is highly successful, and it is vital that it maintains its competitive position.

Encouraging young people to study engineering is therefore essential. Although the number has started to increase, engineering students still only account for around 6% of the student population. An engineering career needs to appeal to more women; currently women make up only 8% of the engineers in the UK, the lowest number in Europe. Engineering industries are huge employers and ensuring that we have enough engineering graduates to meet the demand is essential; it is estimated that over the next 10 years, we will need 2 million new engineering recruits to remain competitive

The Queen Elizabeth Prize for Engineering (QEPrize) is a new international award of £1m, for up to three individuals responsible for a pioneering advance in engineering that is of benefit to humanity. It has been established by the Queen Elizabeth Prize for Engineering Foundation, chaired by Lord Browne of Madingley. The prize will be awarded biennially and is being generously funded by donations from leading engineering companies: BAE Systems, BG Group, BP, GSK, Jaguar Land Rover, National Grid, Shell UK Ltd, Siemens UK, Sony, Tata Consultancy Services, Tata Steel Europe and Toshiba. The support of these multinational companies highlights not only the prestige of the award but also its global reach.

Media reaction to the prize has been wholly positive, with coverage stretching across the world, from the USA to Korea. The prize is stimulating a significant amount of discussion about how the public, and young people especially, perceive engineering. One conclusion is that societal development hinges to a large extent on advances in engineering, whether through innovative medical techniques or improved communications systems. The engineering press and industry are behind the prize and much debate and enthusiasm have been sparked in the engineering community. Nevertheless, appreciation of engineering remains low and raising this level is one of the key objectives of the Prize.

The QEPrize was launched officially on 17 November 2011 at the Science Museum in London and was attended by the leaders of the three major political parties. David Cameron, Nick Clegg and Ed Miliband all signalled their support for the prize and spoke of the need for engineering to be promoted both in the UK and internationally. The Prime Minister expressed hope that this "magnificent new prize" would eventually achieve the same stature and recognition as the Nobel Prize, stating that "it is a chance to celebrate our great pioneers and those committed to change our world for the better". Cross-party support in thinking about engineering policy is crucial to the development of the economy and it is encouraging that the QE Prize is helping to place it more firmly on the radar of parliamentarians.

At the end of February, in a worldwide campaign, the website was launched, nominations opened and membership of the Judging Panel was announced. The panel is chaired by Lord Broers, who sits on the Lords Science and Technology Committee, and comprises leading figures from the international engineering community including Professor Shih, President of the King Abdullah University of Saudi Arabia, Diane Greene, a Director at Google, Professor Brian Cox of CERN and Madam Deng, Chief Executive Secretary of the China Association for Science and Technology. The prestigious panel reflects the diversity and reach of the prize, bringing business and academia together, to inspire interest in engineering globally.

The search for a winner has begun and the QEPrize team is developing media opportunities and designing activities that will engage the public, and young people in particular, in the promotion of engineering across the world.

The inaugural prize will be awarded by the Queen in Spring 2013. In the interim, the Olympics will be a major platform for great feats of engineering, from the stadia to the sports equipment to the infrastructure. Engineering in communications, technology and medicine will continue to grow.

With the announcement of the first award, the QEPrize will be on its way to securing a lasting legacy of engineering.

For more information on the prize, please visit www.qeprize.org

> . . . it is time engineering is acknowledged for its contributions to improving our quality of life. . .

SCIENCE IN THE CLASSROOM:
The School of the Future

Dr Ellie Dommett
Brain and Behavioural Sciences,
The Open University

Since its inception in 2006, the All-Party Parliamentary Group (APPG) on Scientific Research in Learning and Education has heard about a number of issues but underlying these has been the need to translate scientific research relevant to education into the classroom. The group recently held a discussion forum to look at what a school of the future might look like in terms of use of scientific research.

The meeting was chaired by Baroness Greenfield and heard from four experts in the field of education. Opening the meeting were Professor David Reynolds, of Southampton University, a world-leading expert on teacher effectiveness, and Dr Paul Kelley, Headteacher of the innovative Monkseaton High School. Professor Reynolds began by stating that although education has undergone a series of changes, its rate of change is not as fast as many areas surrounding it and the dominant mode of teaching; one teacher to thirty pupils, has largely remained unchanged. He suggested that there is a number of reasons for this, not least the lack of applied research; with teacher effectiveness research, for example, being less prominent than research into the history of education. Additionally, he stated that the dominant model in education is one of apprenticeship with the pupils learning from the teacher and not an empirical model. A school of the future would involve shared databases, where schools could test ideas and create new thinking and communicate this thinking more widely. Critically, he suggested it was important to engage with mixed research methods ranging from action research to randomised controlled trials. Kelley then described some of the innovative practices implemented at Monkseaton High School. These included shifting the start of the school day back to 10am to fit better with the circadian rhythms of pupils and prevent some of the consequences of sleep deprivation hitting the classroom, including increased irritability, increased anxiety and decreased immunity. He also described the use of Spaced Learning in the classroom and suggested that outcome measures had shown clear improvement in pupils.

The meeting then heard from Dr Paul Howard-Jones, of Bristol University, about how gaming can be used in the classroom to support learning. Howard-Jones described the effects of computer gaming on the brain and, in particular, the effects on the mesolimbic dopamine pathway, which is implicated in motivational behaviours such as eating and sex. He described scientific research that showed dopamine levels increased the most in situations of uncertainty and that this dopamine response was indicative of the level of learning. He suggested that for science like this to impact on education three things needed to occur. Firstly, more research had to be done in areas relevant to education and this will require a dialogue to establish what is relevant. Secondly, studies needed to occur to check that effects found in the laboratory could be seen in the classroom. Finally, practice-based studies are needed, which merge with the teachers and therefore take advantage of their expertise. Howard-Jones then went on to describe how these three levels of testing had been used to develop gaming technologies in the classroom.

The final speaker for the meeting was Richard Churches, Principal Consultant for Learning and Teaching with the CfBT. He suggested that the problem so far has been a gulf in research methods between fields such as neuroscience and education, with the contrast between action research and controlled trials. He believed that it is possible to find suitable measures and control conditions for education research and therefore this way of thinking should be entertained. Finally he compared the current situation with the ideal future and suggested that we need to move from the politically driven approach that swings from pole to pole to a diagnosis and treatment approach. In terms of research methods, he felt that education needs to shift from being a one-trick pony using action research only to using a variety of methods, perhaps with schools combining in their efforts.

A lively discussion followed the presentations and it was clear that all speakers agreed that education can benefit from engaging with science and with scientific method and therefore as we look to the future we not only need to think "What" we should be investigating in education but also "How" and collaboration is likely to be a key factor in further development effective classroom strategies.

> . . . education can benefit from engaging with science and with scientific method . . .

Dr Dommett has asked us to point out that in her last article (vol 68 no 2 p 45) she should have referred to Dr Lauren **Stewart**, not to Dr Lauren Scott.

INTRODUCTION TO PAPERS ON GROUND ENGINEERING

Keith Gabriel
Past Chairman of The Ground Forum
Director, Gabriel GeoConsulting Ltd

Do we need to be able to maintain the UK's transport infrastructure?

Do we want to be able to adapt the UK's flood defences and other infrastructure to meet the climate change challenge?

Do we need to be able to dispose of our nuclear waste safely underground?

Do we want to improve the energy efficiency of the foundation systems for offshore wind farms?

The answer to all these questions is, of course, yes. Skilled ground engineering professionals are essential for all these activities, and for many others which the nation relies on to construct and maintain our built environment and infrastructure. However ground engineering professionals need post graduate degrees that neither they nor the industry can afford.

At the meeting of the Parliamentary and Scientific Committee (P&SC) on 28th February 2012 four presentations were given concerning the substantial contribution of ground engineering to the UK's infrastructure and the significant shortage of locally-based ground engineers in the UK which, despite the recent downturn in construction, is likely to get worse.

These papers include the presentations from that meeting. The concluding paper considers in more detail the nature and causes of the skills shortage in ground engineering, describes a recent initiative by the Ground Forum[1] to improve coordination between industry and academia and presents possible solutions to the current skills shortage.

WHAT IS GROUND ENGINEERING?

Ground engineering is defined by the Ground Forum as "An understanding of geological structures, materials and processes, combined with the systematic application of investigative, scientific and mathematical techniques to produce practical solutions to ground-related problems for the benefit of society".

All buildings and civil engineering structures are supported by the ground or are constructed underground so it follows that ground engineering is essential to the built environment, including all forms of infrastructure. Ground engineers provide advice, undertake design and supervise construction in a range of activities that involve the ground.

These include foundations (for buildings, bridges, wind farms, power stations, etc); retaining walls; tunnels and pipejacks; earthworks, including embankments and cuttings for roads and railways; port and harbour developments; and underground storage facilities for gas and nuclear waste. Ground engineers also undertake design and maintenance of reservoirs and landfill sites.

Even when no buildings or rigid structures are involved ground engineering plays an important role: coastal defences, flood control embankments, remediation of contaminated land, landslide mitigation, renewable energy (ground source heat pumps and geothermal), and recycling of materials to protect natural resources – all require people with an understanding of both geology and engineering.

WHAT IS A GROUND ENGINEER?

A ground engineer typically has a first degree (usually civil engineering or geology/applied geology), followed by a second degree (MSc or PhD) in soil mechanics, geotechnical engineering, engineering geology or a similar ground-related subject. (Civil engineers require knowledge of the ground; and geologists require knowledge of engineering. This is usually acquired in a one year MSc).

However ground engineers are in short supply. Job titles in the sector have been on the official Shortage Occupation List since 2004, and remain on it despite the increased rigour which the Government now applies to the regular reviews of the list, most recently in 2011. This enables the UK to rely on migrant professionals from outside the EU to meet the nation's needs for ground engineers and was described by one major employer as "our life saver". The Shortage Occupation List provides a short to medium term solution to the skills shortage but does not provide a sustainable long-term solution; 'home grown' ground engineers are essential.

1 The Ground Forum brings together Learned Societies and Trade Associations representing construction-related ground engineering disciplines; see www.ground-forum.org.uk for list of member organisations. The Learned Societies undertake the dissemination of information and oversee professional qualifications; while Trade Associations represent the commercial interests of consultants, contractors, and manufacturers in the sector. The Ground Forum is therefore a single voice which draws together construction-related ground engineering interests of both companies and individuals.

GROUND ENGINEERING – WHY IT MATTERS

VALUE OF GROUND ENGINEERING

Barry Clarke
Professor of Civil Engineering Geotechnics, University of Leeds
Senior Vice President, Institution of Civil Engineers

We know more about the solar system than we do about the ground beneath our feet. This was the view of Leonardo da Vinci in the 15th Century and remains valid today. Our knowledge of the ground has increased significantly, especially on the macro scale, but at a scale relevant to the construction industry we still struggle to understand what is there and how it will affect the structures we build. This can lead to contract delays, increased construction costs, damage to property and potentially failure during and post construction. To minimise the risks we need engineers and geologists who have appropriate skills and the tools to be able to investigate the ground and to work with nature to design, construct and maintain the built environment.

Everything built is either on, in or with ground. Buildings and bridges are supported by the ground using foundations. The amount of the ground needed to support a structure depends on the characteristics and use of the structure and the properties of the ground. Ground engineers design systems that transfer the weight of a structure and all that it contains, and the external forces acting on the structure, such as wind and snow loading, to the ground. Most structures are built of manufactured materials such as bricks, concrete and steel which are much stronger than the ground on which they are built. This means the load of the structure has to be spread onto or into the ground using foundations. Therefore the volume of ground affected by the structure can be considerable. The spreading of the load can be compared to the concept of using snowshoes to stand on snow; and the volume affected is similar to the concept of the iceberg in that much of the support to a structure is hidden beneath the surface. The support of the ground not only has to ensure that the structure remains stable it also has to limit the movement or settlement of the building. All buildings settle. The classic case of differential settlement is the Leaning Tower of Pisa but with most structures this would be unacceptable. The foundation has to control that settlement so that the building functions as designed.

Ground engineers also build structures, such as tunnels, pipelines, basements and retaining walls, in the ground. Most of the services, including water, gas, electricity, communication and sewers, are installed in the ground. The difference between these structures and foundations is that the ground imposes the load on these structures; foundations impose the load on the ground. However, many of

the principles that apply to foundations also apply to these embedded structures. In both cases the ground engineer has to work with the ground that exists which requires understanding the formation of the ground through extensive studies of the literature, how it impacts on the behaviour of structures and an interpretation of maps, plans and in situ investigations to establish what is actually there.

Ground can be natural, formed by geological processes, or manmade. In the latter case this includes archaeological deposits especially in towns and cities as well as the soil and rock used to build structures such as embankments, landscaping and earth dams. These manmade structures involve considerable quantities of ground being excavated, transported and placed in an engineering manner. The largest structures in the world, earth dams, are built of soil and rock; they have been used for centuries as a construction material. Embankments and excavations form part of the surface transport networks including roads, rail and canals; are used to develop level sites; and to build flood embankments and water retaining structures.

The design of all of these structures depends on detailed knowledge of the ground conditions established from investigations undertaken by competent professionals skilled in assessing the spatial variability of the ground and how it will perform during and post construction. These are supplemented and informed by geological and topographical maps, borehole records, utility plans, mining and quarrying records, surface and sub surface surveys.

Thus understanding the ground is critical to the success of the construction industry and ground is a key component of the built environment. The built environment is broadly split into domestic property; social infrastructure such as schools, hospitals, retail outlets, leisure facilities and other community structures; and economic infrastructure such as utility, communication and transport networks.

Infrastructure UK, created in 2009, focuses on the economic infrastructure, which allows society to function as it facilitates the movement of materials, products, energy, knowledge and people. These infrastructure networks are complex interdependent systems. For example, according to the Treasury, the road network comprises forty types of roads and includes a variety of structures such as bridges, culverts, walls and overhead gantries; communications equipment; and land. The highway network, a subset of the road network, has a replacement value of £77.5B, and there are some 11250 km of highways with 17,000 structures including 8,800 bridges. Transport and utility networks extend to about 1.41m kilometres and include hubs such as railway stations (2,770), ports (60) and airports (120) and major assets such as power stations, treatment plants (11,500) and reservoirs (1,090). In addition to these infrastructure networks that connect and service communities there is also the infrastructure that supports agriculture which includes some 400,000 ponds a source of water for irrigation.

The Treasury splits assets into residential buildings, (valued at £211B), commercial, industrial and other buildings (£245B) and civil engineering works (£780B). Civil engineering works are primarily the economic infrastructure. The infrastructure is continually being adapted to meet the needs of society and make use of emerging technology. Modern infrastructure can be traced back over 2000 years. The road network can be traced back over 2000 years; the rail network was started over 150 years ago; modern utilities were first laid down over 100 years ago. The UK has a mature infrastructure that has to be continually maintained, repaired, adapted and replaced.

Replacement cost is more useful than historic value because much of the UK Infrastructure is either nearing the end of its life and will have to be replaced or it has to be adapted to meet the needs of society, cope with emerging technology, deal with climate change or conform to new regulations. The economic life of components within the infrastructure network varies from less than seven years to more than one hundred years but replacement of any one component can result in replacement of components that have not reached the end of their economic life. This is routine. Climate change and the move to a low carbon economy are introducing new concerns. Climate change is a particular issue for ground engineers since the impact of rising ground water levels below certain cities, rising sea levels and the increase in extreme events will impact on the stability of foundations, slopes, embankments and other ground related structures. Some 40% of the built environment will have to be adapted for climate change over the next forty years.

The value of the ground works is unknown but given the amount of excavation for tunnels, cuttings and embankments, and the scale of the network the ground work contributes between 30% and 40% of the total value of the economic infrastructure; that is between £234B and £312B. This excludes the cost of the materials such as concrete and steel that are used to build the structures such as foundations within the ground.

While the focus is on the importance of ground engineering in construction, ground engineers are also engaged in the extraction of minerals. The average American needs some 1,500 tonnes of minerals during their life. This is made up of about 42% of energy (gas, oil and coal), 9% of various economic minerals (eg iron, limestone for cement and bauxite for aluminium) and 49% stone, sand and gravel. Over 50% of the minerals extracted from the ground are used in the construction industry with the majority of those used either to make concrete (25%) or as fill (75%) to form structures such as road, rail and flood embankments and landscaping. Water, ground and fossil fuels in that order comprise the majority of materials society uses to function.

Understanding what is beneath our feet and how it behaves is challenging but is fundamentally important because of the value of the ground in providing energy, construction and manufacturing resources and underpinning the built environment. The most important technical risk in construction is the uncertainty of the ground. The most important risk in ground engineering is the current shortage of qualified ground engineers.

WHAT ARE THE BENEFITS OF GROUND ENGINEERING TO SOCIETY AND GOVERNMENT?

Rodney Chartres
Past Chair, Ground Forum

HISTORICAL BACKGROUND

Let us take as an example, travel and communication. Our early ancestors would follow animal trails which developed into tracks, then turnpikes with the advent of horse transport. These were then metalled in the early part of the last century to take motorised traffic. Historically, if there was an event such as a landslide or other geohazard encountered, the track would be re-routed. This would have been at negligible cost with little effect on the surroundings.

The development of canals and railways led to these linear routes following the best alignment through a valley. This has led to modern roads having little choice logistically other than following a more difficult and complex route from the ground engineering perspective. As the pressure on land has increased, economic and social factors mostly dictate linear infrastructure routes.

It was in 1959 that the first section of the M1 motorway was opened between London and Birmingham. The ground engineers had to deal with the geological conditions along this alignment with little deviation being possible.

The same applies to almost all other ground engineered projects today. A topical example in the UK is the route of the High Speed Railway 2 through the Chiltern Hills. The Secretary of State has announced the preferred alignment recently that will entail the design and construction of increased lengths in tunnel rather than cutting a swathe through this environmentally sensitive landscape. This poses some interesting ground engineering problems that will need to be resolved.

PLACE IN TODAY'S SOCIETY

Risk and failure are becoming more and more unacceptable to modern society. These concepts come at a price.

Perhaps the turning point and the awakening of such an approach in the United Kingdom to geohazards was the tragic consequences of the failure of the coal spoil tips above Aberfan, South Wales, in October 1966 with the deaths of 144 people, including 119 children at the local school.

Following this tragedy, Government made available the necessary funding for all spoil tips throughout the UK to be investigated by ground engineers. The tips that were found to be unstable were either removed or made safe with continuing monitoring.

FINANCIAL BENEFIT AND COST TO UK PLC

Ground engineering is to be found everywhere beneath our feet and is for the most part taken for granted.

However, the prospect of a new development or infrastructure project in recent years has often created a public outcry from mostly "Nimby" protestors.

The social and economic benefits to society brought by an improved infrastructure and built environment are often overlooked.

The impression of complete desecration of the countryside by large construction machinery and occasional deposition of mud on surrounding roads is a fashionable image.

How many of us today complain about the M25 or that the Channel Tunnel and its high speed railway link to London were constructed? The role of the ground engineer is to minimise the impact of such projects on the environment whilst delivering a safe and cost effective solution.

The Treasury and other financial models indicate that the construction sector makes up around ten per cent of the United Kingdom's Gross Domestic Product.

It is also recognised that between a quarter and a third of a project's construction costs are to be found beneath the ground. This equates to about 2-3% of GDP. This figure excludes open cast mining, sand and gravel abstraction and the winning of other minerals together with the

challenges of the waste disposal and recycling sectors that are heavily dependent on good ground engineering advice. The true value of ground engineering to the UK economy has not been assessed accurately.

In addition, it should be noted that the halting of a major construction project has an immediate effect on the local and national economies.

The UK has a tradition of offering an innovative and quality engineering service worldwide. The positive contribution made to our overseas trade balance has been significant in the last thirty years. However, the competition from the Chinese ground engineering community is increasing, particularly in the field of minerals extraction and its associated infrastructure in sub-Saharan Africa and South America.

Can UK plc afford to sit by and watch as our international competitors invest in educating ground engineers to the highest standards at their universities and train professional staff to be in direct competition?

THE PRESENT AND THE FUTURE

The challenges being met today by ground engineers are increasingly more complex.

Good ground engineering is dependent on the need for accurate geological data that will form the basis of any ground model. We should not forget the vital role of the British Geological Survey (BGS). It is not only custodian of our various rock and soil collected material but also responsible for the preparation of themed maps and the dissemination of geological information.

The advance of the use of 3D and other technologies at BGS has been exceptional. This work is the cornerstone of current and future ground engineering and it is important that sufficient funding is found in order for this work to continue and flourish.

Following the offshore earthquake in Japan in March 2011 and the effect of the tsunami on two nuclear power plants, scrutiny has never been more stringent. Ground engineers have always played a key part in the design of the substructure and foundations of nuclear power facilities and the repositories that are required to store waste for long periods generated by this industry. We are at the dawn of a massive construction programme within the nuclear power sector.

As a green alternative to nuclear power, the use of wind and tidal/wave energy has expanded rapidly in the last few years. This is set to continue with the challenges that need to be overcome in the designs for both offshore structural foundations on the seabed and on the peat that covers most of our remote upland moorland locations in west Wales and Scotland.

Tokyo and San Francisco lie in seismically active zones. Such locations around the world lead ground engineers to design more and more complex structures in a quest to build in greater resilience against earthquake damage.

Hydrogen is recognised as a likely replacement for oil to power road transport in the future. Following electrolysis from the night time power capacity, the hydrogen will need to be distributed in liquid form by pipelines to the consumers. This very low temperature transportation will open up new challenges to be overcome beneath the ground.

The entire utilities buried infrastructure requires constant repair and modernisation. So much dates from the Victorian era and is now in urgent need of replacement.

This summer will see severe water shortages in the south and east of England at a level not experienced since 1976. The role of the ground engineer to come up with innovative solutions such as the previously proposed Craig Goch transfer from Wales to the Thames catchment or other micro reservoir schemes is clear. In the meantime, the agricultural and industrial sectors will suffer.

LEGISLATION

There is a number of anomalies within the legislative process that need addressing to ensure the continued improvement and delivery of ground engineered projects.

As a Borough Councillor, I have seen at first hand the constraining effects of our planning system. This is being examined as a part of the Government review.

An anomaly that needs addressing is that structural engineer's reports are asked for as a matter of course for minor residential extensions. Interestingly, detailed ground engineering reports are rarely sought. The cumulative costs of resulting foundation failures to UK plc is significant, albeit through insurance and other claims.

There is an abundant and free source of geothermal heat beneath our feet. This is harvested in urban areas by the installation of energy piles as part of the foundation system for new and refurbished buildings and structures. The problem lies in the question of the ownership of this heat source and the contention that heat is being harvested from beneath adjacent properties. Let us hope that the lawyers can resolve this potential conflict and that appropriate legislation can be introduced as a matter of urgency. The ground engineering profession certainly can meet the technical challenge.

In my time as Head of Geotechnics of the Property Services Agency it took more than two years for the Treasury Solicitor to deliberate prior to permitting publication of a map to show potential geohazards throughout the UK. It was feared that it might have blighted those properties and areas identified. Quite the opposite has been the case. Let us hope that the ownership of ground source heat can be resolved more quickly!

CONCLUSION

What a feeling of wonder one gets on rising from the Jubilee Line at Westminster Station on the journey to the surface via the various escalators. The scale and enormity of the massive struts supporting this bold excavation adjacent to the Thames is there for all to see and appreciate. Portcullis House sits atop this sophisticated infrastructure, supported on its six massive piles. This is a fine example of what good ground engineering has to offer modern society.

TRAINING OF GROUND ENGINEERING PROFESSIONALS – How can UK provide skills required to maintain infrastructure?

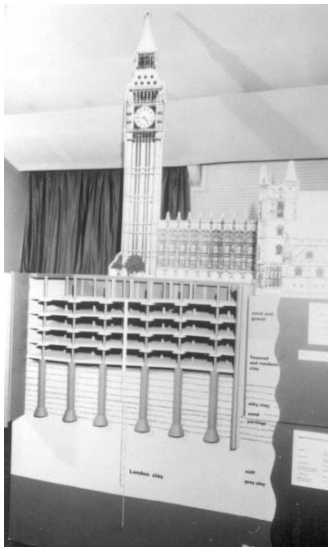
John Burland
Emeritus Professor of Soil Mechanics, Imperial College London

Richard Jardine
Professor of Geomechanics, Imperial College London

The Palace of Westminster has been impacted by two major civil engineering projects, the underground car park in New Palace Yard in the 1970s and the new Westminster Station for the Jubilee Line Extension in the 1990s. These can be used to illustrate the types of skills required of a ground engineering professional.

The underground car park is nearly 20m deep and its retaining walls come to within 2.5m from the north edge of Westminster Hall and 10m of St Stephens Tower. The retaining walls were initially designed on the basis that the clay was homogeneous and continuous – standard practice at that time. However Professor Burland examined the samples in detail and made the significant discovery that between a depth of 20m and 30m the London Clay contains thin layers of sand and silt. This transformed the design of the project. Because the ground water is in hydraulic continuity with the River Thames there was a significant risk that, as excavation took place, water would seep in horizontally through the sand layers and burst upwards into the excavation, which would have been catastrophic. The design was changed to eliminate this risk.

A key requirement of the design of the underground car park was to ensure that there was no risk to the stability of the surrounding historic buildings and that any damage was at most superficial. This necessitated the use of advanced computer modelling of the excavation process – the first time it had been used in the UK. Such an analysis is useless unless the appropriate



strength and stiffness parameters of the ground are known. At that time laboratory methods of determining such parameters were crude. We analysed the movements that had been observed around other excavations in London. The stiffness values derived in this way were generally very much higher than those obtained from routine laboratory tests. Accurate measurements of ground movement were made during construction. The predictions were broadly in agreement with the measurements but there were some subtle and important differences.

An intense programme of research work was then carried out at Imperial College aimed at (1) improving our ability to measure accurately the stress-strain properties of soils (led by Professor Jardine) and (2) the development of advanced computer modelling techniques (led at Imperial College by Professor David Potts). The outcome was a significant improvement in our ability to predict ground movements and their impacts on nearby structures.

This account of the work carried out on the New Palace Yard car park illustrates a number of skills that are required of a competent ground engineer:

1. The knowledge and experience to investigate the ground and ground water conditions at a site so as to identify risks and uncertainties and to develop cost effective designs that minimise the risks.

2. Knowledge of the applied mechanics principles governing the stiffness and strength of soils and rocks that is far in advance of what can possibly be taught at undergraduate level.

3. Knowledge of the advanced experimental techniques required for investigating the mechanical properties of soils and rocks.

4. An understanding of how to carry out and interpret advanced numerical modelling of ground engineering problems together with the limitations and

pit-falls associated with such modelling.

5. A knowledge of case histories and the lessons learned from them – an essential aspect of good ground engineering.

The construction of the 40m deep new Westminster Station beneath Portcullis House was a major civil engineering achievement. The sophisticated computer modelling that was carried out was informed by the measurements that had been made during the construction of the car park. Precise monitoring of movements of the clock tower and the surrounding buildings was carried out under the direction of Dr Jamie Standing of Imperial College.

This demonstrates the key role played by novel geotechnical construction processes. For example, to reduce ground movements the bottoms of the retaining walls of the station box were propped by struts constructed in tunnels before excavation commenced. Most importantly a novel method of controlling the settlement of the foundations of the clock tower was developed. The method, known as compensation grouting, consists in injecting cementitous grout into the ground at chosen locations beneath the foundations so as to jack them up in a controlled manner if any settlement takes place. The technique was used very successfully to control the changes of inclination of the clock tower during the works – a topic of considerable press speculation recently.

A geotechnical engineer requires knowledge of the various geotechnical processes that have been developed in recent years. Such processes require careful monitoring and control so that techniques of monitoring form another essential skill of good ground engineering.

Awareness of what the Romans could achieve, or of Brunel and Bazalgette's achievements can make it difficult for modern Civil Engineers to convince others of the rate of advance in our subject, its complexity and its importance to the economy. But there have been many big, innovative and important developments over the last few decades and these require a high ability, well trained cohort of specialised professionals to carry this progress forward.

For example, offshore Geotechnics has progressed from working in a few 10s of metres of water to astounding projects achieved at 2000m depth or more. Academic research and engagement has helped this significantly. The group at Imperial College has provided contributions to many of the major new deepwater developments. These include for example the Ormen Lange field, offshore Norway, that provides a large part of the UK's gas from the rear scarp of a huge landslide that developed a tsunami 8,000 years ago that would devastate much of coastal NW Europe if it were to be repeated in modern times. This clearly required very careful, advanced and specialist work. Our contributions have also been important in deepwater Gulf of Mexico projects (the events of 2010 make us all aware of the potential risks faced in that region), deepwater Angola and elsewhere – as well as contributing to the latest developments in the Atlantic Frontier sites West of Shetlands and new high capacity wind farm developments in Germany and other North sea sectors. The economic impact of this work is huge. Major infrastructure projects are taking place within urban areas world-wide involving tunnelling and excavations. The design methods of assessing and mitigating impacts on buildings are based largely on the research work carried out within the UK.

None of the above could have been done in the same way 30 years ago. There is a wealth of new knowledge being created by the universities and industry here and abroad. This has to be disseminated in a consistent and systematic way. The knowledge transfer mechanisms open to us include academic papers (great for Research Excellence Framework (REF), but not read or understood by many practitioners), short courses (important, but really only trailers and taster sessions), undergraduate teaching which is inappropriate for the specialisms involved and finally specialist Masters Courses.

In our experience MSc courses have been the most efficient means. They give us a chance to really teach advanced and specialised material in a broad context, and make sure that the material is understood by requiring testing examinations and coursework. The geotechnics MSc courses run at Imperial College contain all of the elements described above. Moreover they are kept up to date by the latest research findings, technical developments and notable engineering projects. It has been our experience at Imperial College that a full year of 'total immersion' is required for a student to gain most benefit.

These courses have become the backbone of UK geotechnics profession and about half the membership have an MSc, and of those about half took their degree at Imperial College. Around 40% of Arup's geotechnical staff have an Imperial MSc degree including all six of the geotechnical directors.

The history and the product is good, but what is happening now? The bad news is that student debt, four-year MEng courses, the cancellation of Research Councils' MSc support schemes and the coming fee hikes are wiping out the UK take-up of places at the top MSc schools. We are now down to 10% UK take up in the Imperial geotechnics courses, and this will probably reduce further as the fees bite. The courses are therefore principally training the UK's economic competitors. Without financial support it simply doesn't make sense for an able MEng graduate with a good degree and a good job, to quit, spend £30k and risk possible unemployment just to attain specialist skills that the Industry does not seem able to reward.

Clearly, the UK industrial and educational governance system has missed a very important trick. Decisions made to meet the interest of our individual research councils, student funding bodies, industries and universities have all come together to produce a perfect storm in which our future ability to design, build and manage our expensive infrastructure is at risk. Our Civil Engineering work covers around 10% of the UK's GDP, with energy supply adding a further substantial segment of value. This is far too important an economic issue to ignore.

GROUND ENGINEERING IS EVERYWHERE – BUT GROUND ENGINEERS ARE IN SHORT SUPPLY

What are the issues: What can we do?

Keith Gabriel
Past Chairman of The Ground Forum
Director, Gabriel GeoConsulting Ltd

Dianne Jennings
Ground Forum Secretary

Ivan Hodgson
Chairman of The Ground Forum
Associate, URS

There is an almost uniquely broad need for adequately trained ground engineers within the construction industry. No other construction sector is involved in such a breadth of project types as ground engineers. This skills shortage is recognised by the Migration Advisory Committee and has led to at least sixteen ground engineering disciplines being included on the Government's Shortage Occupation List ever since it was first established.

Provision of an adequate supply of locally-based 'home grown' ground engineers is essential if the United Kingdom is to stop relying on migrant professionals, but courses are under threat because of budget pressures in universities and the economic crisis in the construction industry. UK-based students for the crucial MSc degrees are also in short supply because of the increasing cost of courses, the recent withdrawal of funding by the Research Councils, the level of debt which most graduates now accumulate, and competition from other sectors. Against this background, representatives from academia and industry met recently to consider: What are the issues? What can we do?

WHAT IS THE PROBLEM?

There are currently 15 universities in the UK offering MSc courses in subjects that would qualify as ground engineering. These courses are continually under pressure and several have closed in the past few years – including courses in hydrogeology, even though this is an area of acute shortage. Some of the pressures come from factors that affect all university courses: the need to diversify university income; the Government-driven move towards research and research funding; and the need to ensure that courses, even in specialist areas, are financially self supporting.

Most taught MSc degree courses require a minimum of 16 students in order to break even. In the past student numbers were limited by a shortage of students completing first degrees in civil engineering and geology. This problem has been resolved to some extent in recent years, to be replaced by new difficulties. In response to other pressures a number of universities now offer four-year first degrees in civil engineering leading to an MEng or a four-year geology course leading to an MSci. Neither an MEng nor an MSci contains sufficient specialist content to produce a Ground Engineer of the calibre produced by a three-year first degree and a specialist MSc. However, there is little incentive for someone graduating from MEng/MSci courses to undertake a further year of study to obtain an MSc when they already hold a master's degree.

This reluctance is compounded by financial considerations for potential MSc students. A survey by Birmingham University of students who enrolled for a ground engineering MSc course but withdrew before the course began ('non-arrivals') revealed that finance was a significant factor. MSc course fees are currently £4,000 to £5,000 and, while not employed, the students must also cover their living costs. Many now graduate from their first degree with substantial student debts which they are reluctant to increase further. MSc courses are not eligible for government loans and must be paid for 'at the door' (ie: on arrival); unlike undergraduate courses there is no delayed payment option. This is the biggest problem as many graduates simply do not have the money available or cannot access bank loans (especially in the current economic climate) to pay for MSc course fees. These factors will intensify in the coming years. The increase in undergraduate tuition fees will result in even greater student debt after 2015. Additionally, undergraduate tuition fees as high as £9,000 a year will have a knock on effect on

postgraduate course fees which are expected to reach £12,000 from 2012. An early warning about the effect that this might have was given by Leeds University who raised fees to £5,000 last year and experienced a 40% drop in enrolments.

Inclusion of at least sixteen ground engineering disciplines on the Government's Shortage Occupation List has been a huge help to the industry. Such reliance on migrant professionals is not a long term solution however and the industry has already found various shortcomings with migrant ground engineers such as an inability to write contractually sound technical reports in English, no familiarity with UK ground conditions, only staying in the UK long enough to be trained and get experience up to Senior level and then going back home leaving us with a shortage of experienced senior technical management.

Should industry be taking a greater share of the financial burden being faced by both universities and individuals? The argument from university authorities is that vocational training is not their responsibility; and from elsewhere, including Government, that industry should pay for the skills it requires. Most of industry agrees in principle, provided Government recognises that everyone needs Ground Engineers and therefore public expenditure must also play its part. Two further factors are relevant:

1. Government agencies and local government have been estimated to be the client for up to 40% of all ground engineering work, and

2. Government supports knowledge transfer from academia to industry; taught MSc degrees are one of the fastest means of achieving that transfer of knowledge because the students are back in industry within one year.

PROBLEM SOLVED?

Profit margins in the ground engineering industry are typically less than 5%. This means that a bursary of £12,000 (enough for an MSc course fee from 2012) requires turnover of around £240,000. In some quarters, UK construction is considered unduly expensive in comparison with other European countries. There is little opportunity, even in normal economic conditions, to increase charge-out rates and hence profit margins; and in the current climate, with reduced rates to win work and keep staff employed, increases are unthinkable.

Since 2008 the turnover of many geotechnical consultants and contractors has fallen dramatically; margins have dropped (some are operating at a loss), several medium-sized piling contractors have closed down, and takeovers and mergers have increased. Expenditure is constantly scrutinised and cut (including, sadly, support for universities and training); and graduate recruitment has been reduced or stopped.

Many companies already supply 'in kind' support in the form of visiting lecturers, prizes, work experience, research projects (and supervision) for MSc dissertations; research facilities; and personnel for research steering groups. Additionally, even a well-qualified MSc graduate requires further training in order to develop in their career to chartered status and beyond. For most companies commitment to CPD represents a significant investment in terms of staff time, cost of courses and provision of training officers and mentors.

THE FUTURE

A recent meeting brought industry and academic representatives together and greatly enhanced understanding of the problems which each are experiencing.

But what can this achieve?

- Industry and academia can work together to ensure that courses meet the needs of industry.
- We can maximise the effectiveness of industry support 'in kind'.
- We can do our best to increase the visibility and attractiveness of the sector to potential students.

However, most companies cannot, at the moment, increase salaries or recruitment, nor can they provide additional cash for bursaries because no spare cash exists. Industry cannot alleviate the need for university courses to be self-sustaining, although all parties are very concerned that if student numbers fall any further then the continuity of these essential courses will be threatened.

Over the past years the UK has had to import Ground Engineers to plug a gap in skills and experience especially amongst experienced practitioners. The gap goes back to the beginning of the 1990s when recruitment dropped and candidates were snapped up by the City hungry for numerate and computer literate graduates. Unless a solution can be found, there will be an even greater skills shortage in 10 years time that will extend indefinitely into the future.

It is not only the construction industry that needs Ground Engineers – the country needs Ground Engineers. This is a problem that requires a sustainable solution, and this depends on industry, academia and government. The Ground Forum considers that the Government should reconsider its current policy towards funding of postgraduate training for Ground Engineering professionals and in particular the MSc courses. Funding support for MSc degrees in ground engineering subjects does not necessarily have to be provided by the Research Councils; it would seem reasonable that the Government departments which use ground engineering expertise should provide the required support. The total support required is modest, in the order of £3 million per year (100 UK-based students per year at an estimated fully funded cost of £30,000). This would guarantee that the UK has a sufficient Ground Engineering skills base for all normal circumstances.

If even such modest full funding of these essential courses is not feasible then Government support could be provided through tax concessions for employers who fund postgraduate training of their professional staff and provision of affordable loans to postgraduate students on the same basis as undergraduate loans. Such measures would help to alleviate the supply problem.

Current Government policy is to reduce or eliminate reliance on migrants from outside the EU so finding a new source of funding for locally-based students on taught MSc courses in ground engineering has the potential to resolve two problems simultaneously. The one certain conclusion is that doing nothing will result in a disastrous shortage of ground engineers in the UK and an even greater reliance on migrant professionals.

SCHMALLENBERG VIRUS – KILLER IN THE WOMB

Professor S P Borriello
Chief Executive, Veterinary Medicines Directorate

Professor Trevor Drew
Head of Virology, Animal Health and Veterinary Laboratory Agency.

This time last year few knew of the German town and no one had heard of the virus. Not so now. So where did it come from, how did it get here, why is it a problem, and what is likely to happen next?

WHERE DID IT COME FROM AND HOW DID IT GET HERE?

Throughout late summer and autumn of 2011, farmers and veterinarians in northwest Germany, and in the Netherlands reported an unidentified disease in dairy cattle, consisting of fever, decreased milk production, and diarrhoea. In October 2011, an investigation of such a case in dairy cows in the small German town of Schmallenberg finally yielded a novel virus that was related to a number of exotic viruses that also caused birth defects and were known to be transmitted by insects. German scientists spread the word about their findings and continued to monitor cases and were particularly concerned when, in December 2011, they detected the virus in a stillborn calf.

Scientists all over Europe, including the Animal Health and Veterinary Laboratories Agency (AHVLA) in the UK, set up diagnostic capability and the Netherlands soon reported the virus in cases of malformed aborted lambs, as well as in calves. They were quickly followed by other European countries, with more reports of infection in Germany and also in Belgium, UK, France, Italy, Spain and Luxembourg. A few cases in goats have also been reported on the continent.

How the Schmallenberg virus appeared in Europe is unknown, though it is most likely to have been introduced either by an infected animal and transmitted by infected midges, or directly by infected midges from abroad. For England, the most likely route of introduction was by infected midges arriving from Northern Europe aided by prevailing winds. It is estimated that the virus first arrived here during the summer or autumn of last year.

A more interesting question is the origin of the virus. Is it a known virus that has simply been given a different name, a variant of a virus that has until now been harmless to mammals and only came to our attention because of a mutation that enables it to cause fetal abnormalities, or one that causes undiagnosed problems in less developed parts of the world and has now spread?

Analysis of the genetic make-up of the virus means we can identify the family to which it belongs (Bunyaviridae) and the genus (Orthobunyavirus). We also know that it is closely related to other viruses in that genus, which were first described in Japan (Akabane, Aino and Shamonda), which cause infection in livestock, and probably originated in Africa.

THE CURRENT SITUATION IN THE UK

At present cases have only been detected in the South of England, as of mid-April 243 farms located in 24 counties are known to be affected. The most severely affected counties are Kent, East Sussex and West Sussex with 42, 41 and 38

. . . Analysis of the genetic make-up of the virus means we can identify the family to which it belongs . . .

TABLE 1: CONFIRMED CASES OF SCHMALLENBERG VIRUS IN EUROPE

COUNTRY	CATTLE	SHEEP	GOATS	TOTAL
England	28	215	-	243
Belgium	195	167	2	364
France	104	1058	12	1174
Germany	293	840	45	1178
Italy	1	-	1	2
Luxembourg	6	5	1	12
Netherlands	148	107	6	261
Spain	-	1	-	1
TOTAL	775	2393	67	3235

. . . Of 619 reported likely cases where there has been clear laboratory diagnostic confirmation, 39% were positive . . .

affected farms each. Of the remaining counties 13 have less than five affected farms; four have between five and ten affected farms, and four have between 10 and 21 affected farms.

The figures have to be treated with caution for a number of reasons. Firstly, there is no single absolute method of diagnosis, and even though the figures for England are based on a molecular method which detects the nucleic acid of the virus (and thought to be the most sensitive and specific test currently available), we know of some cases that fit all of the case definitions for this infection and have all of the expected histological features at post-mortem investigation, but which are negative in the molecular test. Secondly, we must remember we are looking at an infection that actually occurred last year – we are only seeing the effects today. For lambs, the virus survives the pregnancy period, but for cattle, with a longer pregnancy period, the virus has often disappeared by the time of birth. Thirdly, the disease is not notifiable, so there is no obligation to report. However, the number of submitted samples strongly indicates a willingness to report presumed cases. Of 619 reported likely cases where there has been clear laboratory diagnostic confirmation, 39% were positive, showing a high level of submission of suspected (but negative) cases (61%). For affected calves, laboratory confirmation is more difficult as the virus has disappeared by birth, due to the longer gestation.

WHY IS IT A PROBLEM?

The most obvious problem of course is that it causes loss of life in utero and birth deformities, with economic consequences and disrupting replenishment of livestock. The deformed fetus can damage the dam at birthing, particularly as a consequence of deformed limbs. Although symptoms in adult animals are very mild, there may be a drop in milk production in dairy cattle. Farmers also have to employ more staff to assist in lambing and calving, also often incurring extra costs if a vet needs to be called. Compounding the economic problem is anxiety amongst unaffected countries leading to eight suspending imports of ruminants (and in some cases also pigs) from affected countries. Though the US has not stopped importation of live animals, it has suspended importation of European source embryos and semen, as have some other countries.

WHAT'S NEXT?

Although much has been learnt about the virus in a very short period of time, it remains the case that there is more we don't know than there is that we do know. Can it infect humans? What explains the current host range for the virus? Will sheep that have been infected attain an immunity that will protect against fetal infection in the future? Will the virus survive the winter in some way and the disease become established in Europe to become a new endogenous infection? Is a vaccine needed and can an effective vaccine be easily produced? Are there other ways the virus can be transmitted?

Fortunately, it is now considered very unlikely that humans are at risk. Reassurance comes from the fact that very few of the relatives of the virus cause disease to humans and despite heightened awareness and opportunity for exposure, along with some monitoring for evidence of exposure, no human cases (or other cases other than in ruminants) of this virus have been found. Interestingly this is not because the virus cannot grow in the laboratory in cells from other species. Evidently, inability to infect other animals is not due to a lack of virus receptors on the cells (viruses must bind to and enter cells in order to hijack the host cell's machinery to replicate itself).

The pattern of cases will change as the lambing season closes, and as calving occurs later than lambing, an increase in infected calves is expected. It will be interesting to see whether a few cases occur in the less commonly farmed ruminants such as deer and whether new world camelids, such as alpacas, are also susceptible. What is less clear is the extent to which this disease is now established and will become part of the usual endemic diseases profile in the UK. We now know that the biting midges normally resident in the UK can likely transmit the virus, and that the virus can most likely establish in midges, meaning that the virus doesn't have to survive in animals for midges to become re-infected next spring, but could survive over the winter in the midges themselves. We need to find out whether other biting insects, like mosquitoes are also involved, or if infected animals can spread disease just by contact. We also don't know how long immunity in sheep or cattle (or other ruminants) lasts, and if such immunity would protect fetuses. If there is good long-lasting protective immunity following natural infection, this would help reduce the number of cases, and may already have done. Husbandry practice could be tailored to maximise this effect. However, it is likely that areas less affected or unaffected by the disease could be vulnerable next year, particularly on the borders of the area where disease has occured this year. Reliance on such an approach would be less effective than a vaccine, though if required it is unlikely to be available until next year other than for emergency use. There is a good precedence for a vaccine to this virus in that an effective vaccine has been produced for Akabane virus, a close relative.

This is a rapidly unfolding story, exemplifying the rapid progress that can now be made in identifying new causes of disease, developing diagnostic tools, characterising the new pathogen, and developing interventions, made possible by new technological advances. It is also a reminder of the continual threat of new pathogens and how much we still don't know.

. . . less clear is the extent to which this disease is now established and will become part of the usual endemic diseases profile. . .

EXAMINING THE STRATEGY FOR UK LIFE SCIENCES

Report of a Meeting of the All Party Parliamentary Group (APPG) for Life Sciences held on 1st March 2012

Chairman: Penny Mordaunt MP

In early December 2011 the Government launched the 'Strategy for UK Life Sciences', aimed at providing vital support for the Life Sciences industries in the UK with an ambition to implement the strategy in full by the end of 2012. To understand what progress has been made towards achieving these aims so far, the APPG on Life Sciences invited the Government's three life sciences advisers to update members of the group. The meeting was well attended with a strong presence from industry and the third sector.

George Freeman MP, as the Government's Business Adviser on Life Sciences, provided an overview of the ambitions of the initiative and how it had been developed. He spoke about the key elements of the venture capital fund which aims to bridge the 'Valley of Death' and provide a much needed life-line to companies which may otherwise not succeed. The newly appointed 'Life Sciences Champions' – Professor Sir John Bell and Chris Brinsmead – then spoke about the five key elements of the initiative and the progress that had been made in each area, as follows:

Collaboration and Partnerships: Collaborative work was described as a 'central part of the story' and aimed to open up the most powerful academic research places. Professor Bell spoke about how the previous Government had grown research funding, and this Government had maintained it despite the recession. Professor Bell spoke about how new initiatives were encouraging academic institutions to start working together effectively, highlighting the five sectors in the South East that had already started working together. He spoke about how Translational Research Partnerships (TRPs) under the NIHR Office for Clinical Research Infrastructure (NOCRI) were an important and successful new initiative in bringing together academia and industry, but that more improvements still needed to be made in this relationship.

Fiscal Incentives: The 'Catalyst Fund' was identified by Professor Bell as one of the key elements to overcoming the 'Valley of Death'. Significant announcements in this area are expected during 2012. Professor Bell spoke about how the catalyst fund will help provide leg room for private funding and will have a significant impact for smaller companies. He also spoke about the important progress that will be made with improved NICE appraisals on medical technology and the use of adaptive licensing in areas of unmet medical need, where 'Early Access Schemes' are to be introduced, enabling access to selected treatments at the end of Phase 2 clinical research.

NHS Innovation: The Government has recognised that procurement of innovation within the NHS is crucial to supporting the Life Sciences industry in the UK. Chris Brinsmead highlighted the important role of the report 'Innovation: Health and Wealth' in supporting the industry in the UK, which had been launched at the same time as the Strategy for UK Life Sciences. He spoke about how the NHS is still not using medicines recommended for use by NICE, but this report marked a commitment to achieve this. He also spoke about how the NHS needs to stop spending money on outdated practices but that this report marked a significant change in the understanding of the leadership of the NHS in how they should be responding to this challenge.

Open Data: Mr Brinsmead spoke about the 'UK Biobank', which has already established the UK as an international leader. It has over 0.5m people aged between 40-69 involved in the programme. He then spoke about plans included in the Strategy for UK Life Sciences to improve the connections between hospital and GP data.

Internationalisation: Finally, Mr Brinsmead spoke about how one of the most important aspects of the Strategy will be to make the global pharmaceutical community aware of the UK Government's commitment to supporting this sector. He said the Foreign Office and the UK Trade and Industry (UKTI) Branch are already undertaking extensive work to promote the role of the UK in the life sciences sector. He admitted that the UK had a limited appeal in being only 3% of the international market, but the role of the Life Sciences Champions and others was to promote the value the UK brings in research and development.

The Chair then opened the meeting to guests and members. The Life Sciences Champions

. . . the catalyst fund will help provide leg room for private funding and will have a significant impact for smaller companies. . .

made the following observations:

- When asked about implementation of the strategy they confirmed that Ministers were expecting a report on progress by the end of 2012, with an interim report to the Prime Minister by mid-2012. Implementation was a key concern about the strategy and was part of the role of the Life Sciences Champions to ensure it would be achieved.

- The comment was made that the UK is becoming increasingly irrelevant to global companies and that slow adoption of innovation was having a major impact on this. The Life Sciences Champions responded that this was the key challenge, but that significant progress had been made in getting the NHS to agree. It was added that the introduction of NICE assessments had added to this, but that all other European countries would begin to introduce cost-effectiveness decisions in a short period of time.

- It was agreed that health economic assessment through NICE had been previously a concern to industry but that there was a realisation that it is now a reality of the UK market; however, the slow uptake continued to be a concern. Many treatments (60%) do not go through the NICE process and the NHS needs to assess the 'healthcare bill' rather than just the 'medicines bill'.

- It was highlighted by a guest that the main conversation between industry and the frontline of the NHS was the need to save money on supplier costs. In addition there was significant tension between primary and secondary care and no joined up approach to investing in services. In response, the Life Sciences Champions agreed that these were key challenges within the NHS and that a short term approach within the NHS was a significant challenge, as was siloed budgeting. It was important to make sure that the constant approach to these challenges would be to continue to seek a way to address these challenges.

- The comment was made that innovation should not be viewed as an annual cost, but that budgeting should be decided over a longer term basis as the savings can only really come into place over a 5-10 year period. In response, Professor Bell made the comment that in the commercial sector innovation is introduced to reduce costs but in the NHS they layer innovation on top of existing cost. He also spoke about how many of the NHS costs are not related to Life Sciences – for example the cost of the work force. Mr Brinsmead spoke about how it is important that the NHS now implements the 'Innovation: Health and Wealth' report quickly and that there is a demonstrable change as a result of this report; however, this would not be possible overnight.

> . . . many of the NHS costs are not related to Life Sciences . . .

> . . . the role of the Life Sciences Champions and others was to promote the value the UK brings in research and development. . .

- Concerns were raised by a guest about the uneasy dynamic between collaboration and competition and asked where the Research Excellence Framework (REF) system fits within the ambitions to improve collaboration. Professor Bell responded that the previous system siloed people and caused competition and the REF is a step forward in changing this. He spoke about how grant funders do understand this change. Professor Bell felt there was a significant lever in the increased availability of funding that will be available if groups work collaboratively. He admitted that academics in the UK were very competitive but that there had been a change to the tone of this in recent years.

- It was highlighted that the Strategy for UK Life Sciences had acknowledged a specific interpretation of innovation and that this agenda should be joined up with the Government's agenda for Value Based Pricing (VBP), with the same interpretation being used across Government. Mr Brinsmead agreed that this was important and said that work was going on to achieve this. The additional point was made that societal benefits that may be considered under VBP only come to fruition after treatments had been used for some time and that this must be considered in the decisions being taken. In response Professor Bell said that it was important that access to Real World Data be improved and brought together at the earliest opportunities. He added that the hurdles posed by the cost of Phase 3 trials was so significant that even small amounts of funding will help. Mr Brinsmead commented that there is currently a period of change and that it must be realised that Governments currently do not have deep pockets but that it is important that the value of innovation is recognised as we progress.

In closing the meeting, Penny Mordaunt MP commented that it is essential that industry and other relevant sectors continue to make their voice heard as this programme progresses.

The next APPG on Life Sciences will examine the progress in implementing the 'Innovation: Health/Wealth' initiative. This meeting will be held in October 2012.

This meeting report has been provided by AS Advocacy who provide secretariat support to the APPG on Life Sciences

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:
Caroline Dinenage (Conservative, Gosport), Gareth Johnson (Conservative, Dartford), Stephen Metcalfe (Conservative, South Basildon and East Thurrock), Andrew Miller (Labour, Ellesmere Port and Neston), Stephen Mosley (Conservative, City of Chester), Pamela Nash (Labour, Airdrie and Shotts), Sarah Newton (Conservative, Truro and Falmouth), Jonathan Reynolds (Labour/Co-operative, Stalybridge and Hyde), Graham Stringer (Labour, Blackley and Broughton), Hywel Williams (Plaid Cymru, Arfon) 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. Caroline Dinenage, Gareth Johnson, Sarah Newton and Hywel Williams were formally appointed on 27 February 2012 in the place of Gavin Barwell, Gregg McClymont, Stephen McPartland and David Morris.

CURRENT INQUIRIES

Science in the Met Office

On 19 July 2011 the Committee announced an inquiry into Science in the Met Office.

On 26 October 2011 the Committee took evidence from: Professor Paul Hardaker, Chief Executive, Royal Meteorological Society, Professor Ed Hill OBE, Director, National Oceanography Centre, and Professor Alan Thorpe, Director General, European Centre for Medium-Range Weather Forecasts.

On 2 November 2011 the Committee took evidence from: Nick Baldwin, Independent Chairman, Public Weather Service Customer Group, Professor Sir Brian Hoskins CBE, Chair, Met Office Science Advisory Council, and Professor John Pyle, Chair, Hadley Centre Science Review Group; Phil Evans, Government Services Director, John Hirst, Chief Executive, and Professor Julia Slingo OBE, Chief Scientist, Met Office.

On 9 November 2011 the Committee took evidence from: Edward Davey MP, Minister for Employment Relations, Consumer and Postal Affairs, Department for Business, Innovation and Skills.

The written evidence is on the Committee's website. The Committee's Report was published on 21 February 2012.

Malware and Cyber-crime

On 19 July 2011 the Committee announced an inquiry into Malware and Cyber-crime.

On 9 November 2011 the Committee took evidence from: Dr Richard Clayton, Senior Research Assistant, University of Cambridge, Professor Peter Sommer, Visiting Professor in the Department of Management, London School of Economics, and Dr Michael Westmacott, BCS, The Chartered Institute for IT, but also representing Royal Academy of Engineering & Institution of Engineering and Technology.

On 14 November 2011 the Committee took evidence from: Gordon Morrison, Director of Defence and Security, Intellect, Janet Williams, Deputy Assistant Commissioner, Charlie McMurdie, Detective Superintendent, Head of Police Central e-Crime Unit, Metropolitan Police, and Lesley Cowley OBE, Chief Executive, Nominet; James Brokenshire MP, Parliamentary Under-Secretary of State for Crime and Security, Home Office.

The written evidence is on the Committee's website. The Committee's Report was published on 2 February 2012.

Engineering in Government: follow-up

On 14 September 2011 the Committee announced an inquiry following its predecessor's inquiry into Engineering in Government.

On 7 December 2011 the Committee took evidence from: Chris Aylett, Chief Executive, Motorsport Industry Association, and Philip Greenish, Chief Executive, Royal Academy of Engineering.

On 14 December 2011 the Committee took evidence from: Sir John Beddington, Government Chief Scientific Adviser.

The written evidence is on the Committee's website. A Report is being prepared.

The Census and social science

On 9 November 2011 the Committee announced an inquiry into The Census and social science.

On 7 December 2011 the Committee took evidence from: Professor David Blane, Deputy Director, ESRC International Centre for Life Course Studies, Professor Heather Joshi, President, Society for Lifecourse and Longitudinal Studies, and Professor Les Mayhew, City University.

On 14 December 2011 the Committee took evidence from: Professor Tim Allen, Local Government Association, Aleks Collingwood, Joseph Rowntree Foundation, Professor David Martin, Royal Statistical Society, and Professor Phil Rees, Royal Geographical Society; Adrian Alsop, Director of Research and International Strategy, and Jeremy Neathey, Deputy Director of Policy, Economic and Social Research Council, Glen Watson, Census Director, and Peter Benton, Deputy Director, Office for National Statistics.

On 18 January 2012 the Committee took evidence from: Richard Bartholomew, and Jenny Dibden, Joint Heads of the Government Social Research Service.

The written evidence is on the Committee's website. A Report is being prepared.

Risk perception and energy infrastructure

On 9 November 2011 the Committee announced an inquiry into Risk perception and energy infrastructure.

On 18 January 2012 the Committee took evidence from: Andrew Bloodworth, Head of Science - Minerals and Waste, British Geological Survey, Professor Nick Pidgeon, Director of Understanding Risk Programme, Cardiff University, and Professor David Spiegelhalter, Royal Statistical Society.

On 25 January 2012 the Committee took evidence from: Tracey Brown, Managing Director, Sense about Science, Fiona Fox, Director, Science Media Centre, and Mark Henderson, former Science Editor, The Times; Bob Brown, Corporate Director, Sedgemoor District Council, Richard Mayson, Director of Planning and External Affairs for Nuclear New Build, EDF Energy, and Dr Rick Wylie, Executive Director, Applied Policy Sciences Unit, University of Central Lancashire.

On 1 February 2012 the Committee took evidence from: Dr Paul Leinster, Chief Executive, Environment Agency, Dr Jill Meara, Deputy Director of the Centre for Radiation, Chemical and Environmental Hazards, Health Protection Agency, Geoffrey Podger, Chief Executive, Health and Safety Executive, and Dr Mike Weightman, HM Chief Inspector of Nuclear Installations and Executive Head of the Office for Nuclear Regulation.

On 19 March 2012 the Committee took evidence from: Charles Hendry MP, Minister of State for Energy, and Professor David Mackay, Chief Scientific Advisor, Department of Energy and Climate Change.

The written evidence is on the Committee's website. A Report is being prepared.

Science and international development

On 11 November 2011 the Committee announced an inquiry into Science and international development.

On 1 February 2012 the Committee took evidence from: Professor Graham Furniss, Chair of the Africa Panel, British Academy, Professor Peter Guthrie OBE, Fellow, Royal Academy of Engineering, Professor Robert Souhami CBE, Foreign Secretary, Academy of Medical Sciences, and Dr Beth Taylor, Director of Communications and External Relations, Institute of Physics.

On 8 February 2012 the Committee took evidence from: Professor Anthony Costello, Professor of International Child Health and Director, UCL Institute for Global Health, Dr John Kirkland, Deputy Secretary General, Association of Commonwealth Universities, Professor Melissa Leach, Director, STEPS Centre, and Professor Andrew Westby, Director, Natural Resources Institute, University of Greenwich.

On 22 February 2012 the Committee took evidence from: Dr Jo Beall, Director Education and Society, British Council, Kate O'Shea, Deputy Director, UK Collaborative on Development Sciences, Sir Mark Walport, Director, Wellcome Trust, and John Young, Director of Impact Assessment, Partnerships and Head of the RAPID Programme, Overseas Development Institute.

The Committee expects to hold a further oral evidence session in June. The written evidence is on the Committee's website.

Bridging the "valley of death": improving the commercialisation of research

On 16 December 2011 the Committee announced an inquiry: Bridging the "valley of death": improving the commercialisation of research.

On 18 April 2012 the Committee took evidence from: Professor Luke Georghiou, Vice-President (Research and Innovation), University of Manchester, Dr Paul Nightingale, Science and Technology Policy Research, University of Sussex, David Connell, Senior Research Fellow, Centre for Business Research/UK Innovation Research Centre, Judge Business School, University of Cambridge, and Dr Douglas Robertson, Chair, Praxis-Unico. The Committee also heard from: Dr Ted Bianco, Director of Technology Transfer, Wellcome Trust, Dr Ian Tomlinson, Senior Vice President, Head of Worldwide Business Development and Biopharmaceuticals R&D, GlaxoSmithKline, Dr David Tapolczay, Chief Executive Officer, Medical Research Council Technology, Dr Gareth Goodier, Chair, Shelford Group (Chief Executives of ten leading Academic Medical Centres and large teaching hospitals); Chief Executive, Cambridge University Hospitals NHS Foundation Trust, and Dr Andy Richards, Serial biotechnology entrepreneur and business angel.

The Committee will announce dates for future evidence sessions. The written evidence is on the Committee's website.

Medical implants

On 26 March 2012 the Committee announced an inquiry: Regulation of medical implants. Written submissions on the following issues were invited by 26 April:

1. Are current legislation and regulations on safety and efficacy of medical implants fit for purpose?
2. How effectively does the MHRA implement the Directive in the UK?
3. How could the legislation and regulations be improved?
4. How could the European Commission ensure that potential changes to the Medical Devices Directive do not hinder the introduction of innovations in medical implants to the market?

The Committee will announce dates for evidence sessions. The written evidence received will be available 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].

Pre-appointment hearing with the Chair-elect of the Engineering and Physical Sciences Research Council

On 7 March 2012 the Committee took evidence from Dr Paul Golby, Chair-elect of the Engineering and Physical Sciences Research Council.

REPORTS

Malware and cyber crime

On 2 February 2012, the Committee published its Twelfth Report of Session 2010-12, *Malware and cyber crime*, HC 1537.

Science in the Met Office

On 21 February 2012, the Committee published its Thirteenth Report of Session 2010-12, *Science in the Met Office*, HC 1538.

Pre-appointment hearing with the Government's preferred candidate for Chair of the Engineering and Physical Sciences Research Council

On 9 March 2012, the Committee published its Fourteenth Report of Session 2010-12, *Pre–appointment hearing with the Government's preferred candidate for Chair of the Engineering and Physical Sciences Research Council*, HC 1871.

GOVERNMENT RESPONSE

Government Response to the Science and Technology Committee report 'Alcohol guidelines'

On 26 March 2012, the Department of Health published the Government and Response to the Committee's Report on Alcohol guidelines, Cm 8329.

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, Stephen McGinness, or from the Senior Committee Assistant, Darren Hackett, on 020 7219 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 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 were co-opted to the Committee for the purposes of its inquiry into nuclear research and development capabilities and Baroness Sharp of Guildford has been co-opted for the science and heritage inquiry. Lord Lucas of Crudwell and Dingwall has been co-opted to Sub-Committee 1 for the purposes of the inquiry on Higher Education in STEM subjects.

Membership of the Committee will be subject to change at the beginning of the next session in May. Please check the Committee's website for further information.

Higher Education in Science, Technology, Engineering and Maths (STEM) subjects

In September 2011, the Select Committee appointed a Sub-Committee, under the chairmanship of Lord Willis of Knaresborough, to conduct an inquiry into higher education in STEM subjects. The inquiry will consider how the UK can ensure that the supply of graduates in STEM subjects meets current and future needs, looking at 16-18 supply, undergraduate and postgraduate education and at what can be learnt from the experience of other countries. Oral evidence sessions began in December and finished in April 2012. It is anticipated that the Committee will report in the summer, 2012.

Science and Heritage Follow-up

In December 2011, the Select Committee launched a short follow-up inquiry to its report into science and heritage in session 2005-06. The Committee wrote to Government and contributors to the original inquiry to provide an update of developments since the original report in 2006 and the update in October 2007. Oral evidence sessions were held from February until March 2012. The Committee will report in May.

The role and function of departmental Chief Scientific Advisers (CSAs)

In July 2011, the Committee launched an inquiry into the role and function of Chief Scientific Advisers. The inquiry looked at a number of aspects concerning the role of CSAs including: the ability of CSAs to provide independent advice to ministers and policy makers; the extent of their influence over research spend; and their role in providing independent challenge and ensuring that departmental policies are evidenced-based. The Committee took oral evidence from October to December and published their report on 29 February 2012. The report will be debated in the House in the forthcoming session following receipt of the Government's response.

Nuclear research and development capabilities

In March 2011, the Select Committee launched an 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 focused on what the Government should be doing if they are to ensure that the UK's R&D capabilities are sufficient. It examined the R&D implications of scenarios up to 2050 and whether the UK has adequate R&D capabilities, including infrastructure, to meet its needs for a safe and secure supply of nuclear energy.

The report was published on 22 November 2011 and the Government response was received on 17 February 2012. It will be debated in the House in the forthcoming session.

Behaviour change policy interventions

In June 2010, the 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.

The Committee considered the current state of knowledge about which 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 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. The inquiry included two case studies, one on obesity and the other on reducing car use in towns. The Committee published its report on 19 July 2011. The Government response was published on 15 September. The report will be debated in the House in the forthcoming session.

FURTHER INFORMATION

The written and oral evidence to the Committee's inquiries, 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 Rachel Newton, Policy Analyst, newtonr@parliament.uk or 020 7219 2491. The Committee's email address is hlscience@parliament.uk.

PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY (POST)

RECENT POST PUBLICATIONS

Open Access to Scientific Information

January 2012 *POSTnote 397*

The internet has transformed the nature of scientific research, opening up new ways to collect, use and disseminate scientific information. This has led to increased demand for access. Open Access (OA) to scientific journal publications means making them available online, rather than charging readers. OA to research data means making research data more widely available for use by others.

Solar Photovoltaics

January 2012 *POSTnote 398*

Solar power can provide low carbon electricity. This discusses the development of solar power in the UK and summarises debate over feed-in tariffs – financial support policies introduced in 2010 to stimulate take-up.

Measuring Energy Security

January 2012 *POSTnote 399*

Security is a central aim of energy policy. In the 2010 Strategic Defence and Security Review, the government said it would strengthen delivery of energy security by "more robust reporting and monitoring". This explores ways in which energy security may be measured for monitoring purposes.

Climate Variability and Weather

February 2012 *POSTnote 400*

Short-term differences from long-term climate, or "climate variability", can increase the risk of extreme weather events. This examines the causes of climate variability and the use of climate models to predict these variations.

Biotechnology Patents

February 2012 *POSTnote 401*

In October 2011, the European Court of Justice banned patents for inventions involving stem cells derived from embryos. This highlighted some of the challenges the patent system faces when assessing biomedical inventions. This POSTnote considers how patent law is applied to biomedical inventions and examines the potential impact on patient access to diagnostic tests and innovation.

Resilience to Natural Hazards in Developing Nations

February 2012 *POSTnote 402*

In the last 10 years, over 500,000 people have lost their lives and around 1.5 billion people have been adversely affected due to rapid-onset natural hazards such as earthquakes, tsunami, floods and tropical storms.

Low Carbon Technologies in Energy Intensive Industries

February 2012 *POSTnote 403*

Energy-intensive industries such as chemicals, paper, ceramics, cement, iron and steel are responsible for 45% of carbon emissions from businesses and the public sector in the UK. This discusses carbon dioxide (CO_2) abatement technologies for these industries and policies to support their adoption.

Livestock Super Farms

March 2012 *POSTnote 404*

UK dairy and pig farmers have recently put forward plans to establish very large livestock facilities. Such proposals are controversial. This examines the issues surrounding intensification of livestock production in the UK.

Impacts of Video Games

March 2012 *POSTnote 405*

There is debate surrounding the impact of violent video games on behaviour. This POSTnote summarises the key aspects of the

discussion, and other impacts of gaming such as addiction. It examines the educational use of games, and reviews mechanisms to ensure children's game safety.

Personalised Cancer Treatments

March 2012 *POSTnote 406*

Recent advances in diagnostics and therapeutics can make the treatment of cancer more personalised. This POSTnote discusses the application of these technologies in the NHS and the challenges involved in providing such treatments.

Consumer Genetic Testing

March 2012 *POSTnote 407*

DNA sequencing is getting faster and cheaper. This has paved the way for the development of genetic tests for predisposition to diseases. These are now being marketed directly to consumers over the internet. This POSTnote explores the scientific, regulatory, and ethical issues related to such tests.

Seeking Sustainability

March 2012 *POSTnote 408*

This POSTnote summarises issues in defining and achieving sustainability.

CURRENT WORK

Biological Sciences – Review of Stem Cell Research, HIV – developments in prevention and treatment.

Environment and Energy – Heat Pumps, Bioenergy, Energy Efficiency, Drought Resilience, GM Crops and Developing Countries, Land Sharing versus Land Sparing.

Physical sciences and IT – Open Source and Open Standards, Open Public Sector Data, ICT for Disabled People.

Science Policy – Science, Technology, Engineering, and Mathematics (STEM) Education for 14-19 years old.

CONFERENCES AND SEMINARS

Natural Flood Management

On 17th January, POST organised a parliamentary seminar to follow up on POSTnote 396 on Natural Flood Management. The event was chaired by Anne McIntosh MP, Member of Parliament for Thirsk & Malton and Chair of the Environment, Food, and Rural Affairs Select Committee and the All-Party Parliamentary Group on Flood Protection. Presentations were made by: Martin Whiting, Chartered Institute of Water and Environmental Management Rivers and Coastal Group Chair; Dr Neil McIntyre, Reader in Surface Water Hydrology, Imperial College London; Dr Paul Quinn, Senior Lecturer in Catchment Hydrology, Newcastle University; and, Dr Wendy Kenyon, Senior Researcher, James Hutton Institute.

Undergrounding of Power Lines

On 31st January, POST, in collaboration with the Commons Energy and Climate Change Committee, hosted a seminar on the costs of electricity power lines. The seminar summarised the findings of an independent report on the subject, which was published the same day and endorsed by the Institution of Engineering and Technology. The meeting was chaired by Tim Yeo MP, Chair of the Energy and Climate Change Committee, and gave parliamentarians the opportunity to hear a summary of the report on the day of publication, as well as to ask questions of the authors.

Future of UK Research

On 7th February, POST hosted a special meeting of the 'Foresight Action Network' to examine the future of UK scientific research, in collaboration with the Science and Technology Facilities Council. About 50 participants from a wide range of organisations took part. The results were then reported and examined collectively. A summary will be placed on POST's website.

Parliament Talks.... Science

On 15th March, POST took part in an event discussing science in Parliament as part of National Science and Engineering Week. Organised by Parliamentary Outreach and held at the University of Leeds, the seminar featured four talks and a discussion session for an audience of around 100. The speakers were Lord Willis, Member of the Lords Science and Technology Committee; Lord Oxburgh, Member of the POST Board; Xameerah Malik, Committee Specialist for the House of Commons Science and Technology Committee; and Dr Stephen Allen, Energy Adviser at POST.

STAFF, FELLOWS AND INTERNS AT POST

Fellows

Dr Stuart Basten, Oxford University, Oxford University

Gemma Cassells, Edinburgh University, Natural Environment Research Council

Dr Craig Childs, University College London, University College London

Elena Kazamia, Cambridge University, Natural Environment Research Council

Alistair McVicar, Imperial College London, Grantham Institute

Sophie Redford, Oxford University, Science and Technology Facilities Council

Dr Sridhar Venkatapuram, London School of Hygiene and Tropical Medicine, Wellcome Trust Bioethics Programme

Edward Yoxall, Imperial College London, Engineering and Physical Sciences Research Council

Staff

Professor David Cope retired as Director of POST on March 31st after 14 distinguished years at the helm.

The Physics and IT POST adviser, Dr Chandrika Nath, has been appointed interim head of POST.

INTERNATIONAL ACTIVITIES

Dr Mara Almeida represented POST at a planning meeting of the European commission Parliaments and Civil Society in Technology Assessment (PACITA) project, hosted by the Norwegian Board of Technology in Oslo.

POST African Parliaments Programme

From 25th to 27th February 2012 Dr Nath organised a conference on Evidence Informed Policy Making along with UK NGO INASP (International Network for the Availability of Scientific Publications) and Nigerian governmental science organisation NACETEM (with support from the Wellcome Trust) from 27th February to 1st March. The conference was attended by researchers, government and parliamentary officials from the UK as well as Latin America, South East Asia and Africa. Dr Nath gave presentations on scientific advice in the UK as well as on POST's programme in Uganda.

POST and INASP are also piloting a remote mentoring scheme where staff from the Parliament of Uganda are linked up with international experts who will mentor them to produce a policy briefing for their MPs. Two pairs have been set up, working on digital switchover and solid waste management.

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

Contact Christopher Barclay Head of Section Tel: 020 7219 3624 email: barclaycr@parliament.uk

The Water Industry (Financial Assistance) Bill 2010-12 SN/SC/6234

The Bill contains two measures. One gives the Government discretion to reduce water bills in certain regions. The other gives the Government discretion to provide financial assistance for major water and sewage infrastructure projects.

Initially the Government plans to use these powers to reduce water bills in the South West of England and to support the Thames Tunnel project.

The Bill only applies to water or sewerage undertakers whose areas are mainly in England. The Bill received Royal Assent on 1 May 2012.

The Rio+20 UN conference on sustainable development SN/SC/6246

From 20-22 June 2012 the UN will hold a conference on sustainable development in Rio de Janeiro, Brazil, twenty years on from the 'Earth Summit' of 1992, also held in Rio.

Unlike the first Rio Summit, which resulted in the climate change and biodiversity conventions, along with a sustainable development action plan, this conference will focus on sustainable development. Its two themes are the 'green economy' and an institutional framework for sustainable development. One aim is to develop sustainable development goals, like the UN millennium development goals. In January 2012 a 'zero draft' outcome document was produced.

In October 2011 the Environmental Audit Committee (EAC) published its Report on Preparations for the Rio+20 Summit which noted inadequate progress since 1992.

Nuclear power SN/SC/6228

Successive Governments have pursued policies aimed at encouraging investment in new nuclear power stations.

Safety considerations will be much to the fore, prompted by memories of Chernobyl and Fukushima. A report by the Chief Nuclear Inspector, Dr Mike Weightman, provides some reassurance on the safety of existing and future nuclear stations, while counselling against complacency. In addition to ensuring the continued safe operation of Britain's nuclear power stations, disposal of the radioactive waste produced will need to ensure that radiation exposure is kept to within the current low levels. Physical security and other safeguards are in place to lower the risk that radioactive or fissile material could fall into the wrong hands.

Nuclear power currently contributes 16% of the UK's electricity supply and recent studies of its economics appear favourable – at least when carbon costs are factored in. These are low for nuclear power and renewables compared with fossil fuels. Nuclear decommissioning costs are relatively small, at least when substantial discounting of future costs is included.

It is highly likely that nuclear power will continue to make an important contribution to the UK's electricity. It will do so within a "mixed economy" of gas, coal and renewables like wind farms.

EU ETS and aviation SN/SC/5533

As part of the effort to reduce emissions the aviation sector has been included in the EU Emissions Trading Scheme (EU ETS) since 1 January 2012. This applies to all airlines which fly in and out of the EU. Emissions will be capped at 95% of historical emissions and revenues raised will be retained by Member States. It is expected that the majority of the cuts will be met by airlines purchasing international credits created through the Kyoto protocols rather than through the purchase of EU ETS credits or reducing their own emissions.

International aviation organisations and non EU countries have expressed strong opposition, with countries such as India and China instructing their airlines not to take part. This could, in the long term, lead to non compliant airlines being banned from flying to EU countries. However, the first EU ETS credits are not due to be submitted by airlines to the EU until April 2013.

Smart meters SN/SC/6179

Between 2014 and 2019 more than 50 million new electricity and gas 'smart meters' will be installed in 30 million premises. These meters, with in-home-displays (IHDs) will allow consumers to see and adjust what energy they are using.

In July 2010 Ofgem published a Prospectus for consultation on a range of proposals for the launch. In March 2011 DECC and Ofgem jointly published a Government response to the consultation and concerns raised and DECC then assumed responsibility. In April 2012 the Government issued an update on the programme, along with a new range of consultation documents and government responses.

Ofgem considers that smart metering could "transform how energy markets operate". The Government estimates that over the next 20 years, the use of smart meters will deliver over £7

billion of benefits to consumers, energy suppliers and networks.

However, the National Audit Office (NAO) and the Public Accounts Committee (PAC) have raised concerns about the risks and the potential benefits to consumers; the PAC considers the associated challenges are 'huge'.

Waste Water National Policy Statement SN/SC/6259

This describes planning policy for nationally significant waste water treatment projects such as the Thames Tunnel. It was approved by Parliament in March 2012.

Wind Farms - Distance from housing SN/SC/5221

There is concern that wind farms might be too close to houses. There are no statutory limits in the UK.

England has no separation distance, although noise limits suggest a minimum separation distance of 350 metres for a typical wind turbine. Scotland has guidance suggesting 2km and Wales suggests 500m between a wind turbine and housing. The Government has rejected the idea of a separation distance for England. Two Private Member's Ten Minute Rule Bills have suggested a separation distance.

There is no compensation for those living near a wind farm. It is not clear how much house prices are reduced when a wind farm is built nearby. There is a compensation scheme in Denmark.

An independent study concluded in 2011 that flicker was not a serious problem and Government guidance has been left unchanged. An independent study on noise has supported the Government approach.

On 27 March 2012, DCLG published the final version of the National Planning Policy Framework. It contains only very brief guidance on renewable energy applications.

Green Belt SN/SC/934

This describes the Green Belt policy, which forms an important part of British planning policy. The area of the Green Belt has not been reduced recently. Reductions in some areas have been offset by increases elsewhere. On 27 March 2012, DCLG published the final version of the National Planning Policy Framework. It contains only very brief guidance on renewable energy applications.

In 2011 the Institute of Directors called for land to be released from the green belt to stimulate house building. Also in 2011 the OECD criticised the green belt system for being an obstacle to house building.

On 27 March 2012, DCLG published the final version of the National Planning Policy Framework. It came into effect immediately, superseding the 2011 draft and all other planning guidance (except on waste). It maintains protection for the Green Belt.

Agriculture – CAP Reforms SN/SC/3680

The Common Agricultural Policy (CAP) was reformed in 2003, with minor changes in the "Health Check" in 2008. Individual schemes based on high guaranteed prices for farmers were largely abandoned in favour of paying farmers a Single Farm Payment (SFP) based upon the area of the farm. Modulation allowed SFP to be reduced so as to fund the Rural Development Plan. The 2003 reform was based upon an agreement to maintain EU spending on agricultural support until 2013.

The European Commission published preliminary ideas on the CAP after 2013 in November 2010 and more detailed plans in October 2011. The EFRA Select Committee in April 2011 criticised both the Commission's 2010 proposals and Defra's handling of the negotiations.

SELECTED DEBATES

Listed opposite (grouped by subject area) 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 10th January and 28th March 2012.

Agriculture
Common Agricultural Policy – 8.3.12 HoC 343WH

Animal Welfare
EU Directive on Animal Experimentation – 27.3.12 HoC 366WH

Education
Technology (Primary Schools) – 11.1.12 HoC 142WH
Design Education and Growth – 24.1.12 HoL 993
Postgraduate Education – 25.1.12 HoC 103WH
16-18 Mathematics Education – 27.3.12 HoC 334WH

Energy
Carbon Capture and Storage (Scotland) – 17.1.12 HoC 217WH
North Sea Oil and Gas – 25.1.12 HoC 377
Offshore Renewable Energy (East Anglia) – 31.1.12 HoC 258WH
Future of Biomass – 20.2.12 HoC 715
Clean Coal – 28.2.12 HoC 65WH
Renewable Energy – 29.2.12 HoC 100WH
South West Marine Energy Park – 29.2.12 HoC 142WH

Fisheries
Fishing Quotas – 22.2.12 HoC 326WH
Common Fisheries Policy – 15.3.12 HoC 431

Health
EU: Healthcare – 11.1.12 HoL 176
Melanoma – 18.1.12 HoC 320WH
Stereotactic Body Radiotherapy – 8.2.12 HoC 413
Healthcare Professionals – 22.3.12 HoL 1104
Diabetes – 23.3.12 HoC 1129
Para-Phenylenediamine – 26.3.12 HoL GC215

Industry
Manufacturing and Engineering – 6.3.12 HoC 199WH
Pharmaceutical Industry – 21.3.12 HoC 897
Thamesteel – 21.3.12 HoC 193WH

Miscellaneous
Green Agenda – 12.1.12 HoL 267
Intellectual Property – 7.2.12 HoC 1WH
Forensic Science Service – 27.2.12 HoC 81

Water
International Development: Sanitation and Water – 19.3.12 HoL 717
National Policy Statement (Waste Water) – 19.3.12 HoC 589
Water and Sanitation – 21.3.12 HoC 218WH

SCIENCE DIRECTORY

DIRECTORY INDEX

MSD
The Physiological Society
The Royal Institution
Society of Biology
UFAW
The Welding Institute

Motor Vehicles
Institution of Engineering Designers
The Welding Institute

Oceanography
The Geological Society
Institute of Marine Engineering, Science & Technology
National Physical Laboratory
Natural Environment Research Council
Royal Society of Chemistry
Society of Biology
Society of Maritime Industries

Oil
The Geological Society
Institute of Marine Engineering, Science & Technology
Institution of Chemical Engineers
LGC
The Welding Institute

Particle Physics
Institute of Physics
STFC

Patents
The Chartered Institute of Patent Attorneys
NESTA
Society of Biology

Pharmaceuticals
ABPI
AMPS
British Pharmacological Society
British Society for Antimicrobial Chemotherapy
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
EPSRC
The Geological Society
Institute of Marine Engineering, Science & Technology
Marine Biological Association
National Physical Laboratory
Royal Society of Chemistry

Physics
Cavendish Laboratory
Institute of Physics
Institute of Physics and Engineering in Medicine
National Physical Laboratory
STFC

Pollution and Waste
ABPI
The Geological Society
Institute of Marine Engineering, Science & Technology
Institution of Chemical Engineers
Institution of Civil Engineers
Marine Biological Association
National Physical Laboratory
Natural Environment Research Council
Royal Society of Chemistry
Society of Biology
Society of Maritime Industries
The Welding Institute

Psychology
British Psychological Society
Economic and Social Research Council
Society of Biology

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
The Linnean Society of London
NESTA
Prospect
Royal Society of Chemistry
Society of Biology

Quality Management
GAMBICA Association Ltd
LGC
National Physical Laboratory
The Welding Institute

Radiation Hazards
Institute of Physics and Engineering in Medicine
Institution of Engineering and Technology
LGC
Society of Biology

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
Economic and Social Research Council
Eli Lilly and Company Ltd
EPSRC
EngineeringUK
The Food and Environment Research Agency
GAMBICA Association Ltd
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Institution of Civil Engineers
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LGC
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The Physiological Society
Prospect
Research Councils UK
The Royal Academy of Engineering
Royal Botanic Gardens, Kew
The Royal Institution
The Royal Society
Royal Society of Chemistry
STFC
Society of Biology
UFAW

Sensors and Transducers
GAMBICA Association Ltd
Institute of Measurement and Control
Institution of Engineering and Technology
STFC
Society of Maritime Industries
The Welding Institute

SSSIs
The Geological Society
The Linnean Society of London
Royal Botanic Gardens, Kew
Society of Biology

Statistics
Economic and Social Research Council
EPSRC
EngineeringUK

Surface Science
STFC

Sustainability
The British Ecological Society
CABI
EPSRC
The Food and Environment Research Agency
The Geological Society
Institute of Marine Engineering, Science & Technology
Institution of Chemical Engineers
Institution of Civil Engineers
The Linnean Society of London
Royal Botanic Gardens, Kew
Royal Society of Chemistry
Society of Biology
The Welding Institute

Technology Transfer
AIRTO
CABI
The Food and Environment Research Agency
Institute of Measurement and Control
Institution of Engineering and Technology
LGC
NESTA
National Physical Laboratory
Research Councils UK
Royal Society of Chemistry
STFC
Society of Biology
The Welding Institute

Tropical Medicine
The Linnean Society of London
Natural History Museum
Royal Botanic Gardens, Kew
Society for Applied Microbiology
Society for General Microbiology
Society of Biology

Viruses, Fungi and Bacteria
ABPI
The Linnean Society of London
Society for Applied Microbiology
Society for General Microbiology
Society of Biology

Water
The Geological Society
Institute of Measurement and Control
Institution of Chemical Engineers
Institution of Civil Engineers
LGC
Marine Biological Association
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
Marine Biological Association
Natural History Museum
Royal Botanic Gardens, Kew
Society of Biology
UFAW

The Academy of Medical Sciences

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Website: www.acmedsci.ac.uk

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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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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AIRTO – The Association for Independent Research and Technology Organisations – is the foremost membership body for organisations operating in the UK's intermediate research and technology sector. AIRTO's members deliver vital innovation and knowledge transfer services which include applied and collaborative R&D, frequently in conjunction with universities, consultancy, technology validation and testing, incubation of commercialisation opportunities and early stage financing. AIRTO members have a combined turnover of over £2Bn from clients both at home and outside the UK, and employ over 20,000 scientists, technologists and engineers.

AMPS

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Website: www.amps-tradeunion.com

We are a Trades Union for Management and Professional Staff working in the pharmaceutical, chemical and allied industries.

We also have a section for Professional Divers working globally. We represent a broad base of both office and field based staff and use our influence to improve working conditions on behalf of our members.

We are experts in performance based and field related issues and are affiliated to our counterparts in EU Professional Management Unions.

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.

The British Ecological Society

The British Ecological Society
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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 In Vitro Diagnostics Association (BIVDA)

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BIVDA is the UK industry association representing companies who manufacture and/or distribute the diagnostics tests and equipment to diagnose, monitor and manage disease largely through the NHS pathology services. Increasingly diagnostics are used outside the laboratory in community settings and also to identify those patients who would benefit from specific drug treatment particularly for cancer.

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.

BPS BRITISH PHARMACOLOGICAL SOCIETY

Today's science, tomorrow's medicines

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The British Pharmacological Society has been supporting pharmacology and pharmacologists for over 80 years. Our 3,000+ 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 Science Association

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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.

British Society for Antimicrobial Chemotherapy

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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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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

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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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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

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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

The Council for the Mathematical Sciences

The Council for the Mathematical Sciences

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The Council for the Mathematical Sciences is an authoritative and objective body that works to develop, influence and respond to UK policy issues affecting mathematical sciences in higher education and research, and therefore the UK economy and society by:

- providing expert advice;
- engaging with government, funding agencies and other decision makers;
- raising public awareness; and
- facilitating communication between the mathematical sciences community and other stakeholders

Eli Lilly and Company Ltd

Lilly

Answers That Matter.

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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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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'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

GAMBICA

AUTOMATION INSTRUMENTATION & CONTROL LABORATORY TECHNOLOGY

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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

The Geological Society
serving science & profession

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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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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.

Institute of Marine Engineering, Science and Technology (IMarEST)

Institute of Marine Engineering, Science & Technology
IMAREST

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Established in London in 1889, the IMarEST is a leading international membership body and learned society for marine professionals, with over 15,000 members worldwide. The IMarEST has an extensive marine network of 50 international branches, affiliations with major marine societies around the world, representation on the key marine technical committees and non-governmental status at the International Maritime Organization (IMO) as well as other intergovernmental organisations.

The Institute of Measurement and Control

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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

Institute of Physics and Engineering in Medicine

IPEM

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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, RSci and RSciTech, and by the Engineering Council to award CEng, IEng and EngTech.

IChemE

ADVANCING CHEMICAL ENGINEERING WORLDWIDE

The Institution of Chemical Engineers

With over 33,000 members in 120 countries, IChemE is the global membership organisation for chemical engineers. A not for profit organisation, we serve the public interest by building and sustaining an active professional community and promoting the development, understanding and application of chemical engineering worldwide.

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Kuala Lumpur | London | Melbourne | Rugby | Shanghai | Wellington

Institution of Civil Engineers

ice

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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

iED 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.

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

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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 36 laboratories and centres across Europe and at sites in China, Brazil, India and the US.

The Linnean Society of London

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The Linnean Society of London is a professional learned body which promotes natural history in all its branches, and was founded in 1788. The Society is particularly active in the areas of biodiversity, conservation and sustainability, supporting its mission through organising open scientific meetings and publishing peer-reviewed journals, as well as undertaking educational initiatives. The Society's Fellows have a considerable range of biological expertise that can be harnessed to inform and advise on scientific and public policy issues.

A Forum for Natural History

Marine Biological Association

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For over 125 years the Marine Biological Association has been delivering its mission *'to promote scientific research into all aspects of life in the sea, including the environment on which it depends, and to disseminate to the public the knowledge gained.'* The MBA has extensive research and knowledge exchange programmes and a long history of providing evidence to support policy. It represents its members in providing a clear independent voice to government on behalf of the marine biological community.

MSD

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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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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

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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

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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

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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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PHARMAQ is the only global pharmaceutical company with a primary focus on aquaculture. Specialising in the manufacture and supply of veterinary pharmaceuticals for the global aquaculture industry including vaccines, anaesthetics, antibiotics, sea lice treatments and biocide disinfectants.

The Physiological Society

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The Physiological Society brings together over 3000 scientists from over 60 countries. Since its foundation in 1876, our Members have made significant contributions to the understanding of biological systems and the treatment of disease. The Society promotes physiology with the public and Parliament alike, and actively engages with policy makers. It supports physiologists by organising world-class conferences and offering grants for research. It also publishes the latest developments in the field in its two leading scientific journals, The Journal of Physiology and Experimental Physiology.

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

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

The Royal Institution

Ri The Royal Institution of Great Britain

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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

THE ROYAL SOCIETY

Contact: Dr Peter Cotgreave
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The Royal Society is the UK academy of science comprising 1400 outstanding individuals representing the sciences, engineering and medicine. It has had a hand in some of the most innovative and life-changing discoveries in scientific history. Through its Fellowship and permanent staff, it seeks to ensure that its contribution to shaping the future of science in the UK and beyond has a deep and enduring impact.

RSC Advancing the Chemical Sciences
The Royal Society of Chemistry

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Royal Society of Chemistry
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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.

Society for Applied Microbiology

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*Sf*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.

*Sf*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

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Head of Communications
Society for General Microbiology
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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

Contact: Dr Stephen Benn
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The Society of Biology has a duty under its Royal Charter "to serve the public benefit" by advising Parliament and Government 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

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Secretary General
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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

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Society of Maritime Industries
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London EC2R 8AY
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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

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.

The Welding Institute

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The Welding Institute creates value and enhances quality of life for Members and stakeholders through engineering, materials and joining technologies.

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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Website: www.bbsrc.ac.uk

BBSRC invests in world-class bioscience research and training on behalf of the UK public. Our aim is to further scientific knowledge to promote economic growth, wealth and job creation and to improve quality of life in the UK and beyond. BBSRC research is helping society to meet major challenges, including food security, green energy and healthier, longer lives and underpins important UK economic sectors, such as farming, food, industrial biotechnology and pharmaceuticals.

Economic and Social Research Council

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

SCIENCE DIARY

THE PARLIAMENTARY AND SCIENTIFIC COMMITTEE

Tel: 020 7222 7085
annabel.lloyd@parliament.uk
office@pandsctte.demon.co.uk
www.scienceinparliament.org.uk

Tuesday 12 June
16.30 Annual General Meeting
17.30 Discussion Meeting
Animal Experiments

Tuesday 10 July 17.30
Discussion Meeting
British Scientific Advances in the last 60 years

Autumn Dates
Tuesday 16 October 17.30
Wednesday 31 October Annual Lunch
Tuesday 6 November 17.30
Tuesday 11 December 17.30

THE ROYAL SOCIETY

6-9 Carlton House Terrace
London SW1Y 5AG
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 Royal Society at Chicheley Hall – home of the Kavli Royal Society International Centre, and other venues. Many past events are available to watch or listen to online at http://royalsociety.tv

For full details visit royalsociety.org/events:

Until 20 June
Intersections: Henry Moore and Stringed Surfaces
An exhibition of science and art

Monday 28 May 18.30 – 20.00
Do we need friends?
Café Scientifique with Professor Neil Macrae

Tuesday 29 May 18.00 – 19.45
The search for a deeper understanding of our universe at the Large Hadron Collider
International lecture by Professor Rolf-Dieter Heuer, Director General of CERN

Wednesday 30 May 18.30 – 19.30
The mechanics of memory
Croonian Lecture 2012 by Professor Tim Bliss FRS

Thursday 31 May to Sunday 10 June
The Royal Society Platform at the Hay Festival

Tuesday 12 June to Sunday 17 June
The Royal Society at Cheltenham Science Festival

Monday 18 and Tuesday 19 June
Photoactivatable metal complexes: from theory to therapy

Wednesday 20 and Thursday 21 June
Photoactivatable metal complexes: exciting potential in biotechnology and medicine?

Thursday 21 and Friday 22 June
Curiously Drawn: Early Modern Science as a Visual Pursuit

Thursday 28 and Friday 29 June
New frontiers in anisotropic fluid-particle composites

Tuesday 3 – Sunday 8 July
Summer Science Exhibition 2012
at The Royal Society, London

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

Friday 25 May 20.00 – 21.15
Free range chemistry: No added chemicals!
Peter Wothers

Thursday 14 June 19.00 – 20.30
Time warped
Claudia Hammond

Thursday 21 June 19.00 – 20.30
The long Earth
Sir Terry Pratchett and Stephen Baxter

Friday 29 June 20.00 – 21.15
The pointless universe
Michael Green

Tuesday 10 July 19.00 – 20.30
The most human human
Brian Christian

Wednesday 11 July 19.00 – 20.30
Imagining the past, remembering the future
Charles Fernyhough

Thursday 19 July 19.00 – 20.30
It's not rocket science
Ben Miller

THE LINNEAN SOCIETY OF LONDON

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Piccadilly
London W1J 0BF
Tel: +44 (0)20 7434 4479 ext 11
Visit www.linnean.org for further details

Thursday 14 June 18.00
History of Coffee
Fernando Vega
The Linnean Society of London

Thursday 21 June 18.30
Withering – the English Linnaeus and the Flowering of pharmacology
Peter Sheldon
Birmingham and Midland Institute

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NPL National Physical Laboratory | Centre for Carbon Measurement

Supporting climate research and a low carbon future

Reducing uncertainties in climate data, underpinning carbon markets and accelerating innovation

www.npl.co.uk/carbon-measurement