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"What goes up must come down", and presumably the converse is also true.

So the FTSE went down, and is now back up. Gold went up and has recently declined.

These numbers affect many, but not all of us.

Of even greater impact in the longer term for all on the planet is the atmospheric CO_2 concentration, and this is rising inexorably. We have little expectation that it will decline in the foreseeable future.

In May it finally broached the "psychological" 400ppm barrier. We know from analysis of air bubbles trapped in ice to expect average temperatures to rise by as much as 2ºC as a consequence. It is predicted that this may happen as early as 2035. The undesirable consequences have been widely publicised, as the need to reduce our dependence on burning fossil fuels, including the recently welcomed shale oil and gas. Increasing the efficiency of tidal and wind power, as well as photovoltaic, remain important scientific challenges.

Alfred Russel Wallace, the centenary of whose death we are commemorating this year, would have been fascinated by this uncontrolled experiment in changing the environment, and then observing which of the fittest survive.

While mankind as a species will make it through, there will be many who will suffer from increased drought conditions, and changes in seasonal temperatures and rainfall. We will undoubtedly need to step up our research into new crops able to cope with the new weather conditions. Fortunately, we have recently had public statements from both Owen Paterson (Defra) and David Willetts (Science), advocating that the UK (and indeed the rest of Europe) need to abandon their blanket opposition to the exploitation of GM crops. Where BRIC (Brazil, Russia, India, China) leads Britain will eventually follow!

Andrew Miller MP
Chairman, Parliamentary and Scientific Committee

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

The Parliamentary and Scientific Committee

Science in Parliament has two main objectives:
1. to inform the scientific and industrial communities of activities within Parliament of a scientific nature and of the progress of relevant legislation;
2. to keep Members of Parliament abreast of scientific affairs.

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WIND FARM NOISE ASSESSMENTS: ETSU-R-97 and The Three Legged Stool

David Unwin is a retired academic and Emeritus Professor in Geography, Birkbeck, University of London.

Richard Cox is a retired electrical engineer.

Both write in a private capacity.

English planning law does not mandate any set separation distance between wind turbines and dwellings, with the minimum separation set by use of a sixteen-year-old noise assessment methodology. In the mid-1990s the wind energy industry persuaded the then DTI to replace the usual regulatory framework for industrial noise assessment (BS4142) with an alternative called ETSU[1] specifically and only for wind turbines. Turbines being built during the mid-1990s were typically of 30-40m hub height with rotors of around 25m radius. Sixteen years on, ETSU remains unchanged but the size of the turbines now being installed has increased dramatically with hub heights of 80m and rotors of 45m radius with correspondingly very different noise generation profiles.

Wind turbine noise can be masked by existing background noise, so ETSU compares the predicted turbine noise at each at risk property with the derived background noise at these same locations over a range of winds from around 2m/s (a light breeze) to 10-12m/s (a strong breeze) at 10m above ground. If the turbine noise exceeds the background by 5dB then the property concerned is considered to be at risk. The entire assessment process is complex, requiring an understanding of basic acoustics, meteorology and statistical analysis. Clearly, it is important that this process should be based on secure and proven science, yet the science or lack of it behind the assessment process is increasingly coming under fire from engineers and scientists from different fields[2].

In essence the ETSU methodology is a three legged stool. The first leg is the measurement of the background noise at various wind speeds, the second is the predictions of the turbine noise, and the third is the comparative analysis of these data. For the first, rather than at the façade of any at risk property, ETSU asks for microphone measurement in a nearby 'free field' location at a height of 1.2-1.5m above ground. The screening effect close to a façade can result in background noise around 3dB lower than at a free-field location whereas reflection of a specific noise such as from a turbine can be 3dB higher, giving up to a 6dB difference in the developer's favour by using the free-field location.

Similarly, to prevent contamination of the data by wind induced noise, microphones should be adequately shielded but in practice this is almost never done. Wind induced noise is impossible to identify in measured noise data and will always work in the developer's favour. All this measurement uncertainty is compounded by the recommended practice of taking data over a very limited time period of perhaps only two weeks giving an absurdly limited sample of the annual noise climate at each site. Furthermore, it is increasingly being realised that many assessments should be modified to account for wind direction, for example in places where the noise climate is dominated by road traffic and so determined by wind direction and time of day.

Figure 1 shows an example of how ETSU suggests these background data are to be processed. The measured noise is plotted against the average wind speed over the same 10-minute time intervals. It is by no means unusual for the measured background noise at any one wind speed to show a range of up to 20dB around the average, equating to a possible doubling or halving of the loudness. This entire data scatter is then summarised by a 'best fit' (average) curve and the curve value at each whole number wind speed is taken for comparison with the predicted turbine noise.

There is no science to guide the choice of curve and almost any curve that gives a statistically reasonable fit can be used. This isn't science or statistics, and sometimes the result is just plain silly[3]. In Figure 1 the curve

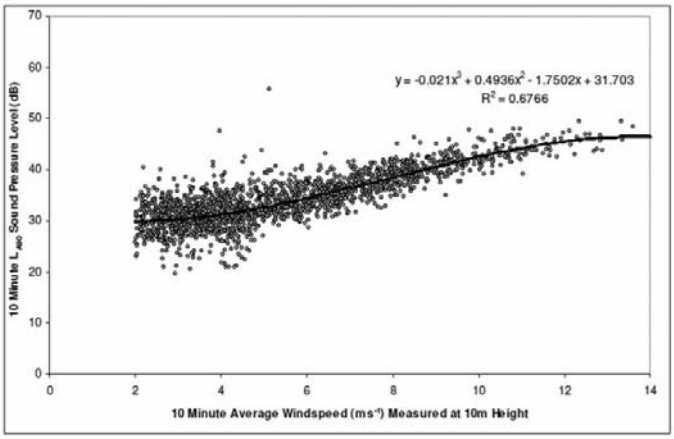


Figure 1: A typical summary plot for wind farm background noise data

suggests that in still air at the dead of night in a very quiet rural location there is a background noise of 32dB when 20-25dB would be typical. More worryingly still, due to the averaging process, at most wind speeds there is a wide range of measured values that can either double or halve the value that will be carried forward into the comparison. Worst case situations of low background noise levels are essentially ignored.

The second leg of the stool is equally unsupported by science. ETSU uses the turbine manufacturer's noise output data as an input into a very simple model based on the ISO9613-2 standard to estimate the noise propagation at distance. This standard was designed for low height, non-wind speed dependant stationary noise sources where wind shear, turbulence and wake effects are not significant. Despite claims to the contrary, ISO9613-2 has never been independently and properly validated for use with modern tall turbines in high wind shear conditions. ISO 9613 predicts a +/-3dB level of prediction uncertainty for the conditions for which it is valid, but, for high level noise sources under high wind shear, turbulence and high wind speeds the degree of prediction uncertainty is likely to be significantly greater.

The rate of change of wind speed with height, known as *wind shear,* enters into these assessment predictions twice. First, through its effect via the refraction of the sound waves, it plays a major role in the propagation of outdoor noise, an effect not considered by the current guidance. Second it affects the wind speeds at different heights used in the final comparison. ETSU assumes a constant and low level of wind shear that gives the predicted 80m wind speed as some standard multiple of that measured at, say, 10m. This ignores years of meteorological experience. More recently wind power developers have been measuring wind shear but are applying shear corrections based on average values, not worst case situations where high shear can occur for significant periods of time.

The correct way to estimate hub height wind speed is to measure wind speeds from a meteorological mast at a series of heights to find the so-called shear exponent that quantifies the change in speed with height for each and every period for which data exist and then use this to estimate the hub height wind speed. Figure 2 plots the shear exponent (alpha) against wind speed for a year's worth of data at a meteorological mast in the Midlands.

Clearly, there is a spread of wind shear exponents at each and every wind speed (negative values imply that the wind decreases rather than increases with height), much of which is due to a diurnal cycle in which the shear is at maximum at night in calm, settled conditions and at a minimum around midday. We are not aware of any analysis in the academic literature of the climatology and geography of wind shear, but our analysis of mast data at four sites across the Midlands suggests that what are normally considered to be high values are found to occur for roughly 10% of the time, usually during the evening and night time. ETSU's failure properly to factor this variation into a noise assessment results in both an under-prediction of the wind speed at the hub (and thus turbine noise) and an over-prediction close to the ground (and thus greater masking noise than is the case). This doubly disadvantages anyone living near the turbine and the result is almost certainly for wind farms to be consented at shorter separation distances than are safe.

Underlying all these concerns is a single issue that must be of concern for the integrity of the third leg of the stool in which these two data sets are compared. ETSU seems to assume that the entire process contains no scientific error or uncertainty. If true, this must make wind turbine acoustics the only exact science known to mankind other than hindsight. Using conservative estimates of the error at each step we estimate that the ETSU assessment methodology has a total uncertainty of around 9dB in the headroom between background and predicted turbine noise.

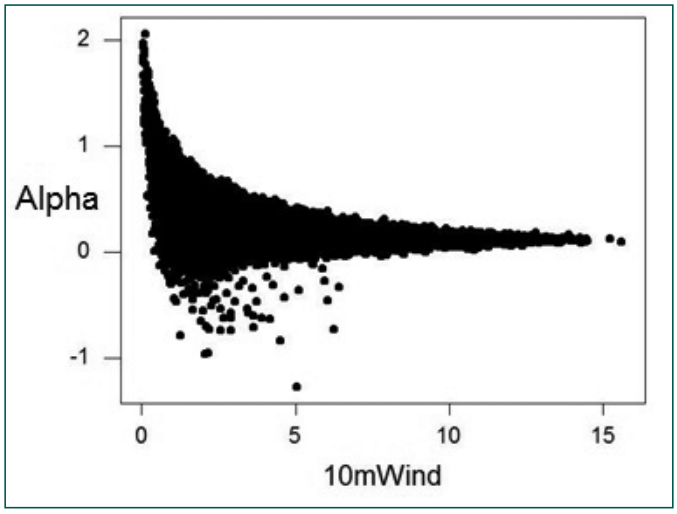


Figure 2

WHY THIS MATTERS

Today, industrial wind turbines measuring in excess of 125m to rotor tip are being sited less than 500m from adjacent residential properties, a process justified by citing noise assessments that show them to be 'ETSU compliant' but with 'headroom' of less than 3dB and even less than 1dB. This is lunacy[4]. Given the uncertainties and scope for error associated with this ageing and eccentric assessment methodology we would not be surprised to see a substantial increase in turbine-related noise complaints in years to come.

References

1: ESU-R-97 (1996) *The Assessment And Rating Of Noise From Wind Farms* (ITSY for the dti) 153 pages

2: For more details of the arguments in this note see Cox, R., Unwin, D. and T Sherman (2012) *Wind farm noise assessment: where ETSU is silent*, 41 pages, and Cox, R. and Unwin D. with Bingham, D. and R. Greenough (2013) *The 'Bad Science' behind Wind Turbine Noise Guidance* (Powerpoint Presentation, 86 slides with notes). Both are available from the author at david.unwin@onetel.net

3: Greenough, R and D Unwin (2013) A neglected source of uncertainty in potential wind farm noise assessment using the ETSU_R-97 process. (Accepted for publication in *Acoustics Bulletin*, May 2013)

4: The *Institute of Acoustics* recognised these concerns and reconvened a wind industry-dominated working group to develop draft a *Good Practice Guide* to the process. Regrettably, the result, launched in late May does not address any of the fundamental issues raised in this note.

UNDERGROUND COAL GASIFICATION - Burning coal in situ and storing CO_2

Dr Michael B Green
Director, UCG Engineering Ltd

Underground coal gasification, first tested in the Durham Coal field in 1910, is the partial burning of the in-situ coal seam to produce a usable gas for heat and power generation (figure 1). The process has been demonstrated in over 60 pilots throughout the world and a UCG power plant from the Soviet era has been operating in Uzbekistan for 40 years. Recently a revival of interest has occurred in the coal producing countries of Europe, Asia, Australasia, North America and S Africa for power generation, hydrocarbons and chemical production, driven by security of supply, advances in drilling technology and the potential for lower cost production.

The UK did its own UCG trials in the 1950s, it participated in the EU trials of 1990s, and UK companies and universities are currently involved in commercial and research projects in China, India and the EU.

The mainland of Britain still has an estimated 100BT of useable black coal and considerably more under the North Sea[1], but coal production by traditional mining methods has decreased to 17.1MT/y in 2012, while coal imports increased by 37% to 44MT/y. UCG is in a position to make a major contribution to Britain's energy supply; bringing security of supply, high efficiency combined cycle gas turbine generation (CCGT) and independence from overseas suppliers of fuel or technology.

The UK initiative on the feasibility of UCG (2000-2004) conducted by the then UK Department of Trade and Industry (now DECC) examined the environmental impact, coal resource, advanced drilling technology, economics and public perception of UCG in the UK[2]. It concluded that UCG with CCS has the potential for the exploitation of UK coal resources, particularly under river estuaries and nearshore, and identified the Firth of Forth as a leading demonstration opportunity for an industrial consortium to exploit UCG in the UK.

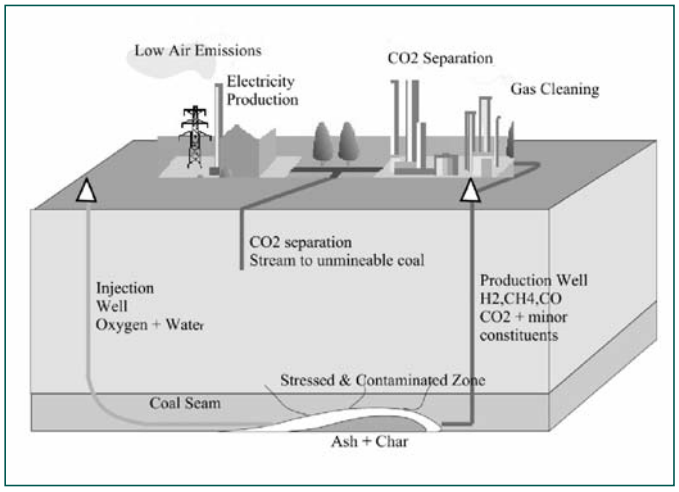


Figure 1: UCG with CCS for Power Generation

Figure 2: Exploration Areas for UCG (2012, courtesy UCG Ass)

A variety of companies, mainly UK and Australian have since taken up the challenge of UCG in the UK, and London also hosts the UCG Association annual conferences, training courses and worldwide information service on UCG. Furthermore, the UK Coal Authority leads most other countries in the licensing of UCG and has issued more than 18 provisional exploration licences for UCG in estuaries and offshore coal fields since 2008 (figure 2) in places like the Firth of Forth, the Humber and Swansea Bay. The Welsh Government and the North East Region continue to support UCG development in their areas.

South Africa has become the new focus for commercial UCG. The largest company Eskom, and the petrochemical giant

Sasol announced in June 2013 the formation of a one billion Rand (£63M) joint UCG development programme and a major African coal mining company has committed £13M for the licensing of UCG technology for sub-Saharan commercial UCG projects. Roman Abramovich has recently announced an agreement to study UCG technology to convert coal to diesel fuel in the Chukotka region of Russia in order to decrease its reliance on imports.

UCG TECHNOLOGY AND RISKS

Given the right geological conditions, the record of testing and demonstration leaves no doubt that a commercial UCG project could be developed in the UK and elsewhere, and the estimates of levelised cost of electricity (LCOE), when compared with the alternatives for power generation (figure 3) are lower. The commercial risks largely result from the absence of a fully operational UCG project, although there are many feasibility and demonstration studies around the world. Concerns about ground water contamination and the public perception of all unconventional gas (shale, CBM, UCG), both on and offshore are further risk factors. So far, there has been a lack of appetite for investment in these technologies in the UK, due to the current economic climate, but projects are moving forward overseas.

. . . the UK Coal Authority leads most other countries . . .

Advances in technology by the oil and gas industry have greatly enhanced the reliability and environmental control of the UCG process. The process wells are constructed and connected by directional drilling; ignition and control use coiled tubing engineering and advanced geo-mechanical modelling is used for site selection and monitoring support of the coal seam. Pressure control of the underground process and new techniques for well abandonment minimise the spread of contamination.

UCG has impressive credentials in the area of low carbon. Firstly, gas turbines for power generation work efficiently (>50%) with medium-calorific value UCG syngas, (hydrogen, methane and carbon monoxide) and the high pressure gas reaching the surface can be decarbonised, partially or completely, by the shift and acid removal processes (all well proven technologies) at a lower cost than for competing gas and coal alternatives. The resultant pipeline CO_2 is then available for underground storage or use in enhanced oil recovery, for example, in the North Sea. The Government's £1B power generation CCS programme, announced in April 2013, is likely to be undertaking FEED studies followed by demonstration (>300MW) of two plants using these technologies. The results are directly relevant to UCG-CCS.

In addition, research into UCG-CCS, is pointing to some interesting and novel approaches to achieve the same low carbon result. One of these is the option of storing CO_2 in the abandoned cavity. An EU supported modelling and economic study of UCG-CCS in the Dobroujda Coal Deposit, Bulgaria has shown that deep coal seams (>1,200m depth) can permanently store 20-25% of the CO_2 produced in the cavity alone, and more in the surrounding stressed strata. Storage costs are low because the UCG process and monitoring boreholes are reused and CO_2 transportation costs are virtually eliminated. Geological and hydrogeological modelling of the deposit by Bulgarian and UK scientists have shown that stress fields, contamination pathways and subsidence can be satisfactorily evaluated, and that the UCG and CO_2 injection processes will be contained within the strata.

An EU study, led by Poland (HUGE, or Hydrogen Underground Gasification Europe) found that the sequential firing of the UCG process with air followed by steam, could achieve hydrogen levels in excess of 70%, thereby partially decarbonising the product gas without expensive acid gas separation techniques. The project has recently been extended as HUGE2.

Another exciting area, with application to UCG, is the oxy-firing of gas turbines, described as a potential game changer, because only power, water and compressed CO_2 ready for storage are produced from the cycle. A British Peace Prize Winner and big players like Toshiba and the US based Exelon are engaged in the prototype development.

CONCLUSIONS

In summary, coal must be clean to survive as a long-term fuel. UCG, which achieves coal extraction and conversion to high pressure clean syngas without men underground, can meet the challenge. Innovation by the EU, the UK and others in UCG-CCS has identified process, cost and environmental impact improvements. UCG activity, leading to commercialisation in coal countries like S Africa, Central Europe and N America is under way, and the UK offshore coal resources are prime targets for exploitation by UCG-CCS.

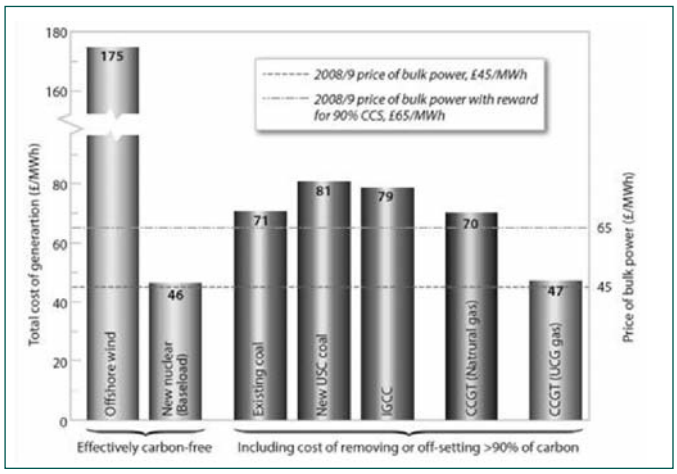


Figure 3: Costs of Electricity (courtesy UCG Ass)

References

1 A Cluff Letter to Financial Times 6th May 2013

2 Review of the Feasibility of Underground Coal Gasification in the UK. DTI Publication, URN 04/1643, October 2004.

PHYSICS AND CHEMISTRY SHOW THEIR WORTH

Dr Beth Taylor
Director of Communications,
Institute of Physics

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

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

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

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

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

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

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

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

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

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

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

HOW DOES RADIOTHERAPY WORK?

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

IMPACT

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

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

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

around 150 Gamma Knife units, which have collectively treated around 500,000 patients with brain tumours.

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

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

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

FUTURE

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

In figures

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

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

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

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

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

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

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

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

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

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

In figures

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

DO QUALITY, INNOVATION AND PERFORMANCE COMPETE OR COMPLEMENT?

Prof Sa'ad Medhat, FIKE, CEO
Professor Medhat is the founder of NEF with an established reputation for driving forward initiatives from policy through to implementation.

Dr Sarah Peers, MIKE, Director of Programmes
Dr Peers leads NEF's professional development programmes for STEM improvement and has extensive experience of engineering education at HE and FE combined with business.

NEF: The Innovation Institute is a professional body, educational charity and a leading provider of SciTech innovation and growth services to business, education and government. Guided by its Innovation Council, NEF: The Innovation Institute influences policy and supports its members, partners and stakeholders to achieve performance excellence and stimulate innovation.

Quality and innovation play vital roles for organisations to remain competitive. Quality aims for high and sustainable performance, while innovation aims for breakthrough. Although these concepts are diametrically opposed (performance equates to consolidation; innovation equates to creation), the need to ensure quality (offers that are fit for purpose) results in these concepts often being intertwined.

Creating value requires organisations continuously to develop innovative and high quality products and services, and deliver them on time and at a lower cost than their competitors. This requires employees to be creative, but also to ensure standards are met.

Equilibrium between quality and innovation is achieved by embedding cultural values and enabling characteristics that drive creativity, efficiency and responsibility. What are these, and can they be systemically nourished?

This paper outlines the role of accreditation. It also describes an approach to achieving a balance of quality, innovation and performance through recognising traits which enhance individual capability.

NEF: The Innovation Institute has developed two accreditation frameworks, namely T-shaped Technologist, and the Innovation and Knowledge Exchange (IKE), recognising that demarcation between work and study is blurring.

T-SHAPED TECHNOLOGIST ACCREDITATION

Demonstrating to prospective learners and employers that the provider supports skills that empower creativity and problem solving is a powerful differentiator.

Is accreditation by a university or college enough? Should the benchmarks used be universal to achieve recognition and value for the user?

Employers, particularly those leading in SciTech sectors, are beginning to be explicit in their requirements in recruits as well as improving the performance of the existing workforce[1]. When recruiting new graduates and technicians, employers look for personal qualities, beyond technical skills, that may be indispensable.

T-shaded Technologist Accreditation is used to demonstrate that a STEM (science, technology, engineering, mathematics) education or training programme produces fit-for-industry individuals. A matrix of capabilities, transferable skills, qualities and attributes describes what a T-Shaped Technologist for the 21st Century looks like[2]. These capabilities can be broadly categorised as:

- Technical knowledge and experience – largely discipline- and sector-specific 'know-how' combined with 'know-why', an

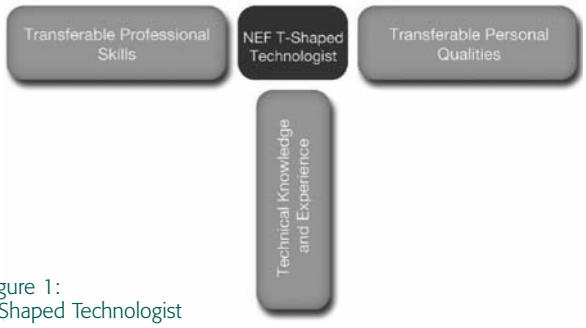


Figure 1:
T-Shaped Technologist

. . . We need to close the gap between education and industry, so as to increase employability and our ability to innovate. But how do we drive this? . . .

Dr Jonathan Reeves, Group Head of Technical Innovation, Britvic

understanding of STEM theory behind practice

- Transferable professional skills – including business acumen, and the skills related to knowledge transfer and innovation
- Transferable personal qualities – including enterprise and initiative, and some highly valued behaviours.

T-SHAPED TECHNOLOGIST

Key benefits to the T-Shaped Technologist Accreditation for providers, particularly in further education, include:

- Identifying the commitment to develop attributes valued in the workplace
- Recognising capability to deliver T-shaped learning, which is forward thinking and able to address future skills for new and emerging sectors
- Supporting employability routes
- Providing STEM programmes with a benchmark
- Delivering a competitive advantage which positions programmes as fit-for-purpose.

Graduates of T-shaped programmes are eligible for a certificate showing they are a T-shaped Technologist which:

- Provides employers with assurance that the learner is work-ready, with a level of commercial awareness and with skills beyond the purely technical
- Delivers a much more rounded package for the learners to promote themselves so increasing self-esteem and self-confidence
- Provides a differentiation for the learner when competing for positions.

The value of the T-shaped Technologist lies in articulating capabilities of interest to an employer. These capabilities can be fostered and assessed.

NEF advocates the embedding of the T-shaped Technologist model in programmes of STEM-related training at schools, colleges and universities. This supports the development of more than just technical skills. Other attributes such as initiative, learning to learn, responsibility, teamwork, the love of their discipline, an awareness of different cultures, are also encouraged. The model can be used to unearth hidden skills such as knowledge of another language, or a practical technical skill from a past job or work experience, which add value for a potential employer.

… We are passionate about teaching and learning to transform lives. Helping learners to develop skills for success beyond college is essential and T-shaped Technologist accreditation supports in this…

Simon Friend, Head of Science and Technology, South Devon College

THE IKE ACCREDITATION

To address issues of performance and growth of business and industry, NEF: The Innovation Institute has developed the IKE Accreditation framework. This integrates quality and innovation into a coherent package.

IKE Accreditation demonstrates the value and relevance of innovation skills within professional development programmes. The framework recognises the diverse needs of employers and sectors in terms of characteristics and skills required, both in new recruits or the existing workforce. It overcomes the difficulty that educational providers have in translating specific requirements of diverse sectors as well as enabling employers to articulate their needs.

…Innovation is the lifeblood of any successful company…

Ana Andres del Valle, IT R&D Manager, Jones Lang LaSalle

In addition, the IKE framework supports employers, particularly those from large SciTech industries, to develop skills not currently being used. This is yet another way in which quality and performance can drive innovation.

…We have been through many developments, from improving design to quality management. These don't guarantee performance improvement. The glue that holds quality and innovation together and links to performance improvement is behaviours…

Dave Drury, Chancellor, EDF Energy Campus

IKE Accreditation benefits employers and education providers by:

- Signifying the value of creativity and innovation within a training or CPD programme
- Maintaining a high level of consistency in the quality of training or CPD provision
- Identifying organisational ability to improve continually
- Offering reputational and competitive advantage.

Graduates from IKE accredited training can obtain a Certificate of Professionalism in Innovation. This provides recognition to employees who have led and driven innovation.

IKE ACCREDITATION FRAMEWORK

Concluding remarks

Something innovative has synonymity with improved performance and through that quality of the product is implied. Is this always true? Can the connection of innovation be enough for high quality? Is performance a determinant of quality?

There is an argument of a trade-off between quality, innovation and performance. They may compete within an organisation, depending upon strategic direction and availability of resource, but when used in a systematic way they become complementing forces that provide the organisation with a powerful position and unique capability.

References

1 Open Innovation in STEM Learning, NEF Report, Dec 2012

2 T-shaped Learning for the New Technologist, NEF White Paper, Dec 2012

Figure 2: IKE Accreditation Framework

ENGINEERING TOMORROW'S WORLD

Why Britain must Invest in Infrastructure Research

Professor David Delpy
Chief Executive, EPSRC

A society's infrastructure, like an ecosystem, is complex and interlinked. It has components developed over time, as well as more dynamic elements which are constantly renewed.

Much of the UK's physical infrastructure, roads, railways and utilities, has been built up over the last two centuries. These were built to last. However, the country has grown and changed; investment in the skeleton that supports our economy is now overdue. The Government's National Infrastructure Plan, which sets out the priority infrastructure investments, is beginning to address this issue and the research community has a key role to play, injecting new ideas and technologies that will both shape and inform choices.

Infrastructure is not just the visible structures like highways, it has many layers – communications networks, energy production, storage and transmission, knowledge transfer and learning and skills development, to name just a few. Like the systems of a human body, these perform their own tasks, but are interdependent and act collectively to form the whole. Understanding these relationships is a key challenge for researchers, planners and government.

There are demands for greener energy; better building design; smarter, faster communications and better skills in our workforce, how can we meet these? As science and research bring about new discoveries, how will they affect the texture and fabric of our society and infrastructure? We know things will look very different in 30 years' time, so how can we engineer tomorrow's world?

The scale and potential longevity of these structures is such that we have to look beyond the short term, we have to plan properly and, as we plan, we must look to several possible futures.

A successful example of this approach to research is the Mapping the Underworld project, a 10-year multidisciplinary research programme, that the Engineering and Physical Sciences Research Council (EPSRC) began funding in 2005. The initial four projects emerged from an intensive workshop that drew on academic and industry knowledge. These investigated both the use of multisensory tools to locate underground utilities, and whether accurate 3D maps could be created to aid developers. The results of the research have attracted international interest and are helping to determine new standards of training for utility mapping.

How will our infrastructure integrate with the rest of the world and how do we model this? We must ask planners, developers, engineers, builders – and the general public – what they want and need, factor in realistic timescales for financing, building and realising returns and take account of the needs of future generations. Different models will take account of variables and how society may be structured both physically and economically. We have to future-proof.

Lord Deighton, Commercial Secretary to the Treasury, recently announced two new research centres that will shape the way the UK's infrastructure is planned and implemented, with funding of £7 million from two of the UK's research councils, the Engineering and Physical Sciences Research Council (EPSRC) and the Economic and Social Research Council (ESRC).

Developing new infrastructure presents opportunities to stimulate growth and create jobs domestically, but it also gives UK academia and industry the chance to demonstrate their innovative thinking, leadership and skills to global markets. The UK has an outstanding academic research base strongly linked to industry and providing world-leading expertise in infrastructure development, planning and construction. Companies such as Arup, Laing O'Rourke, and CH2M HILL are exporting skills and generating wealth. Likewise, we have first-class skills in the development of the digital economy that has become pervasive. The Digital City Exchange, at Imperial College London, is researching how to digitally link utilities and services within a city, creating new technical and business opportunities.

To continue this trend we must fund world leading research. EPSRC supports around 350 research projects, worth more than £350 million, that relate to infrastructure across the engineering and physical sciences, from fundamental research to applied activities.

EPSRC also funds research in clean energy generation and its more efficient use, and in guarding our vital ICT services and systems through innovations in cyber security.

A case in point is the £39 million investment by EPSRC, ESRC and industry in five End Use Energy Demand (EUED) research centres to look into the complexities of energy use across society – and a further £6 million has been set aside for research into how to apply digital technologies to reduce energy demand in buildings.

Information technology has become ubiquitous and has revolutionised the way society runs. This reliance also creates vulnerabilities for our services and businesses. That is why EPSRC has, in partnership with the security services and government, invested in a new Research Institute for Cyber Security that will advise how to secure systems and safely exploit the possibilities the virtual world offers.

Just as we all need regular medical checkups, the Innovation and Knowledge Centre (IKC) on Smart Infrastructure and Construction at Cambridge, which is funded by EPSRC, the Technology Strategy Board (TSB), and industry, is using research into sensors and data management to monitor how infrastructure like London's Underground system is ageing. Using innovative manufacturing processes, the project aims to bring more efficient, sustainable and economic construction to new infrastructure.

By definition, infrastructure is a long term challenge, requiring highly-skilled experts in their respective fields. EPSRC invests over £250 million a year in developing the infrastructure leaders of tomorrow – from PhD training centres to tailored Fellowship packages for senior researchers. They will focus on addressing the complex demands of the future. An example is the EPSRC sponsored Centre for Doctoral Training in Urban Sustainability and Resilience at University College London, which is training the researchers we need to stay in front of many of the issues facing us.

The latest call for the next round of Centres for Doctoral Training includes priorities for National Infrastructure Systems and other related themes such as Energy Use in Buildings and Transport, Energy Storage and Water.

In tough times some might say that investing in infrastructure is something we could delay until economic conditions improve. I disagree; we have to gear our economy to compete with others, some of whom are already dedicating time and effort to improving their infrastructure.

We also have an obligation to the current generation and our descendants, so that they will have the resources they need to tackle future challenges. We have to play our part in the global infrastructure and produce scientific and engineering solutions that will bring benefits to Tomorrow's World.

EPSRC-SUPPORTED INFRASTRUCTURE RESEARCH

The EPSRC supports research towards a reliable, safe and resilient infrastructure that supplies the water, energy, transport, waste and communications systems essential to our society. This is crucial in facing our changing environmental, demographic and economic conditions and requires innovative solutions to ensure a healthy, productive and sustainable society that is able to support economic growth.

- Integrated project planning is vital for complex infrastructure networks, and EPSRC-funded projects such as Urban Futures, one of the activities under the £45 million Sustainable Urban Environment Programme (SUE), and Liveable Cities, a collaboration between four universities, are looking at how cities can be constructed and planned, taking a long term view of sustainability, managing natural resources and reducing carbon use.
- The Infrastructure Transitions Research Consortium (ITRC) is a partnership between seven UK universities that supports analysis and planning of national infrastructure systems. Its research addresses the major challenges facing the energy, transport, water, waste and ICT systems sectors.
- The LANCS Initiative, a collaboration of four universities, Lancaster, Nottingham, Cardiff and Southampton, is developing understanding of complex systems, including those in the transport and logistics sector.
- Researchers at the University of Cambridge have been working with industrial and academic partners to tackle some of the uncertainties associated with air traffic and the risks these pose to heavily loaded airports. They have also developed award winning technology that uses radio tags to track baggage as it passes through the airport system.

Further information about these projects and more can be found by visiting:

http://www.epsrc.ac.uk/Pages/default.aspx

Who are the EPSRC?

The Engineering and Physical Sciences Research Council is the UK's main agency for funding research and training in the engineering and physical sciences. The EPSRC invests roughly £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 to everyone's health, lifestyle and culture.

Infrastructure Business Model Centres: EPSRC and the Economic and Social Research Council (ESRC) are co-investing £7 million in two Infrastructure Business Model Centres at Newcastle and University College London.

HOW MUCH TESTING DO WE NEED?

Dr Duncan Campbell
Public Analyst for West Yorkshire
and Past President of the
Association of Public Analysts

HISTORICAL BACKGROUND

Food fraud has been around since food was traded and the further the distance that food travels the more likely it is to be adulterated. Prior to the industrial revolution it was only truly exotic foods which were routinely adulterated. The movement of people from rural areas where their food was produced into towns during the 19th century led to basic foods such as flour and milk being targeted by unscrupulous traders. At this time sugar was a luxury food as it was common to use plaster of Paris in sweets. On an occasion in Bradford in November 1858 a pharmacist's assistant made a mistake and supplied the sweet maker with white arsenic powder instead. Twenty people died in agony and another 200 people were seriously ill.

A cartoon from Punch of 20th November 1858 calling for action to prevent food adulteration.

The worsening problem led to the passing of an Act to prevent the adulteration of food and drink in August 1860. This legislation was not a success and it was not until 12 years later that a more workable statute came into force. The 1872 Act gave sampling officers powers, required authorities to appoint a public analyst, defined what food and drugs were and created the offence of "selling to the prejudice of the purchaser any food not of the nature, substance or quality demanded". This offence exists today in Section 14 of the Food Safety Act 1990. The first public analysts had a difficult job, analytical chemistry was very much in its infancy and what was actually meant by adulteration had not been defined. In 1898 it became a requirement for Public Analysts to hold a qualification and that is still the case today: the Mastership in Chemical Analysis is a competence based qualification administered by the Royal Society of Chemistry.

Moving on about 100 years we come to the creation of the Food Standards Agency. The Food Standards Act 1999 sets the main objective of the agency in carrying out its functions ie "to protect public health from risks which may arise in connection with the consumption of food and otherwise protect the interests of consumers in relation to food".

When we think of health we often think of the acute risks that arise from food poisoning be it E. coli O157 or listeria. However, there are also chronic effects, be they from too much salt in the diet, or high levels of heavy metals in seafood.

The other part of the Agency's function "otherwise to protect the interests of consumers in relation to food" covers much of the work of Public Analysts and is the area in which the horsemeat scandal rests. Is it what it says on the burger box?

LOCAL AUTHORITY ENFORCEMENT

Local Authorities play a large role in enforcing food regulations. Where there is two tier local government the district councils are responsible for enforcement of food hygiene and the counties for food standards. In areas with single tier administrations both are dealt with within the same authority. During the media frenzy around the horsemeat scandal there was much confusion about terms so it is worth just clarifying some of them.

Generally when the term food safety is used what is meant is food hygiene and the microbiological safety of food. Food standards covers non-microbiological aspects of food safety such as toxicological risks from pollutants and other toxic substances. It also covers food fraud, labelling, authenticity, diet and health as well as foreign bodies in food.

Part of the local authority enforcement activity includes taking samples, both for microbiological examination (food hygiene) purposes or for chemical analysis (food standards). As the horsemeat

. . . many criminal breaches are only detectable by analysis . . .

scandal progressed, media attention focused on the decline in sampling rates over the last few years. Notable quotes derived from the Local Authority Enforcement Monitoring System (LAEMS) returns submitted to the Agency by local authorities included "Food protection tests slashed by a third in Scotland" (Sunday Herald 17th Feb 2013). "For County Councils [in England] the number of food samples taken for analysis by public analysts has fallen by 47% in the three years to March 2012" (Yorkshire Post 5th Feb2013). "Seven million people [in England] live in areas where [Local Authorities] are not doing any [Food Standards] sampling at all." (Independent on Sunday 17th Feb 2013).

This reduction in sampling has been mirrored by a reduction in the number of Public Analysts and the closure of laboratories with four closing or ceasing to carry out official control work in the last 3 years.

The analysis of samples is only part of the controls on food but it is worth emphasising that many criminal breaches of food law, deliberate or accidental, are only detectable by analysis. Analysis and interpretation of the results of that analysis in the context of the law is what Public Analysts do. This requires a wide range of skills and instrumentation, some of which is familiar to anyone who has studied chemistry at school. At the other end of the spectrum are sophisticated and highly sensitive instruments such as a high performance liquid chromatograph coupled with a tripe quadruple mass spectrometer (LC-MS-MS) and the Real-time PCR techniques used to detect the presence of minute amounts of DNA. Most public analyst laboratories carry out other functions as well as those of official food and feed control. This ranges from air pollution monitoring to testing of consumer goods, asbestos and legionella surveying and testing, and providing scientific support to the emergency services.

There is some specialism in laboratories but its scope is limited by competition for the ever diminishing amount of official work.

FOOD FRAUD

We have all probably been victims of food fraud at one time or another. We may only suffer financially having paid a premium for wild salmon, extra virgin olive oil, organic produce or heather honey but getting a cheaper but perfectly safe product. An exception to this is in the supply of counterfeit or fake vodka where the liquid in the bottle contains one or more toxic compounds such as methanol, chloroform or xylene.

The Food Fraud Task Force in its final report (September 2007) noted "in some cases the food fraudster can apply highly sophisticated techniques and make it very difficult, if not impossible, for the public to detect that food fraud has occurred. Thus, as part of food fraud control enforcement there much be an equally sophisticated analytical service to support the food enforcement officer in the field".

There are some parallels between the horsemeat scandal and the Sudan I scare; Sudan I is a carcinogenic dye which was found in chilli powder in 2003. Laws were introduced across the EU to ensure that consignments of chilli powder were tested on entry. Then in 2005 Sudan I was found in Worcester sauce by scientists in Italy. It had been manufactured in the UK long after the problem had been identified and found its way into many different foods. A huge recall operation was carried out with 580 products being withdrawn. In the wake of this incident a review panel was set up and one of its recommendations was for the Agency to ascertain the UK laboratory capacity available to assist in major incidents such as the Sudan I scare and pursue the matter within Government if it was deemed to be insufficient.

DNA testing using the Polymerase Chain Reaction was very much in the news during the horsemeat scandal. Ten years ago there wasn't much PCR analysis going on in Public Analyst laboratories. In 2006 the Agency helped fund PCR instruments resulting in the equipment being in place in 11 laboratories. However due to laboratory closures and other factors only six laboratories were able to analyse samples for the presence of horsemeat DNA. This is a reflection of the way that official control laboratory capability and capacity is funded in the UK which is solely through local authorities spending money on analysis. As demand has fallen, so has the supply.

. . . only six laboratories were able to receive samples . . .

HOW MUCH TESTING DO WE NEED?

Although central targets are set for the numbers of inspections, none are set for sampling rates. In 2001 it was noted that this had resulted in an increase in the number of inspections but a decrease in the number of samples taken. These decisions are taken locally but, as we have seen, food and its ingredients travel long distances. Levels of enforcement both in terms of inspection and sampling vary widely across the country and there is no central strategic direction or funding to ensure that appropriate resources are in place where they are needed at a local level.

It is frequently stated that local authority sampling is risk based. In my experience this is not the case. Local authority enforcement officers will make the best use of the resources available. They do this within the constraints of available staff and budgets. This is not the same as, firstly, assessing the risks posed by the food business in their area and deciding how many suitably qualified staff are required to carry out adequate inspections and audits. Then, in consultation with a Public Analyst, deciding on the number of samples to be taken and the money required to perform appropriate analysis on them.

Some food businesses have only a local impact but many, either through their own products or supermarket own brands, will be sold across the country. Under the current system there is an unacceptably wide variation in the level of official controls. There is a need for local delivery but also for central funding and strategic direction.

CONTAMINANTS IN FOOD

Elizabeth Moran
President of the Association of Public Analysts

INTRODUCTION

Contaminants are chemical substances that have not been intentionally added to food or animal feed. Their presence in food can pose a risk to animal or human health. They may be present in the environment either in a naturally occurring or man-made form and can also be produced in food and feed during processing.

CONTAMINANTS

The most common contaminants found in food and feed are indicated below:

Heavy Metals

Heavy metals include arsenic, lead, cadmium and mercury. These metals can be naturally-occurring or present in the environment due to industrial contamination. Heavy metals occur in the environment and may be present at quite high levels in some foods like fish and shellfish, though normally in a non-toxic form. Consumption of foods containing toxic forms leads to chronic toxicity.

Heavy metals bio-accumulate particularly in meat and fish and are often found in dried herbs, spices and other foods.

Nitrates

Ammonium nitrate is a common fertiliser which can often make its way into crops, soil and water courses. Although not in itself harmful, nitrate can form nitrosamines which are carcinogenic. Nitrates are found in agricultural crops such as winter lettuce and spinach and levels need to be carefully monitored.

Mycotoxins

Mycotoxins are toxic compounds produced by moulds (myco) growing on plant products. There are several different types depending on the plant and what part of the world it is grown and harvested in. Good agricultural practice should limit the development of mycotoxins on crops but factors such as wet or damp weather, poor drying or storage conditions all lead to problems. The bad winters of the last three years in Europe have led to very high levels of mycotoxins in cereal crops. Some examples are:

- Aflatoxins – aflatoxin B1 is produced by *Aspergillus* moulds. This mould commonly grows on nuts, fruits and grains. Aflatoxins cause cancer and liver damage and are particularly harmful to birds. Aflatoxins consumed by dairy cows can lead to the presence of aflatoxin M1 in milk.
- Ochratoxin A – found on vine fruits and coffee.
- Tricothecenes, Fumonisins and Fusarium toxins are found on cereal crops such as wheat, barley and oats.

Process Contaminants

Certain chemical compounds may not be present in any of the food ingredients but are produced during processing or heat treatment as a result of chemical reactions. Some examples are:

- 3-Monochloropropanediol (3-MCPD) in non-naturally fermented soy sauces that have been made via protein hydrolysis using hydrochloric acid, and can also occur in processed meat products, bread and crackers. 3-MCPD is carcinogenic and possibly genotoxic.
- Acrylamide occurs naturally in cooked starchy foods, eg chips, bread, bakery products. It was first discovered in Sweden in 2002. It is carcinogenic and is also found in black olives and dried coffee.
- Melamine is a white crystalline powder used as a heat-retardant (eg in kitchen work surfaces). It has been used illegally as a protein substitute in pet food and infant formula from China, which led to many pet deaths in the USA, but then to the death and health problems such as kidney stones in infants in China.

> . . . proportion of GM soya on the world market has increased . . .

Dioxins

Dioxins are a group of over 200 chemical compounds containing chlorine which are persistent in the environment. Their presence is mainly due to incineration and the chemical industry. They accumulate in animals and fish and are found in meat, fish, eggs and dairy products.

Polychlorinated biphenyls (PCBs)

PCBs consist of over 200 organo-chlorine compounds with 2 to 10 chlorine atoms. PCBs were widely used as dielectric and coolant fluids, for

. . . occur in foods cooked or processed in certain ways . . .

example in transformers, capacitors and electric motors. Their use is no longer permitted in most countries but they are persistent in the environment and PCBs are harmful.

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are synthesised as a product of combustion and are found in high levels in vehicle emissions and cigarette smoke. They also occur in foods which have been cooked or processed in certain ways, eg traditionally smoked foods, flame-grilled or barbecued food, processed cereal products, dried herbs, herbal supplements and dried vegetables.

Radiation

Foods are irradiated to kill microbes in food which may be harmful to health. If food has been irradiated this must be declared on the product label. Irradiation has been abused in the past to make food which is unfit for consumption 'safe'. Commonly irradiated foods include dried herbs and spices, food supplements, dehydrated Asian meals, soups, sauces and garlic.

A maximum limit of 600 Bq/kg for radioactive Caesium has been set for foods such as wild mushrooms, cranberries and bilberries from non-EC Eastern European countries affected by nuclear fallout from the Chernobyl accident in 1986.

Genetically Modified Organisms (GMOs)

Many GMOs are authorised for sale in food and feed in the EU but their presence must be indicated. Separation of GM and non-GM commodities such as soya has become increasingly difficult as the proportion of GM soya on the world market has increased. Unauthorised GM products which have not undergone a safety assessment have also been detected in foods in the European Union including in rice products from China.

Veterinary and Pesticide Residues

Antibiotics and other drugs used in the treatment of animal disease should be withdrawn from use in good time before animals destined to enter the food chain are slaughtered. Residues of these drugs are found in meat and fish products due to inappropriate use, not in compliance with Good Agricultural Practice. Examples are the illegal use of drugs such as clenbuterol and hormones and levels of permitted drug residues above the Maximum Permitted Residue Limit (MPRL).

Pesticide residues on food can arise for similar reasons such as the illegal use of compounds like DDT or lindane and levels of permitted pesticides above the Maximum Residue Limit (MRL) due to use of excessive amounts of pesticide or use of pesticide too close to date of harvesting.

Illegal Dyes

Farmers and producers add colours to food to boost their appearance and market value. These colours may be harmful to health and not approved for food use. In 2003 Sudan red dye was found in chilli powder used in hundreds of ready meals, sparking one of the biggest product recalls ever in the UK.

Food Contact Materials

Harmful chemical compounds in plastic-ware which comes into contact with food such as kitchen utensils, containers and packaging can leach into food. Examples are primary aromatic amines (PAAs) in kitchen utensils and formaldehyde in melamine ware, eg picnic sets.

IMPORTED FOOD ISSUES

Over the last few years certain contaminant issues have cropped up with food being imported into the UK from other parts of the EU or from outside the EU (third countries). Examples are aflatoxins in peanuts and figs, ochratoxin A in dried fruit, antibiotic residues in honey from China and illegal dyes in farmed fish and spices.

SPIRIT DRINKS

The UK is currently dealing with a high occurrence of adulterated and counterfeit spirit drinks, particularly vodka. The relatively high price of alcohol and the economic recession may partly explain this. Problems encountered include counterfeit products made with industrial alcohol which can be extremely harmful if consumed, causing blindness, paralysis and death. Substitution of well-known quality brands with cheaper versions is also a big problem, particularly in pubs and night clubs.

HEALTH EFFECTS OF FOOD CONTAMINATION

Compared with the nineteenth century few people appear to die as a direct result of eating contaminated food. Some contaminants, such as lead, cause acute or chronic effects. Aflatoxins were responsible for causing acute liver failure and the death of many children in a village in Nigeria just a few years ago. But the long-term effects of consuming contaminated food are more difficult to see.

Many organic (used in the chemical sense) contaminants are carcinogenic, mutagenic and teratogenic. Consumption of very small amounts in foods over many years can lead to build-up in the body. The variety of foods consumed which are sourced from many countries around the world means that the range of contaminants the population is now exposed to is probably much greater than at any time in history. The global scale and complexity of the food chain mean that it is very difficult to monitor the levels of contaminants in food and a great deal of emphasis must be placed on traceability and paperwork. However, in the UK, testing of many food and animal feed products is carried out by public analysts for local authority food safety enforcement officers, port health authorities and the Food Standards Agency. The results of analysis show that while the majority of food contains contaminants below unsafe limits, many products do continue to give rise to problems and constant vigilance is required to ensure the safety and security of the food we eat.

TESTING FOR CONTAMINANTS

Testing of food and feed for contaminants is therefore a very important tool to be used alongside traceability and audit procedures and the UK should ensure that the amount of testing carried out is adequate to ensure the population is not exposed to grossly contaminated food on a regular basis and that future widespread contamination incidents are avoided.

. . . Good agricultural practice should limit the development of mycotoxins . . .

FSA'S ROLE IN FOOD TESTING AND ASSURANCE

Dr Patrick Miller
Head of Science Strategy and Governance, FSA

ROLE OF TESTING

Testing is part of a wider framework of checks and assurance on food that ensure food is safe and what it claims to be. This is the responsibility of food businesses to ensure that this is the case. They do this through their own controls, checks and testing.

Of course government has a role – we don't just leave the industry to it. Our role is to ensure there is effective, proportionate regulation and enforcement that helps businesses comply with their responsibilities, and to ensure there are rigorous, risk-based checks that this is happening in practice, and action where it is not.

The Food Standards Agency is the UK's Competent Authority for food. As such we have a lead and co-ordinating role, which we fulfil by working in partnership with Local Authorities (LAs), Public Analysts; Defra and other Departments, and with other scientists, the food industry and consumers.

Testing is an important part of this. But there are hundreds of thousands of food businesses in the UK – and any of the large retailers, for example, may have something like 30,000 product lines and it becomes clear that we cannot test everything.

Neither should we rely on testing as the first line of defence: that is provided by effective control and assurance over production, processing and supply chains, and by careful checking of these systems by LAs. Two key elements of this, which have proved effective in practice, are risk-based food safety systems – such as those based on HACCP (Hazard Analysis of Critical Control Points), and traceability – so that every food business has an up-to-date audit trail at least one stage back and one stage forward.

Testing can help underpin these measures. It is more efficient to focus testing on raw materials and ingredients, and key points in production to ensure process control, than on finished products – this allows you to pick up issues earlier, and to avoid wastefully producing food that later needs to be disposed of.

Alongside this we need to gather and share intelligence on risks. We also need to keep up with the science, to understand what testing is telling us and what the appropriate response is – for example, how to respond to the ability to detect increasingly low levels of material that would have been undetectable only a few years ago.

Testing thus provides an essential check that controls are achieving the desired result; it can help to provide assurance, to identify problems, and to target remedial action. We need an effective level of testing. But it is not by itself the best or the primary means of achieving control.

WHAT TESTING IS DONE?

Most food law enforcement is delegated to LAs under the Food Law Code of Practice, which requires them to have risk-based sampling and checking programmes in place. These include verifying food safety and standards controls in food businesses, and testing to reflect local and national priorities. The FSA audits LAs to make sure these programmes are effective. We also support LAs through facilitating exchange of good practice, training for officers, a fighting fund to help with enforcement with unexpected resource implications, and grants for LA tests against risk-based priorities.

. . . FSA does not control local funding . . .

There are two complementary strands of activity. First there are the tests and checks that LAs plan and fund at the local level, drawing on their detailed knowledge and experience of the food businesses in their area to target local priorities. This work is funded from local budgets. FSA does not control local funding but we work with local government to highlight the importance of food checks and

. . . meat authenticity as a priority . . .

the types of check we regard as priorities.

The second strand is the National Co-ordinated Sampling Grants Programme funded and co-ordinated by FSA, working with Defra and other departments. This provides additional funds for LAs to carry out co-ordinated testing on products and issues which are a priority at national level, based on evidence and intelligence of particular concerns. The focus is mainly on food safety risks and what could make people ill, but the programme includes checks on information and authenticity where we have reason to believe there may be problems.

In 2012/13 we provided £2 million in this programme and we will provide a similar amount for the 2013/14 programme, which includes meat authenticity as a priority. Funding can cover resource needed to carry out testing as well as the cost of the tests themselves.

Alongside this, the Health Protection Agency (HPA) funds its own laboratories to provide a resource for LAs to have testing done on microbiological safety in food, at no cost to the LA.

In 2011/12 local authorities took 78,653 food samples, which underwent 92,181 analyses by Official Control Laboratories – including 18,219 analyses on composition, 11,879 on labelling and presentation, and 55,546 microbiological analyses.

REPORTING

With all this testing, it is essential that data are shared on what's being tested and on the results. LAs report information to FSA on food and feed testing via two monitoring systems: LAEMS (Local Authority Enforcement Monitoring System) and UKFSS (UK Food Surveillance System). LAEMS covers annual summary information on LAs' statutory food enforcement activity and outcomes (total numbers of inspections and of samples, and overall compliance levels). UKFSS is used by an increasing number of LAs to record the details of individual food and feed sampling activities and results. This co-ordinated reporting gives the FSA and the LAs a picture across the UK of any non-compliant samples, and also where products get the all clear – which, let us not forget, is the majority of cases, even though testing targets areas of potential concern – and helps us to spot gaps and avoid duplication.

TESTING AS PART OF THE WIDER PICTURE

This adds up to a lot of testing, but this is by no means all that is done to check the safety and quality of the food being sold and eaten in the UK.

LAs assess food premises to ensure they are properly run, identify areas for improvement and ensure these are addressed, including through prosecutions where appropriate, and we support them in this. They also check third country imports entering the UK. This helps pick up issues before they get into the production and retail chain.

FSA carries out official inspections at abattoirs and meat plants to ensure meat hygiene rules are followed. We spend about £1m each year on our own surveys on chemical and microbiological contamination of foods. We fund the UK's statutory monitoring for dairy and shellfish hygiene and radiological safety (about £8m in 2011/12), covering thousands of tests, and we provide £1m of support to National Reference Laboratories for food and feed testing, and for training for LAs.

Defra's food authenticity programme (which moved from FSA in 2010) has funded 17 'snap-shot' national surveys on food mis-description and compliance with food standards legislation. And there are national testing programmes on residues of veterinary medicines and of pesticides in food and feed, carried out by the Veterinary Medicines Directorate and the Health and Safety Executive, each covering thousands of samples each year. FSA provides input on the testing and priorities for these programmes, and we work closely with the Health Protection Agency on their monitoring of foodborne illness.

. . . surveys on chemical and microbiological contamination of foods . . .

All this takes place in the context of work across Europe, in ongoing programmes and ad hoc exercises such as that currently under way on horsemeat. We share information with our European and international partners, which helps build up a picture of the food system and to inform future priorities. European countries share information on adverse results through the EU's rapid alert system (RASSF), so that where problems are identified, we can act quickly to remove them from the food chain.

The final piece of this picture brings me back to my first point – which is testing and assurance by the food industry on the products it is selling. We have seen in response to the horsemeat contamination that industry has carried out, and reported, over 5400 tests for horse in meat products in the space of a few weeks, and that over 99% of these are not affected. This has helped address some of the concern about the potential scale of the issue and about industry's control of its processes. It is unprecedented both in scale and in industry's willingness to share and publish its results. This kind of transparency in industry testing and assurance could be really valuable for future assurance across the food system, improving the evidence base, and helping us all to target resources more efficiently.

Alongside this we need to improve our systems for gathering and sharing intelligence on potential new concerns, both with industry and with other countries. And all this will still need to be backed up by ongoing independent checking and verification by the regulators and by local authorities.

. . . transparency in industry testing and assurance. . .

100 YEARS OF THE BRITISH ECOLOGICAL SOCIETY

Julie Hodgkinson
Festival of Ecology Manager
British Ecological Society

At the British Ecological Society's golden jubilee symposium of 1964, JB Cragg wrote that "science is essentially an art from in which a handful of inspired pioneers set the pace". The pace of academic ecology in Britain was undoubtedly set by the founders of the British Ecological Society, the world's first academic ecological society.

In the late 19th century naturalists began not only to record what they saw but to try and explain the patterns and distribution of what they encountered and the environment in which they existed. In 1904 the British Vegetation Committee was set up to review, conduct and establish a methodology for vegetation surveys. The impetus behind this Committee and its work led to the establishment of the British Ecological Society on 12 April 1913. This first meeting launched the world's first academic ecological journal, the *Journal of Ecology* to its 100 members. Since then the Society has expanded and now publishes five internationally peer reviewed journals, runs educational and policy programmes, grants and meetings and provides a supportive network for over 4,000 members.

The Society's centenary was inspired by the words of the first president, Sir Arthur Tansley FRS, in that first issue of the *Journal of Ecology*, that the aim of the new Society was to "foster and promote in all ways the science of ecology". The Society has been doing this for the past 100 years and the centenary is a chance to highlight the work of the Society and academic ecologists across the world.

. . . themed events nationwide for all the family . . .

POLICY

On 25 June 2013 the Society will be launching the latest in its Ecological Issues series entitled *The impact of extreme events on freshwater ecosystems.* The series takes a topical policy-relevant issue – in this case, the consequences of extreme floods and droughts on rivers, lakes and ponds – and provides a general introduction to the ecological science behind it. It is aimed at non-specialists and is a good example of our work in communicating the science of ecology to policymakers.

. . . great success in producing wall charts for schools . . .

JOURNALS AND PUBLICATIONS

One hundred eminent ecologists were asked to nominate the paper from the Society's journals that they felt most influenced themselves of the science of ecology. This has culminated in the publication of *100 Influential papers published in 100 years of British Ecological Society journals*. The publication shows how the scientists of the past influence the scientists of today and how the science of ecology has developed.

FOR SCIENTISTS

Ecology covers many diverse scientific disciplines, a series of cross disciplinary meetings were held across the UK in the spring on a variety of topics. These were the *Marine Ecology Centenary Symposium*, in Edinburgh, *Global change and biosphere interactions* at the University of York and *Evolutionary ecology of infectious diseases* at the Society's offices in London. Nearly 300 scientists attended the meetings.

INTECOL is the International Ecological Association which hosts a major international scientific meeting every four years in partnership with a national ecological society. From 18-23 August 2013 this meeting will come to London. There will be over forty symposia on cutting edge ecological research, over twenty workshops on policy, public engagement or skills development and eleven world

class plenary lectures. Currently around 2000 delegates from across the globe are registered to attend the meeting.

FOR THE PUBLIC

Engaging the public in an appreciation and understanding of the science of ecology is a fundamental part of the centenary. From 15 June to 4 August 2013, the Society will be celebrating with its first Festival of Ecology. In partnership with over sixty organisations, the Festival includes over 120 ecological themed events nationwide for all the family. Events range from a celebration of urban trees in Manchester to a bee survey across the north east, learning more about the habitats of Wales, to exploring the marine ecology of the Scottish Islands, ecological workshops from Newtownabbey to Kent as well as exhibitions, talks, activities and walks. Partners include institutions such as the RSPB and Wildlife Trusts to international museums such as the National Museum of Wales to universities and small volunteer led institutions.

Copyright Buglife

The Society had a garden at the RHS Chelsea Flower Show in May 2013 on the topic of alien species and which of these had been introduced since 1913. Over 2000 people came to the stand to learn more about the science of ecology.

EDUCATION

The Society has had great success in producing wall charts for schools and non formal learning groups. These charts highlight certain ecological issues and show the relevance of ecological science across many different disciplines. The wall charts are *Food, food and more food* focusing on food security, *The competition for life on earth* which is concerned with the ecology of pests and disease, *How diverse is life on earth?* on the diversity of organisms and *Is there life beyond earth?* which shows how extreme environments on earth can tell us about extreme environments in other worlds. The charts were accompanied by a series of competitions. Over 32,000 charts have been distributed.

The Centenary celebrations are only just beginning, for more information please go to festivalofecology.org

SUPPORTING EXCELLENCE IN SCIENCE EDUCATION:

What role can commercial companies play in supporting schools and colleges?

Dr Mark Jones
Director, RLC-lab

RLC-lab is a commercial SME company providing chemical analysis and research support services to a diverse range of companies in the pharmaceutical and fine chemical sectors.

From the outset we were keen to develop a company based on commercial activities to fund in-house research projects and provide free support services for schools and colleges.

In 2011 we set up a unique chemical analysis service for A-level Chemistry and BTEC Science students. The service is free to schools and colleges in the UK.

The aims are:

- to give students access to modern laboratory technology
- bring the theory alive with real data – add value & excitement
- generate positive competition – students comparing data
- provide the teacher & students with an independent measure of their laboratory skills
- build links between Schools, Universities and commercial partners

At school the students are taught about advanced laboratory techniques as part of their course – but for the majority this is limited to a paper exercise. The service gives students access to the real thing – the same technology used by pharmaceutical companies.

Inspire students with modern laboratory technology

The service is based on an outsourced model – common practice in industry but rarely encountered in the education sector.

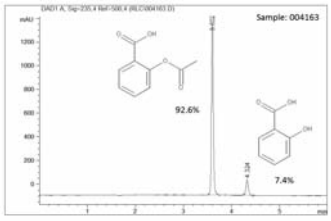
The process is simple:

- The teacher registers online at www.rlc-lab.com and requests barcoded plastic sample vials. There is no limit to the number of samples or the number of experiments
- The student places a small amount of their product in the vial and the samples are returned to RLC-lab in the addressed packaging provided
- RLC-lab performs the chemical analysis – the data are reported online via a secure account for the school. Teachers and students login to view and download their data

The recent SCORE report highlighted a list of concerns about the lack of support for practical science lessons in schools and colleges. I would add another concern to that list – we need students to gain experience of relevant *modern* laboratory skills, as used in industry, to compete in a global market. Due to cost and resource constraints UK students are limited to older, seldom used techniques. For example, when performing a chemical synthesis the key questions the student needs to answer is a) has the reaction worked and b) how pure is the isolated compound. For the majority of students the only technique they have access to, to answer these questions, is a melting point measurement – an important and useful technique to learn – but is it really relevant to *modern* laboratory work life? Short answer….no and not a very interesting technique (when performed in isolation) to excite students and encourage them to consider a career in science and technology.

Bring the theory alive with real data – your sample – your data

An example of the data format that the students can generate when using the service is shown below – HPLC analysis of aspirin sample



Following a successful pilot study, supported by the Royal Society of Chemistry (RSC), the service has now been rolled out to all schools and colleges in the UK.

The best measure of the impact of the service is the feedback we receive from teachers.

Jacquie Hanmer, Robert Smyth Academy, said: "I cannot emphasise how wonderful it is for students to be able to see real data on their products. I used it as an example on open day and it generated huge amounts of interest".

Dr Claire Badger, Haberdashers' Aske's School for Girls, said: "This has been of real benefit to our students … these methods are on the syllabus but to see a method applied to their own samples makes it real".

The most important part is to work in partnership with the teacher – provide the resources and the right level of support to enable teachers to inspire their students.

Using automated equipment and protocols, we have the capacity to support all schools in the UK – using commercial know how to deliver a national outreach programme at low cost.

Universities and learned societies play a vital role in outreach programmes – providing guidance and numerous resources with emphasis on encouraging widening participation (WP) in regions where progression to Higher Education is traditionally low.

Once established we were keen not to operate the service in isolation – we wanted to work with like-minded partners to add value and resources to ensure 'best practice' with respect to working with schools and to address WP concerns. This has been achieved through our partnership with Loughborough University and the Royal Society of Chemistry. Our aim is to maximise uptake of the service and to develop other STEM resources in partnership with teachers.

The service is sponsored by RLC-lab, Loughborough University and the RSC.

On a personal level I really enjoy working with enthusiastic teachers and students. I would encourage other SME companies to use their expertise and resources, based on a similar collaborative model, to help inspire the next generation of scientists, technologists and engineers.

HOW TO MEASURE SPEED

Dr Michael de Podesta MBE
National Physical Laboratory

Michael de Podesta considering the possibilities of the NPL-Cranfield acoustic resonator – the most accurate thermometer in the world.

Measurement is the comparison of an unknown quantity with a standard amount of that quantity. So when we weigh 250 grams of flour to make a cake, we are comparing the mass of flour with the mass of the international prototype of the kilogram. When an engineer measures the temperature of steam to be 337°C, they are comparing the temperature of the steam with the temperature of the triple point of water. This simple idea, when applied with ingenuity and thoroughness, transforms our vision of the world.

Viewing the world through the lens of precision measurement brings our scientific vision into sharp focus. It allows us to see clearly the beautiful patterns in nature, and to compare them with our expectations – and so refine our model of reality. Measurement is a simple idea but one which is central to our scientific world view.

So let us look at precision measurement of speed. We describe speeds as 'fast' or 'slow', but these assignations are anthropocentric. By 'fast' we mean some measurable change has happened in a 'heartbeat' or a 'blink of the eye'. And by 'slow' we mean something which shows only a small change in a 'long' time, perhaps one 'year', one orbit of the Sun, or a 'lifetime' (hopefully) one hundred orbits of the Sun.

But we see phenomena taking place with a vast range of speeds. Things which appear instantaneous to humans are just 'very fast', and we find that tiny differences in ultra-fast speeds can be of profound significance. Similarly processes which are slow enough can appear to be stationary. But precision measurement can reveal even the slowest of motions – and the results can again be of the most profound significance.

The figure shows the range of speeds which are significant for human beings – a range of over 18 orders of magnitude! Shown as dots are the speed of (a) sprinters, (b) bullets, (c) neutrinos, (d) bridges, (e) continents and (f) sound. We will look in turn at how each of these speeds is measured.

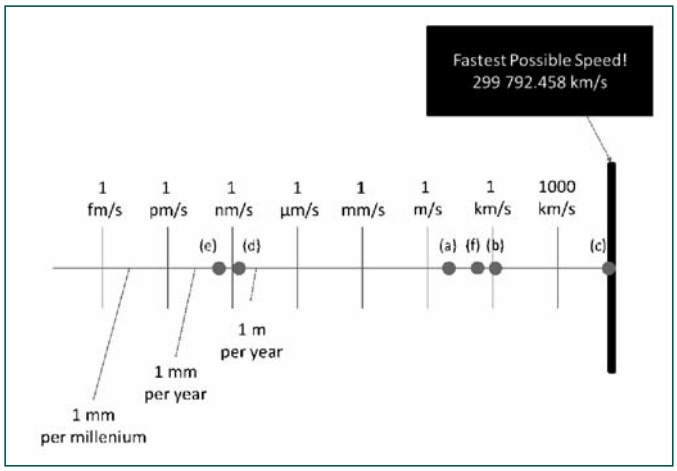
. . . tiny differences can be of profound significance . . .

The timing of a sprint race is easy to understand. A starter fires a gun and the 'bang' is supposed to start the race fairly. However, sound travels through air at approximately 340 metres per second so that a runner on the far side of a 10 metre running track would hear the gun approximately 0.030 seconds later than the runner on the near side of the track. Such a gap – 30 milliseconds – is the difference between winning and losing in many races. For this reason, the starting 'pistol' is now electronic, and it triggers a sound which is played from a loudspeaker directly behind each runner. This 'pistol' also starts 'the clock'.

. . . difficulty in accepting that continents move . . .

The 'clock' is stopped by the first runner breaking a beam of infrared light shone across the finish line. This records the winning time but does not detect who has won! This is determined by a 'photo-finish' system of beautiful ingenuity. A camera captures a picture of the finishing line – just the finishing line –1000 times each second. The images of the finishing line are then stitched together to make an image that looks like a distorted photograph, but is in fact a technical record revealing the time at which each athlete crossed the line.

Bullets are faster than athletes but they are still timed photographically. Cameras not-so-different from those commonly used to capture movies at 30 pictures per second can be 'super-charged' to capture movies at up to one million frames a second. But each image needs lots of light to allow the passage of the bullet



. . . brings our scientific vision into sharp focus . . .

to be recorded. It is at this point – where the apparently instantaneous pulse of a camera flash appears as a slowly brightening and fading light that we truly leave the realm of speed that is appreciable to humans.

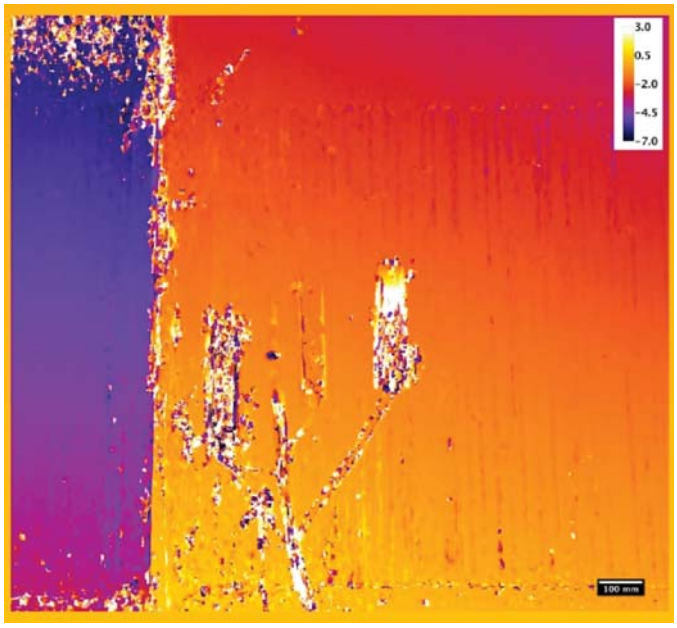
And so to the timing of neutrinos, possibly the oddest particles humans have discovered. They have a lower mass than even the electrons which whizz around every atom in the universe. Neutrinos interact so weakly with ordinary matter that they routinely travel through the Earth without anyone noticing. As a student I wrote an essay on the breath-taking experiment in which neutrinos were first detected! Now we can time neutrinos routinely. Recently it appeared as though neutrinos were travelling faster than 299 792 458 metres per second – the speed at which light travels through a vacuum.

The experiment in which this appeared to happen is complex. Protons (ionised hydrogen atoms) were accelerated in Switzerland and fired into a target which emitted neutrinos. The beam of protons was vaguely pointed towards the Gran Sasso laboratory in Italy, some 730.53461 kilometres away, a distance known with an uncertainty of 20 cm. Over three years approximately 100,000,000,000,000,000,000 neutrinos were emitted in well-timed bunches. This is a number so large that it makes the UK national debt look small!

However, only 0.000 000 000 000 016% of the neutrinos were detected (16111). Nonetheless, instead of taking 2.436801 milliseconds to reach the detector – they took just 2.436741 milliseconds.

In the end this discrepancy was resolved by the discovery of a loose cable which delayed a signal by seventy nanoseconds in a way which no one had considered possible. But the lesson of this experiment is that precision experiments test our expectations of the world. It is only because of precision measurement that anyone dared to check our expectations that nothing can travel faster than light. And if they had been right, the textbooks would have had to be re-written, and our conception of the entire universe would have changed. So, although that didn't happen, that is the power of precision measurement – to make, or break, our most strongly-felt convictions about the world.

So let us now consider something at the opposite end of Figure 1 – something we generally consider to stationary: Bridges. However, if you have ever stood on a motorway bridge while a lorry passes you will realise that bridges move all the time. And temperature changes cause bridges to change shape too. Both vibrations and environmental changes cause bridges and other civil engineering constructions to change over time – something which is of obvious interest to engineers concerned with the safety of such structures.



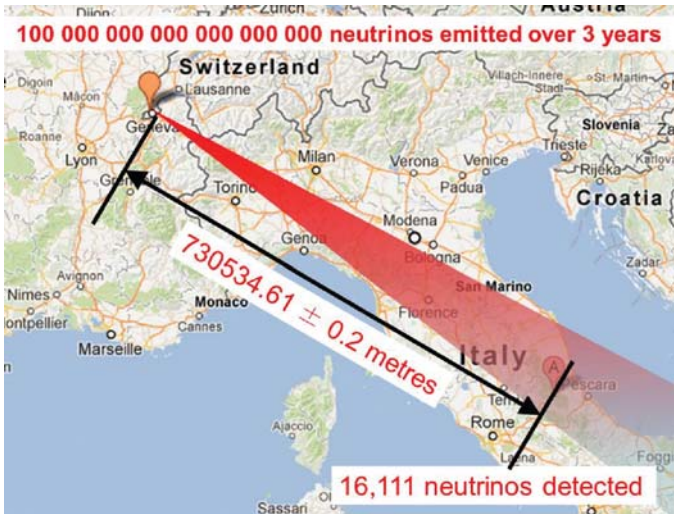
A colour-coded photograph of two concrete components on a bridge showing that the slab on the left (purple) has moved approximately 7 mm with respect to the slab on the right.

Once again photography comes to our aid. Photographs taken from precisely the same location days, months or years apart can detect the slow motion of structures – a few millimetres a year of motion can be quickly detected. This is simpler and cheaper than installing and monitoring arrays of strain gauges and allows the detection of movement in unexpected places.

We appreciate that bridges move, but the idea that continents can move is more challenging. And the story of how we came to understand that not only can they move, but that they are still moving now is no less astounding. From early suspicions based on the shapes of the facing coast of Africa and America; through research showing matching rock and fossil types; to our modern theories of plate tectonics. This gives us a real insight into how science advances.

The fundamental difficulty in accepting that continents move is because their motion is so slow compared with a human lifetime – and the moving parts are so large compared with human perceptions. There is no way we could become directly aware of this motion. Or so it seemed.

Radio telescopes listen to periodic signals from rotating stars called pulsars. A beam of radio waves from such a star



The path taken by neutrinos fired from CERN towards the Gran Sasso Laboratory in Italy.

. . . sound travels through a gas at a comfortable rate . . .

sweeps past the Earth every second, and these signals are analysed by radio telescopes around the Earth. When the signals from widely separated radio telescopes are compared, a small adjustment must be made for the delay as the beam sweeps from one telescope to the other. Analysis of this delay shows that the time difference is changing because the position of radio telescopes is changing as the continents on which they sit are moving.

The movement is slow – typically 20 mm per year or one tenth the speed at which hair grows – but it is real and can be monitored week by week.

My own measurement speciality is the speed of sound. In contrast to the extremely slow and the extremely fast events described earlier, sound travels through a gas at quite a comfortable rate. Fast enough that we are not conscious of the delay as someone speaks, but slow enough that we can hear 'echoes' in large rooms. What is often not appreciated is that the speed of sound in a gas is directly proportional to the average speed with which the molecules of the gas are moving. And because the temperature of a substance is related to the speed of motion of its molecules, a precise measurement of the speed of sound in a gas can enable a measurement of its temperature.

For the last 6 years, my colleagues and I at NPL have been working to make such a measurement. Our measurements – the most accurate ever – will enable a new definition of the units of temperature (the kelvin and the degree Celsius) in the near future. This will link the unit of temperature to measurements of molecular speed and energy – and provide a foundation for future improvements in temperature measurement.

SPEED

FAST HORSES, ROBOTS AND NEUROTECHNOLOGIES: Discovering how to go fast on legs

Dr Andrew Spence
Lecturer in Biomechanics, Structure & Motion Laboratory,
Royal Veterinary College

Understanding how animals move is one of the grand challenges of modern science. It has broad impact on society: it affects our ability to explain the biological world, to treat human and animal disease, and to aid those recovering from injury. The more we know about how biological systems control their movement, and how different organs contribute to locomotion, the better we will be able to treat those with neurological disorders or musculoskeletal injury, and to inspire new technologies, such as legged robots.

Movement is critical to health and quality of life. The total NHS spending on musculoskeletal and neurological disease in 2007 was £7.4bn (Featherstone, 2010; www.policyexchange.co.uk). Circulatory problems and mental health together cost the UK £17.2bn, and a significant fraction of this cost will have its roots in mobility; movement is central to maintaining both good circulation and mental health (Halliwell, 2005; Mental Health Found. London). We hope to lay the foundation for medical advances that improve our ability to treat those facing a lack of mobility, increasingly important as our population ages, and thus have a huge impact on the quality of life of many millions of people.

Locomotion is the signature behaviour of animals. In the face of an unpredictable environment, noisy signals from sense organs and noisy forces from muscles, animals are able to move with speed, dexterity and robustness. Yet for one of the most important types of movement, fast terrestrial locomotion on legs, we do not know how sensory information is used to stabilise the body, or how we manage our noisy muscles. Stability may be largely handled by the mechanics of the body; sensory input may still be incorporated, but on longer time-scales; or, rapid locomotion may be constrained by motor noise.

We are working to uncover the mechanisms by which animals (including humans!) achieve their extraordinary feats of dexterity, in the face of these constraints. To do so, we employ advantageous techniques and technologies from diverse fields: robotics, computer science, mathematics, zoology, evolutionary and cellular and molecular biology. If we can discover the mechanisms that enable legged animals to go fast, robustly and economically, it will have a dramatic impact on medicine, technology, and our

understanding of the world around us.

A COMPLEX, DYNAMIC PROBLEM

When a horse gallops at 20 metres per second its hooves may be on the ground for as little as 90 milliseconds (Fig 1). This is not enough time for signals to come from sense organs on the horse's leg up into the spinal cord (or brain!), for the nervous system to perform a corrective computation, and for signals to be sent back out to muscles, to develop forces that compensate. This means that fast moving animals face a big challenge: can they use this feedback in the next step? Can they use it to change what other legs do? Or are they forced to ignore it altogether?

Exciting hints to how they remain stable have come from basic biology. In a famous experiment, Jindrich and colleages (Journal of Experimental Biology, 2000) perturbed fast running cockroaches by placing a small cannon on their backs, and firing it as they ran quickly. They discovered that the cockroaches recover not through reflexes, but through mechanical tuning of their bodies, legs, and overall locomotion. Just like a car having a tuned suspension to absorb the impact of potholes, evolution can tune the mechanics of fast moving legged animals to handle perturbations with the animal's "chassis," or body! This has major implications for our understanding of the control of fast locomotion, and how animals must overlay feedback on their tuned mechanics.

But this presents a major obstacle to our understanding of how the nervous and musculoskeletal systems work together to produce locomotion. For us to interpret accurately what the role of each of these subsystems is, we need to examine independently and manipulate each subsystem, in an intact, freely behaving animal, in an ethical way. Understanding how each subsystem works in the context of all of them is important not just because history teaches us that linking across subsystems is a reliable way of gaining insight into the whole system, but because disease and injury frequently affect only one of these subsystems, or organs within a subsystem, at a time.

AN INTEGRATIVE, MULTIDISCLINARY, SYSTEMS APPROACH

So called "systems" approaches, where scientists think about how phenomena occur in a broader context, as opposed to drilling down to smaller and smaller constituent parts, are not just proving critical to our understanding of cells and molecules. They are accelerating our understanding of how whole organisms, including humans, move and behave. And they may provide the key to overcoming the problem of understanding the coupled, complex phenomenon of fast legged locomotion.

It is an extraordinary time to work in the neuromechanics of movement, because several new fields of science are converging to make possible more rapid progress. First, we are beginning to formulate quantitative, predictive mathematical models of how animals move, that integrate from molecular processes in the brain and spinal cord, through muscles and the skeleton, all the way out to the forces that limbs exert on the outside world. We are in the early stages, but the fact that we have mathematical models that make testable predictions, despite the complexity of the problem, means that we have a solid foundation to work from.

. . . seeking to build prosthetic limbs . . .

Second, legged robots have matured to become fantastic physical models of moving animals that can bring unprecedented insight into the mechanisms underlying locomotion (Fig 2). Two of the major limitations in animal locomotion research are that 1) the experimenter cannot control the behaviour of, or systematically the body conformation of, the animal, and 2) it can be unethical to perturb freely running animals to the point at which they are likely to fall over, even though this is the most important point for helping with, eg, understanding how humans fall over.

Robots can overcome these limitations. Using legged robots that we know move in a similar manner to animals (like the RHex robot seen in Fig 2, a six legged, dynamic running cockroach inspired robot), we can programme them to use exactly the type of controller that we hypothesise the animal is using, and therefore control the behaviour of the "animal." We can bolt on different legs, or add mass to different parts of the robot, to understand their effects on locomotion. Furthermore, we can then perturb the robot to the point of falling, and in doing so without using animals, we are contributing to the three R's of animal welfare: replace, reduce, refine. Where our robots are decent models of moving animals, they can completely replace the need for animal experiments.

Third, slow motion video cameras have become cheap, and open source libraries for automatic tracking and analysis of video using computer vision software have matured. This means we can gather and analyse large data sets of more and better quality motion than ever before. These technologies allow us to explore and model the extraordinary feats of animals that escape the naked eye.

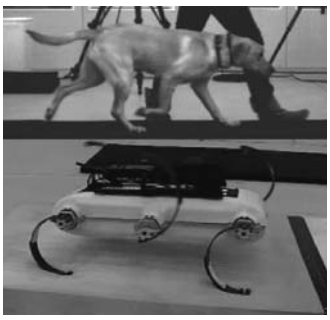


Figure 2

A BRIGHT FUTURE

A fourth and final technology is driving a revolution in neuroscience, and we are working to bring about another one in the neuromechanics of animal locomotion. It is called optogenetics, and in many ways it is the stuff of science fiction.

With optogenetics, specific sets of neurons can be switched on or off very quickly using light. By using genetic tools, we can specify which sets of neurons express these light switches. One of them, Channelrhodopsin, allows us to make neurons fire

Figure 1

when we shine blue light on them. Another, Halorhodopsin, allows us to silence neurons with yellow light.

To understand the neuromechanical basis of locomotion, we need to turn on and off specific parts of the nervous system on the millisecond time scale. The extraordinary, revolutionary capabilities of optogenetics mean that, for the first time in human history, we have the technology to do this.

Furthermore, we can do it in our close mammalian cousin: the mouse. It is revolutionising neuroscience because it allows us to study the function of parts of the nervous system in a causal manner. Optogenetics and movement are a perfect combination because optogenetics can work quickly and reversibly. By combining optogenetics with a neuromechanical approach to locomotion, we can see an exciting future ahead in which we can really tease apart how different systems (neural, mechanical) contribute to locomotion.

CONCLUSION

Over 100 types of peripheral neuropathy have been identified, and many of these illnesses predominantly or exclusively affect the sensory (viruses and bacteria, including shingles, cytomegalovirus, and the Epstein-Barr virus) or motor (spasticity, essential tremor, autoimmune disorders such as multifocal motor neuropathy) nerves. More and more, we are seeking to build prosthetic limbs that interface directly with the patient's body. Thus, the more we understand our bodies and the signals that the nervous system uses to control them, the more we can help people with neurological problems or injury. An exciting aim indeed.

SPEED

SPEED – OF COMPUTERS

Professor Alistair Fitt
Pro Vice-Chancellor (Research & Knowledge Exchange), Oxford Brookes University, and Council member, Institute of Mathematics and its Applications

The majority of people alive today cannot remember life without computers. They know that computers dominate our lives, affect most of our everyday actions, and allow us to connect to the world via the internet and live digitally-dominated existences. They also know that, within their living memory, computer speed and storage have always increased, device size has always decreased, and nothing has ever looked like stopping the relentless advance of computer technology. Current petaflop machines (capable of performing over 10^{15} floating point calculations per second) allow us to make calculations of hitherto undreamed-of speed and accuracy, and the technological advantages of being able to perform such calculations are legion.

For more than 40 years the predictions of increasing computer power supplied by the famous "Moore's law" have served us well, but is there a limit to the march of computing progress, and what are the current important challenges? The huge energy consumption of modern computers is one real issue, which will assume increasing importance as the industry approaches exascale (10^{18} Flops) capability. As increases in basic CPU clock speed falter, ever more complicated technology is needed to ensure that Moore's law still holds, and this will require huge future investment in research and skills. Ultimately, theoretical physics (and in particular quantum theory) places limits on what may be achieved.

Finally, and possibly most intriguingly, will computers ever "wake up"? The possibility of a so-called "technological singularity" where computers become so powerful that they develop a kind of consciousness has engendered serious academic debate, and cannot be ruled out. If this were to happen, would it prove to be a blessing or a curse for humankind?

COMPUTERS ALWAYS GET FASTER

We can all argue about the identity of "the first computer". The Chinese abacus of 200BC, the 1822 Babbage difference engine, the enigma-cracking Bletchley Park COLOSSUS of 1943 and the 1944 Los Alamos ENIAC machine that calculated the details of the Hiroshima atomic bomb all have their claims to being "the first proper computer". One thing that we all agree on is that computers always get faster.

How do we measure how fast computers calculate? Computing speed is usually measured in Flops (Floating Point OPerations per Second), and historical increases in speed have been awesome. The NASA Gemini guidance computer

of 1963 ran at a peak speed of 7,000 Flops (7 KFlops), the first megaflop (10^6 Flops) machine was the CDC 6600 in 1965, the CRAY2 of 1985 was the first gigaflop (10^9 Flops) computer and the 1996 INTEL ASCI RED boasted a peak speed of over a tera (10^{12}) Flops. The November 2012 speed champion is the Oak Ridge CRAY XK7, with a peak speed of over 27 petaflops, giving an awesome 27,113,000,000,000,000 sums per second. Figure 1 shows the increase in computer power over the years: the "N=1" line gives the speed of the world's most powerful computer at that time, the top line gives the sum of the power of the top 500 computers, and the third line traces the evolution of the speed of the world's 500th-fastest computer. The figure also compares supercomputing speed with our current familiar devices: for example, it takes an average of only 6-8 years for the world's most powerful machine to become relegated to 500th place, and my current laptop would have been the world's most powerful machine in late 1993.

What can we do with all this computing power? Many important calculations that were completely beyond us just a few years ago can now be carried out. Highly sophisticated climate change models can help to predict what we need to do to conserve our planet. The calculations carried out by the Large Hadron Collider to confirm the existence of the Higgs boson require the interpretation of mind-boggling amounts of data, and the power of current CFD (Computational Fluid Dynamics) calculations mean that F1 racing teams now rely more on simulation than wind tunnel testing to inform car design. The current capabilities of computational biology and medicine mean that important experiments can be carried out not in vitro or in vivo, but instead "in silico". Bioinformatics (including gene sequencing), social science data analysis and the processing of digital classics assets all require the huge computational power that is now at our fingertips. Our everyday devices are now so powerful that an HTC mobile phone recently won a grandmaster chess tournament. These are all wonderful achievements, but they beg an obvious question, namely whether or not this relentless technological advance can continue, and if so, for how long.

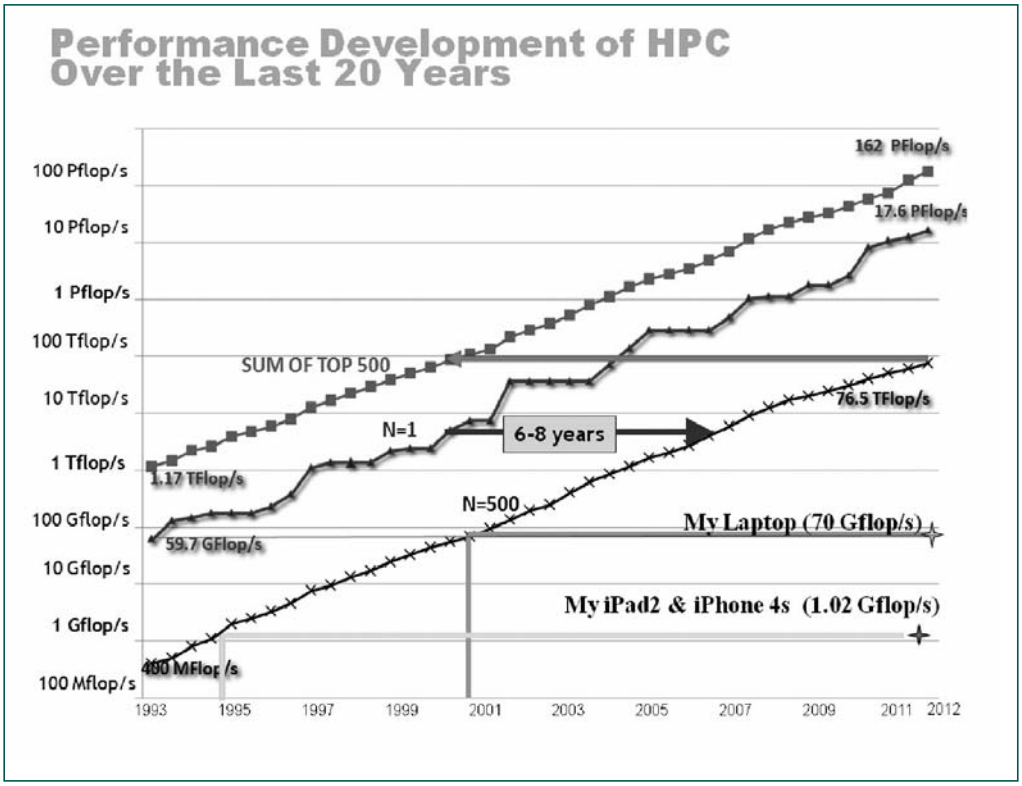
. . . mobile phone recently won a grandmaster chess tournament . . .

WILL COMPUTER SPEED ALWAYS INCREASE?

Many economists have debated what might happen if computer speed were to stop increasing, and the general consensus seems to be that a halting of the speeding-up process could have negative financial consequences, which could lead directly to a global recession. What are the most important barriers to continual speed increases? Many believe that the main things that we should be worrying about can be summarised fairly simply as energy challenges, infrastructure & skills, and natural limits.

First, modern computers use a great deal of energy. Put very roughly, CPUs expend energy doing two activities: floating point operations and moving data around. Though each of these in itself uses only minute amounts of energy, a petaflop machine does each of them in such vast quantities that its energy requirements are ferocious. The 2011 USA McKinsey/Uptime report on data centres estimated that the electricity consumption of an average data centre is equivalent to that of 25,000 households, and the worldwide data centre consumption doubled between 2000 and 2006. This leads to worryingly large carbon emissions: for example, the world's data centres currently emit more tons of CO_2 per annum than major countries such as Argentina and the Netherlands. If an exascale machine is to become a reality, this will require major advances in energy efficiency.

The often-misquoted Moore's law (an observation in a 1965 paper by George Moore, Intel's co-founder) says that the number of components in integrated circuits doubles approximately every two years. Though Moore's law has proved uncannily accurate for over 40 years, there is a great deal of evidence to show that this is unlikely to continue for much longer. As a result, some of our biggest challenges concern the provision of the necessary infrastructure and skills as Moore's law fails. Moore's law has held for many years essentially because of increases in underlying CPU clock speed, and that has now clearly stopped. As a result, Moore's law can only be achieved now via



(Courtesy of Jack Dongerra, Tennessee)

multicore processors, hyperthreading and the use of massively parallel architecture. Unfortunately much of industry uses legacy systems that have been developed over many years. The UK software business (worth over £3bn per annum) faces the huge challenge that almost *all* software will need to change to reflect the new architectures. Research and skills are crucial to these changes, and worldwide investment is urgently required.

. . . worldwide investment is urgently required . . .

Inevitably, there are natural limits to what can be achieved. Nothing can grow exponentially forever, and we are already facing barriers imposed by basic physics. Transistors will soon have to be produced on a quantum scale and be just a few atoms large; circuit etching is limited by the 50nm wavelength of UV light, and hitherto unforeseen quantum complications such as the Heisenberg uncertainty principle and electron leakage from wires will have to be dealt with. The challenges are truly enormous.

"TECHNOLOGICAL SINGULARITY" – THE KRAKEN WAKES

Finally, it is worth debating whether computers will ever become "conscious". As humans we set great store by the fact that we are conscious, living beings – but what are the essential differences between our brains and a computer? Could it be that we are no more than extremely sophisticated robots? Many have debated this exotic question without coming to a conclusion. Nevertheless, eminent computer scientists regularly discuss so-called "Technological Singularity" theory, which countenances the possibility that, at some time in the near future, superhumanly intelligent computers that are in some sense "awake" will develop. Further, large computer networks and their associated users may combine to become an intimate and sentient, superhumanly intelligent entity. One result of this could be that biological science finds ways to improve on the natural human intellect. Some aspects of Technological Singularity theory are rather scary. Some of its exponents refer to the "post-human" era. It has been noted that there is no reason why a conscious, superhumanly intelligent computer should be friendly to humankind. Serious scientists across the world believe that it is only a matter of time before the singularity occurs.

CONCLUSIONS

For many years Moore's law and increased miniaturisation have combined to guarantee that computer speed and capacity increase. However, the days of the improvement via hardware are drawing to a close. We still need investment in supercomputer hardware and data centres, but even more we need investment in research, infrastructure & skills, and software development. The future is still rosy, but the strategic plan forward is becoming ever more complicated and the stakes could not be higher.

SPEED

National Science and Engineering Week Seminar on Thursday 21st March

We also heard from Lord Drayson (a previous Minister for Science) about his development of superfast electric cars. This included a film of him accelerating from 0-100mph in just over 3 seconds!

The final talk was from Professor Steve Jones (UCL), the well known geneticist and writer. He gave an amusing account about the rates of migration of snails (and hence their genes), and then segued into human populations, and in particular the surname "Jones".

AN OASIS IN THE DESERT – The growth of a Science Base in Qatar

Dominic McAllister
UK Science & Innovation Network (Gulf)

The UK Science & Innovation Network has recently appointed an officer to cover the Middle East Gulf region. Based at the British Embassy in Doha, Dominic McAllister covers UK S&I links with Qatar, Saudi Arabia, United Arab Emirates, Kuwait, Oman and Bahrain. He writes about his early experiences of Qatar. You can follow him on twitter @UKScienceQatar.

Coming to a new posting in the Middle East after three years in Seoul has been a big shift for my family. We aren't new to the region – my daughters are proud of the fact they were born in Riyadh. We had some expectations, but returning after 15 years has been an education. The rate of modernisation in Doha was the first revelation. A forward looking royal family, a relatively cohesive society, and a steady investment of income from gas and oil reserves are principally responsible. Doha is literally emerging from the desert (in many places the pavements are still sand). The traditional souk has been rebuilt, but is now air-conditioned. The

peaceful waterfront Corniche provides an escape for families at weekends.

A second revelation was the impact of modernisation on a culturally conservative population. The Qataris are a minority in their own country. Estimates suggest they are 300,000 from a total of 1.9 million. Doha is an expatriate city with all the conveniences of a Western society. Modernisation has affected the Qatari population in both positive and negative ways: easier access to higher education is leading to new employment opportunities for women; changing diets and the advent of fast food have resulted in growing obesity levels – Gulf States have some of the highest levels of diabetes and other metabolic diseases (genetic factors also play a part); fast cars and an array of driving styles result in one of the highest levels of road deaths; and lack of Arabic sources of information on the internet and in the media is leading to a decline in the use of Arabic in the Qatari home. The challenge for Qatar's leaders will be to modernise while maintaining a Qatari identity. They have a lot of ambition. Qatar will host the World Cup in 2022 and is bidding to host the Olympic Games in 2024. Over the next ten years Qatar will invest up to £147 billion in new infrastructure including sports stadia, a metro system, new roads, and new utilities (electricity, water, ICT).

Qatar also plans to invest 2.8% of its expanding government budget on research. It wants to diversify from its oil and gas industry base and sees investment in science and technology as key to the development of a knowledge economy. The biggest challenge remains the size of Qatar's human capital. Tertiary education uptakes are low and those pursuing science-based degrees outside engineering are a minority. Qatari women dominate research, but often have cultural restriction on travelling and studying overseas. The domestic science base will always be small, but is conveniently concentrated around Doha which presents an opportunity to develop a streamlined science, technology and innovation sector.

The research environment divides between a traditional centre based at the segregated Qatar University and a modern centre based around the co-educational international branch campuses at Education City which is home to the Qatar Foundation (QF). Qatar University has expanded research into: environmental studies (ESC), gas processing (GPC) and advanced materials (CAM). Education City hosts international branch campuses from UCL, HEC Paris, Georgetown, Carnegie Mellon, Weill Cornell Medical, North-western, Texas A&M, and Virginia Commonwealth. These focus on undergraduate training (except UCL), but are keen to develop postgraduate courses to support research. QF is currently launching the Hamad bin Khalifa University which will provide postgraduate training and research in partnership with European and US partners. Education City hosts a number of research centres focusing on: environment and energy (QEERI), ICT (QCRI), biotechnology (QBRI) and cardiovascular medicine (QCRC). It hosts the Qatar Science and Technology Park (QSTP) and will be the home of the new SIDRA Research and Medical Centre.

R&D investment to date has lacked an over-arching plan, but this is changing. In October 2012 Qatar launched its R&D strategy in four key areas; energy & the environment, healthcare, ICT, and social sciences & humanities. Qatar is keen to solicit UK advice to ensure research funds are spent wisely and to show the Qatari people the value of this investment.

UK/Qatar research interests are strong and are set to expand. David Willetts visited Qatar and UAE in March and agreed plans to establish high level education and research dialogues. The UK Government is looking to develop a range of research partnerships linking UK research strengths to Qatari and UAE development needs. In Qatar Imperial College has a research partnership through its Carbonates and Carbon Storage Research Centre on QSTP (£47 million over 10 years) – this is Imperial's largest overseas investment. It is also a partner in the Qatar Biobank Pilot Project at the Hamad Medical Corporation (£6 million over 3 years), a robotic surgery centre, a stroke repository, and a cardiovascular research centre. Imperial has links with the new SIDRA Research and Medical Centre. The British Library has signed a £8.7 million Gulf-archive project with the Qatar National Library to digitise and catalogue BL records of the region and to carry out conservation research.

The UK has a good record (second only to the US) in attracting grants from the Qatar National Research Fund (QNRF) National Priorities Programme in partnership with local research centres. In April two UK/Qatar research projects – to expand the Qatar Exoplanet Survey and to help manage the weight of Qatari school children – won QNRF exceptional funding worth £3.85 million. In its five years of operation 43 UK institutions have linked up with Qatari partners to secure 47 QNRF grants worth up to $1 million each over 3 years. Up to 35% of this grant can be spent in the UK. A number of UK institutions are bidding into the sixth round of the Programme, the result of which will be announced shortly.

Qatar's infrastructure development also provides an innovation platform for new technologies. This week BHR Group are leading a water technology mission to Doha composed of SMEs with expertise in telemetry, pressure management, leak detection and water quality that can augment existing water supply systems. Their objective is to get innovation specified in the tender documents for new water supply projects. The Embassy is also pursuing similar technology initiatives in green construction, rail and food security. Qatar scores highly on a range of business indicators (stability, effective government, relative absence of corruption and a booming economy) making it a good destination for R&D investment. Doha is also fast becoming an ICT hub.

Qatar is keen to associate new science investment to an Arab Scientific heritage with its links to Western enlightenment. The Doha Museum of Islamic Arts has been working with UK partners to stage exhibitions: 1001 Inventions – The Enduring Legacy of Muslim Civilisation (Shell) and Arabik Roots (Royal Society). Astronomy has strong Arabic links. Lord Rees, Astronomer Royal, visited Doha in February to give the keynote speech at the 1st Doha International Astronomy Conference jointly organised with St Andrews University and Qatar has announced plans to set up a space museum.

Prospects for closer UK/Qatar and UK/Gulf R&D collaboration look bright. The challenge for SIN Gulf, the Embassy, the British Council and others will be to raise awareness among UK stakeholders of this significant opportunity.

UK SCIENCE AND INNOVATION NETWORK IN USA

A Special Scientific Relationship: Strengthening the Eight Great Technologies through International Collaboration

Earlier this year, David Willetts, the Minister for Universities and Science, identified "Eight-Great Technologies" in which the UK can become a global leader: Agri-Science, Big Data, Regenerative Medicine, Advanced Materials and Nanotechnology, Synthetic Biology, Robotics and Autonomous Systems, Energy and Energy Storage, and Commercial Applications of Space. Ensuring the UK is at the forefront of these technologies will require strong international collaboration and UK scientists working together with the best in the world. The UK Science and Innovation Network (SIN) supports this by working with eminent scientists abroad to try and help remove some of the barriers to international scientific collaboration. A reflection of the strength of UK science is that there are many British scientists in prestigious positions abroad. This helps SIN tremendously in achieving its goals of promoting UK science and facilitating collaborative research in support of HMG's agendas for prosperity and growth. Los Angeles and SIN Chicago interviewed two leading British scientists who are currently working in the United States in the "Great Technologies" of Regenerative Medicine and Nano-Technology.

Dr Andrew McMahon
Director, University of Southern California Broad Center for Regenerative Medicine and Stem Cell Research

Interview by Sally Mouakkad, SIN Los Angeles

Q: What attracted you to your current post at the Broad Center?

A: The opportunity to harness the full potential of the University towards a collective goal of regenerative medicine. At a scientific and translational level, regenerative medicine engages basic researchers, engineers, clinicians and computational scientists. The biological processes involved provide compelling examples for our educational mission that resonate from high school student to clinician. Questions raised by research and its application have ramifications well beyond biomedicine to business, law and public policy. Regenerative medicine is the type of global challenge that is the lifeblood of a great University.

Q: What are the greatest challenges in US-UK collaboration in this field of research?

A: The simplest is funding. Why should any investigator put time and effort into developing any partnership that has no sustainable future? If there is to be success in fostering collaborations, this has to be underpinned by funding that is earmarked for this. Given a means by which collaboration might be fostered, other issues raise their head – intellectual property sharing, regulatory body oversight and of course distance – there remains no substitute to face-to-face meetings for cementing collaborations.

Q: Where is there the greatest opportunity to strengthen US-UK relations in this field, and what mechanisms would you recommend?

A: A Funding mechanism that challenges UK and US scientists to develop teams that are greater than the sum of the parts with translational regenerative medicine as the clear target. The difficulty here is what is this word "translational". Not all regenerative medicine is ready for the patient. Retinal pigment epithelial implants for macular degeneration are. Cell transplantation for chronic kidney disease is not. We should not hobble the development of new therapies for the broad range of degenerative diseases by insisting that all funding ends up at an in patient end-point. At the same time we should ensure that the patient is clearly part of the basic research strategy. Meetings help to develop funding mechanisms to support trainees moving across countries. Clinical research is generally stronger in the US where the physician scientist has been a strength of the medical system. Enabling young clinicians in the UK with a strong interest in the research pipeline to train in the US would be particularly useful. Regenerative medicine should be a target for bringing in the brightest of this group.

Q: What project are you currently undertaking?

A: Personally, developing approaches to tackle kidney disease. There are no effective therapies aside from a kidney transplant to treat chronic kidney disease. We know how the kidney works, we know how the machine is formed during development, but we don't know as much about the normal systems that maintain kidney function and repair acute damage. The normal mechanisms of kidney development, maintenance and repair, provides knowledge for designing new therapeutic approaches to treat kidney disease.

Q: What's the greatest future challenge in the regenerative medicine and stem cells field?

A: To turn knowledge into cures. To change the therapeutic options available to treat injury and disease. Regenerative medicine may employ cells directly to treat disease – the bone marrow transplant is a familiar example. But, equally, regenerative medicine utilises stem cell approaches to model disease, increasingly with the use of patient specific cell types that can replicate disease in a dish. There is enormous potential to gain insights from this type of disease modelling and to develop screens for drugs and biologics in well controlled laboratory conditions with the right model. The approaches underpinning regenerative medicine have

made man the primary model system. Up until now we have used surrogate systems in the hope that they reproduce human biology. The limit is our ingenuity to model our own systems ex vivo.

Dr Amanda Petford-Long
Director, Centre for Nanoscale Materials, Argonne National Lab

Interview by Jack Westwood, SIN Chicago

Materials scientist Dr Petford-Long moved from Oxford to Argonne National Laboratory in 2005 and has been Director of the Center for Nanoscale Materials (CNM) for 3½ years. Dr Petford-Long is a Fellow of the Royal Academy of Engineering and maintains strong ties to the UK.

Q: What attracted you to Argonne and your current position?

A: Argonne was looking to expand their electron microscopy efforts to maximise their strong research in magnetic materials. The opportunity was a great fit for me as there is a large concentration of this research at Argonne and at nearby Northwestern University and the University of Chicago. I was lucky enough also to be able to take a Professorship at Northwestern that allowed me to continue teaching, which is something I loved at Oxford. The CNM has been a perfect fit for me – I have my own research group, which works on magnetic and ferroelectric nanostructures and microscopy and I am close to many of my major industrial collaborators.

Q: What are nanoscale materials and why study them?

A: At a very small, or "nano" scale, materials behave differently. The study of nanomaterials is much more than miniaturisation – we are discovering how changes in size change a material's properties. For instance, red stained glass actually contains gold nanoparticles that alter the wavelength of light as it passes through. Sunscreen contains nanoparticles of titanium oxide that interact with light and prevent UV reaching the skin. Research efforts over the past decade have enabled us to make single nanoparticles – current research efforts are focused on putting different nanoparticles together to make devices and turn nanoscience into nanotechnology.

Q: Nanoscience was recently identified as one of the "Eight Great Technologies" that Britain excels at – what challenges will nanoscale materials help solve?

A: When you look at the list of the 8 technologies, nanoscience really does cut through all of them, and will truly help solve grand challenge problems. Energy is a big one for us. By reducing the distance that electrons have to move, nanomaterials will produce batteries with greater storage capacity. It turns out that the smaller things get, the bigger instruments you have to use to look at them and the more data you produce – CNM is therefore generating truly "big data" and managing this is a huge priority. Nanoscience is also important outside the physical sciences – we are helping to develop a novel cancer treatment with nanoscale magnetic discs which attach to tumour cells and destroy them. So our scope of work at CNM is pretty vast!

Q: What makes the CNM unique and how does it compare to other research facilities?

A: CNM is one of the Department of Energy's scientific user facilities – we provide free expertise and access to our equipment to around 450 industry and academic users per year from all over the world. To gain access, users write a short peer-reviewed proposal. If approved, there is free access providing research is published in the scientific literature. What's unique about the CNM is that users gain not only access to equipment but also expertise of world-leading scientists who will add value and provide support to the projects.

Q: How international are the activities? What is the extent of the interaction with the UK?

A: We have a very international base of users and currently have 18 projects from 7 UK institutions – although we would like to encourage more, especially from industry. The challenge is in letting the international community know about our capabilities, and that it's free for researchers to use. Prof Greg Wurtz from King's College London was formerly chair of our users' executive committee and is currently working with a researcher here to set up a joint student programme between Argonne and King's College London. It would be great to see more UK researchers using the CNM as we have a concentration of facilities and expertise that is not available in universities. Perhaps this is something the Science and Innovation network will be able to help us achieve.

Q: How similar or different is the way science in done in the UK vs the US and how do they complement each other?

A: In the universities, there's a lot of similarity. There is a realisation in both countries that it is now difficult to work in isolation: the days of a single researcher bravely fighting alone are largely behind us. A key difference is the extensive network of National labs in the US, and I believe this is an excellent way to do research. Team science and establishing a critical mass of researchers in one place allows us to work together to solve grand challenge problems. The main commonalties in both countries are the desires to discover, learn and train the next generation of scientists.

Q: Physics can be a difficult subject to engage the public with. How important is outreach in your work?

A: We take outreach very seriously and are committed to engaging with the public. Argonne has held open days where the public can come on site and see firsthand what we do – these have attracted up to 20,000 visitors in a single day! At CNM we participate in "Introduce a Girl to Engineering Day" where young women are linked up with a mentor at CNM and given projects to work on – we hope to inspire young women to consider the physical sciences as a career choice. We also engage with politicians and dignitaries, which is an important part of our work – we recently gave a tour to the Chicago's British Consul-General and we hope to use opportunities like these to build our links outside the US.

Q: Some of the best outreach sometimes comes from more unusual activities – CNM recently helped to solve one of Art History's great debates – how did this come about?

A: We teamed up with the Art Institute in Chicago to figure out what kind of paints Picasso used –a longstanding debate amongst Art Historians. A tiny flake of paint was removed from one of Picasso's pieces and given to us for analysis. We used our unique X-ray nanoprobe to look at the composition of the paint in the flake which revealed that Picasso had used ordinary house paint rather than more expensive artists' paint and solved the mystery!

EQUIPPING THE YOUNG FOR LIFE IN WORK

Ian Morris
Director, British Fluid Power Association

Machine Shop and Printing

A lot is being said, and done, in Great Britain at this time to encourage the young to take greater interest in forging their career in our manufacturing/engineering/science industries. Indeed those very industries are crying out for technically trained staff at all levels. Technicians, engineers, scientists are in great demand and it is fair to say that many of the UK's major businesses are stepping up to the plate and training in ever increasing numbers. However, success is surely the best base from which to build further success thus this piece is not intended to criticise but to add something to the good work already in place.

. . . success is surely the best base . . .

Recently the P&SC held a discussion on skills in the STEM area and relating the effects across science and engineering, although there is no one best way the common agreement suggests that if the student is enthused and this is maintained then success will be the result.

This short article is not intended to exercise the many philosophies and theories which abound regarding apprenticeships and training, but to show how technical training is achieved in two schools in Northern Italy. The pictures were taken in Bologna and Verona at two unrelated schools. These are schools not colleges of further education, but both have a long history of exposing their students to the industrial world.

This is not exclusive to Italian education and equally good examples of such teaching may be seen at UK establishments, such as the JCB Academy in Rocester which has demonstrated the benefits of preparing the young for work. However, establishments such as the JCB are still very much in the minority, although one could reflect that the technical schools which we used to have were based on a similar ethos. One day maybe learning from the past will become acceptable.

. . . exposing their students to the industrial world . . .

The pictures were taken mainly in the mechanical engineering section of both schools, but they show the scale of commitment not just from the education system but from the industries which actively support the process. Many industrial processes were evident from Building, Electrical, Mechanical Engineering, Printing, Computing, Control Systems and much more.

Some outstanding examples were the machines which had been donated by companies giving the students the opportunity to experience a packaging machine first hand, or see a litho press working. Indeed the metrology equipment seen in one school would leave many companies green with envy and all of it was being used, not just gathering dust. To increase the utilisation many companies send their staff to these schools in the evenings for additional training; this brings income to both the school and those members of staff that wish to take up the opportunity.

Creating such an atmosphere in education is undoubtedly special and has been shown to be so in some areas of the UK. The many benefits of exposure to industrial processes at an age when the working world is to a large extent a mystery cannot be overestimated. The JCB Academy and others have started to redress the situation in the UK and must be applauded for their work. It was clear that other countries are very much further down a long road.

. . . many companies send their staff . . .

Controls room and Metrology

SKILLS – An industrial perspective

Julian Braybrook
Director of Strategy and Development, Measurement Research, LGC
http://www.lgcgroup.com/

'Do not train to learn by force or harshness; but direct them to it by what amuses their minds, so that you may be better able to discover with accuracy the peculiar bent of the genius of each', Plato.

Society depends on the nurturing of learning and development of each of us, as individuals. In today's society we should be able to rely on a good science, technology, engineering and mathematics (STEM) education to help us understand, develop and manage the increasing technological changes that face us. As an economy, we trade in a global market against countries which have pursued STEM-growth over much longer periods of time. The challenge critical to our economic growth therefore is to create a sustainable workforce with STEM qualifications.

The Government's Industrial Strategy highlights those economic sectors seen to offer future value to our economy through growth:

- advanced manufacturing and related services (especially the aerospace, automotive and life science industries, but also the emerging industries)
- digital/creative industries
- knowledge-intensive traded services (professional and business services)
- enabling industries (energy, low carbon economy and engineering/construction industries).

With a current 20% of the workforce in science-based roles across all sectors of the UK economy, there is therefore expectation of a need for a 20-25% rise in this workforce by 2030 (representing almost 60% of the new jobs, pre-2017) to meet demand. Yet we face science-skilled workforce shortages already of 200,000, rising to >500,000; technician shortages have already been documented.

. . . strong interdisciplinary collaboration . . .

Whilst the skills required by this workforce differ between the different sectors and career levels within them, it is possible to identify broad translational skill requirements:

- technicians able to work with cutting edge scientific techniques
- graduates able to adopt a common scientific language of statistical enquiry, when undertaking and communicating discovery and innovation
- researchers able to understand the need for strong interdisciplinary collaboration and commercial opportunity and related financials.

LGC, formerly Laboratory of the Government Chemist, is a science-based company operating in a variety of international markets which underpin the safety, health and security of the public and the regulation of industry, for both public and private sector clients. With its origins as a customs laboratory and privatised in 1996, LGC has since grown nationally and internationally from a £15m, non-profit organisation to a >£200m, 20% profit organisation. Its workforce has increased 20% during the last year to almost 2000 people (70% UK-based and 30% international), an almost 8-fold rise since privatisation. Around two-thirds of its workforce is science graduate or post-graduate level representing many disciplines from academia, public sector organisations, the third sector and industry, with its science quality having been retained as an important ingredient of success.

During this time certain common skills shortages have become evident across the organisation in our applicants/recruits:

- sufficient key principles of core practical training
- ability for self-motivated problem solving
- attention to detail
- strong written and oral communication skills
- exposure to an industrial environment.

As a fast-growing organisation in changing market sectors, there are additional, more particular, skills requirements and

. . . skills shortages have become evident . . .

challenges that are currently being faced:

- well-developed business skills such as communication, negotiation, sales and business development
- key project management skills to deliver quality data in time and at cost
- the pace of technological development and growth means skill demands have had to be resourced in a timely fashion to avoid the potential for outstrip of supply
- dependence on a secure supply of strategically important skills leads to a natural nervousness over the on-going and future supply of scientists.

Two case studies from the company highlight the approaches that we as an industry have faced.

LGC Forensics, the UK's largest, full-service forensic science provider, now operates in a highly commoditised marketplace. Fashionable sector-specific, multi-disciplinary qualifications at Masters level have generally shown themselves to be insufficiently appropriate. We therefore wanted to make a change to the way that we recruit forensics scientists; we saw an opportunity for school leavers, with the right training, to offer a real contribution to our business. We therefore recruited our first cohort of 20 apprentices.

LGC chose the optional units from the lab technician framework so that the technical certificate (teaching qualification) was a BTEC in Applied Science (Forensic Science) equivalent to two A levels – awarding body, EDEXCEL – and the NVQ was also equivalent to A level or level 3 standard – awarding body, PAAVQSET. The Royal Society of Chemistry (RSC) Registered Science Technician Award was added by ourselves as external validation of the programme, as we didn't just want to deliver what was needed, rather something that was an example of best practice.

. . . an opportunity for school leavers . . .

LGC enriched the 18-month apprenticeship framework by offering training in a range of other areas, including courtroom training and general forensic awareness, crime scene and disaster victim identification awareness, blood pattern recognition and exposure to a body bequeathal centre.

Many of the apprentices out-performed original expectations to levels comparable with graduate examiners. LGC has therefore developed a new career structure within the business to allow successful graduate apprentices to continue to develop with us. As of today, 80% of our cohort have employment with LGC as junior examiners or with other employers in the science sector or have accepted places at University this autumn. Due to its success, LGC will have extended its apprenticeship programme into 4 of 5 of its Divisions by summer 2013.

LGC Science and Technology measurement research, the home of the designated UK national metrology institute (NMI) for chemical and bioanalytical measurement, and of the Government Chemist, has traditionally recruited post-graduates and provided them with in-house training to develop the ethos and capability for high accuracy reference measurements and reference standards.

Recruitment has however become increasingly more of a challenge over the last 10 years, nationally, such that we have had to recruit internationally to find the necessary skills and aptitude. At the same time, the nature of work also changed with an increasing maturity of available skills; so the staff mix was reviewed to draw on Masters level students with in-house training on the job and potential for PhD programmes with academia (four LGC staff currently completing PhDs in-house, with different academic institutions). We also fund a number of Collaborative Awards in Science and Engineering (CASE) studentships at other academic institutions. We have a Knowledge Transfer Partnership programme to bring in particular expertise to underpin a future potential service offering. By the summer of 2013, our first apprenticeship will also have been placed.

. . . apprentices out-performed original expectations . . .

Currently, recruitment is somewhat better, nationally, perhaps due to changes in the pharmaceutical and financial sectors or with the introduction of academic course and future career potential considerations, but a longer-term provision of measurement science skills, say through a suitable broad-sector post-graduate institute, may offer huge potential benefit to the UK and our business.

In summary, I would like to highlight the following points:

- Business needs to be an integral partner in the development of a demand-led STEM framework which incorporates clear career pathways based on labour market information
- There is a need to gather deeper skills intelligence across ALL business sectors with a view to identifying best practice for STEM engagement and career development
- There should be an increase in focus on the teaching of core sciences and mathematics
- STEM learning needs to be flexible and transportable for easy movement within career pathways and between employment platforms. Learning should also be more investigative and enquiry-based, with the relevance of STEM in everyday life emphasised, so that the changing demands of the economy can be met
- There needs to be greater opportunity for work experience and the development of training and qualifications, especially for technicians.

SKILLS

Meeting of the Parliamentary and Scientific Committee on Tuesday 23rd April

We also had presentations from Diana Garnham (Science Council) and Bill Twigg (SEMTA).

A summary of these will be published in our next issue.

WATER QUALITY – a Water Company Perspective

Clive Harward
Head of Water Quality and Environmental Performance, Anglian Water

At Anglian Water, we're putting water at the heart of a whole new way of living, encouraging everyone to Love Every Drop.

We supply water and wastewater services to more than six million domestic and business customers in the east of England and Hartlepool.

Our population has grown by 20% in the last 20 years, but we still provide the same amount of water today as we did in 1990 – almost 1.2 billion litres every single day – by minimising leaks and encouraging customers to use water wisely.

Our region stretches from the Humber north of Grimsby to the Thames estuary and then from Buckinghamshire to Lowestoft on the east coast. Our 112,833 km of water and wastewater pipes supply and transport water across an area of 27,500 square km.

We're the largest water and wastewater company in England and Wales by area.

DRINKING WATER QUALITY AND HEALTH

Safe drinking water is fundamental to public health and we take our responsibilities for supplying water which is safe, clean and wholesome extremely seriously.

Wholesome drinking water is defined in regulations and has to meet stringent microbiological, aesthetic, physical and chemical standards; not just as it leaves the water treatment works but right up to the point of consumption – usually the kitchen tap, and this brings a whole set of challenges and risks in itself.

Compliance with drinking water standards is extremely high at 99.96%. However the small number of compliance failures is often associated with issues outside a water company's direct control. The most common cause of compliance failures are associated with the impact that customers' premises have on the quality of the water leaving their tap. This can be due to the plumbing system, fittings and devices used in the home, for example taps, water softeners, storage tanks, incorrectly installed rain water harvesting and solar heating systems.

We work closely with WRAS – the Water Regulations Advisory Scheme – to help ensure that products and fittings that are approved for use do not have a negative impact on water quality. We are also a founding member of WaterSafe, the national approved plumber scheme which brings together all the UK approved plumber schemes under a single umbrella so that customers can find a trained, competent plumber to carry out work in a way that will not affect the quality of water.

. . . 1.2 billion litres every single day . . .

The next most common cause is pollution from agricultural sources, for example pesticides. While many of these substances can be removed by our treatment processes, some pesticides, for example metaldehyde (used to control slugs), would cost billions of pounds to remove. In these cases a combination of controls and regulations are needed, as well as a catchment based approach to help prevent the pollution at source.

BEHAVIOURAL CHANGE

Our Love Every Drop strategy is about securing water supplies for local people and businesses, promoting local knowledge about water use and climate change, and changing how people think about and use water.

We currently have two behaviour change campaigns supporting this strategy. Keep it Clear aims to reduce pollution incidents from sewer blockages, and Drop 20 encourages customers to reduce their water use by 20 litres per day and has contributed to saving 60 Ml of water in 2012.

Half of the blockages in Anglian Water's sewer network are avoidable, caused by people putting unflushable items (wipes

. . . supplying water which is safe, clean and wholesome . . .

and sanitary waste) and fats, oils and grease (FOG) down toilets and sinks. 60% of sewer flooding in homes and environmental pollution incidents are as a result of a blockage. By reducing avoidable blockages we reduce the risk of these incidents.

We undertook extensive research with our target audience – householders and food serving establishments (FSEs) to understand current behaviours and the barriers and motivators for change. We then devised interventions to make it easy for customers to act.

Each location starts with a personalised mailing to customers giving advice on how to dispose of FOG and unflushables responsibly. Outdoor and local media advertising and a community engagement programme is then undertaken through a long-term partnership with a lead voluntary organisation – the local messenger that residents "know and trust".

We also work with restaurants and food outlets to advise them on the correct way to dispose of fats, oils and grease.

Overall the programme is achieving sustained behaviour change with an average of 51% blockage reduction achieved across the eight locations targeted to date, compared to previous years.

Our water efficiency behaviour change campaign, Drop 20, focuses on the benefits of simple changes in behaviour to reduce water consumption, from fixing dripping taps (saving 3 litres a day) to spending two minutes less in the shower (16 litres). Using billboards, radio adverts, leaflets and conducting roadshows we are encouraging everyone to take part, and have already given away 5,000 water butts to make it easy for customers to act.

ENVIRONMENTAL WATER QUALITY

As science develops we are able to detect more substances in the environment at lower levels. The real challenge is to evaluate their ecological impact, and determine whether they present a risk to public health and therefore need to be controlled. Recent studies have focused on potentially eco-toxic, persistent or bio-accumulative substances.

Environmental policies have reduced exposure to harmful environmental contaminants in air, water and food over the decades. However, some contaminants are still a problem, and several new health risks are emerging. For example, new chemicals, products and changing lifestyle all play a part.

European legislation sets out a list of substances such as metals and pharmaceuticals which present a significant risk to or via the aquatic environment. The substances, such as metals and pharmaceuticals, are designated as Priority Substances (PS) or Priority Hazardous Substances (PHS), and are required to be monitored in the environment.

In early 2012 the European Commission proposed the addition of new substances to this list. This proposal recommended two hormones (17alpha-ethinylestradiol (EE2), 17beta-estradiol (E2)) and a painkiller (Diclofenac) be added (among others). The excretion of such compounds by humans is recognised as the main source of these pharmaceuticals, as they enter rivers via discharges from wastewater treatment plants.

In order to understand the prevalence and fate of these substances in wastewater, a national study was commissioned by the water industry and supported by regulators, known as the Chemical Investigations Programme (CIP) from 2009 to 2013. Over 70 substances were monitored at 162 treatment plants, with over 200,000 samples analysed.

The study showed that the vast majority of substances were removed during conventional wastewater treatment. However the level of reduction from the process depended on a number of factors, such as the type of treatment employed. Achieving higher levels of removal to meet proposed environmental standards are likely to be particularly challenging. Experience within the water industry has shown that a technology that is successful at one site, or for one substance, is not necessarily successful for another. Also the costs to remove these substances at treatment plants run into billions of pounds and generate significant carbon emissions.

. . . the local messenger that residents "know and trust" . . .

This means that alternative control measures, such as product substitution or more advertising of pharmaceutical take-back schemes need to be explored, to prevent pollution at source.

JOINED UP POLICY MAKING

Overall water quality in the UK is very high. However there are a number of factors beyond the direct control of water companies that can have a detrimental impact. We need joined up policy, and concerted action by all parties, to tackle these environmental challenges. Policy needs to prevent pollution at source rather than rely on expensive and unsustainable treatment to remove it.

EU chemicals legislation (REACH) contains mechanisms suited to controlling substances at source, which is hugely important. However REACH assesses only environmental impacts not drinking water impacts. In our experience prevention is better than cure, and therefore we would like to see products assessed for their impact on drinking water quality as well as on the environment before being approved for market.

Standards setting the level of chemicals allowed in water must be based on strong evidence, taking account of the full environmental impact alongside financial and carbon costs. We would like to see a detailed regulatory impact assessment before the introduction of any new standards for the permissible levels of priority substances in the environment.

. . . Standards must be based on strong evidence . . .

WATER PURITY – MYTHS AND CHALLENGES

Kevin Prior MBA FRSC FCIWEM
CChem CSci CWEM
Chair, Royal Society of Chemistry
Water Science Forum

INTRODUCTION

Water purity is a complex term and is often approached in a subjective manner.

What are we talking about: water contamination or perhaps environmental pollution? In the United States, the EPA defines "pure" water as water free from all types of bacteria and viruses. In the UK drinking water has to be "wholesome". But there is more to purity than just that.

Water is a compound made up of hydrogen and oxygen, so pure water would be water that contains nothing but hydrogen and oxygen. However, pure water of this sort does not normally exist except in the controlled environment of a laboratory. Even in a laboratory pure water is hard to come by. For example, bacterial contamination of purified water can cause major problems in the laboratory. Even if organic and inorganic chemical impurities are removed down to the limits of detection, bacterial growth can still occur, even though very pure water provides an extremely harsh environment with apparently negligible nutrient content. To avoid metallic contamination of the water, laboratory water purifiers are constructed using plastics. The bacteria can use these materials that are in contact with the pure water as a carbon food source to sustain them, and then when they die they release further contaminants into the water. If this bacterial growth is not minimised, it can cause significant difficulties in the day-to-day operation of the laboratory.

WHAT DO PEOPLE MEAN BY "PURE WATER"?

From a drinking water standpoint, most references to "pure water" emphasise bacteria content and not the chemical contaminant concentrations.

There is no such thing as pure water. The very concept of 'pure' water is misleading. Pure water does not exist in nature. Water is the universal solvent. Even as it falls to earth as rain it picks up particles and minerals in the air. And as soon as it hits the ground it captures minerals from the soil and rock upon which it lands and then makes its way into streams and rivers.

Most water will contain certain ions, such as calcium and magnesium, even if it is just a trace amount. These minerals are the ones that define whether water is hard or soft, and they play a role in taste.

Water supply companies achieve healthy water by identifying the unhealthy contaminants in their water and then taking action to remove them. Consumers can further purify if they wish.

The public discussion about water will switch from the notion of 'pure' to 'healthy'. 'Healthy' water is attainable, whereas pure water is not. And just what is healthy water? 'Healthy' water has a pH that does not adversely affect human biological processes; the optimum appears to be between pH 7 and pH 8. Harmful contaminants such as disinfection by-products eg trihalomethanes, and any harmful chemicals or metals, whether man made or naturally occurring, have been identified and removed with the appropriate treatment.

WHAT DOES A WATER SCIENTIST MEAN BY "PURE WATER"?

From a water scientist's perspective, water purity is considered within the context of its anticipated use. Drinking water should be wholesome and meet all regulatory requirements whereas water destined for use by industry, agriculture or horticulture should be "fit for use". The quality standards are determined for the most part by the user. In the case of environmental waters they would be expected to have achieved good (ecological) status as described in the EU Water framework Directive.

WHAT IS REQUIRED TO DETERMINE ACHIEVEMENT OF THOSE CRITERIA?

In order to determine if water has achieved the required standards the following measures are required. There must be:

- Appropriate evidence based quality standards
- Appropriate risk based monitoring and testing
- By accredited laboratories
- With competent technical staff

All these need to be reviewed at appropriate intervals.

Examples of evidence based quality standards include World Health Organisation's drinking water standards and UK Environmental Quality Standards.

EUROPEAN DRINKING WATER DIRECTIVE

This Directive (98/83/EC) concerns the quality of water intended for human consumption and forms part of the regulation of water supply and sanitation within the European Union. The Directive protects human health by laying down healthiness and purity requirements which must be met by drinking water within the Community. It applies to all water intended for human

consumption apart from natural mineral waters and waters which are medicinal products.

In setting contaminant levels the Directive applies the precautionary principle. For example, the EU contaminant levels for pesticides are up to 20 times lower than those in the WHO drinking water guidelines, because the EU directive not only aims at protecting human health but also the environment.

WHO CONTAMINANT LEVELS

The WHO contaminant levels are already set so that there would be no potential risk if the contaminant was absorbed continuously over a person's lifetime. EU drinking water standards and cases where these standards are temporarily exceeded by a small margin should be interpreted in this context.

WHO specifies health related guideline values rather than one fixed blanket limit, irrespective of substance toxicity.

For example WHO states "Because of their low toxicity, the health-based value derived for AMPA [1] alone or in combination with glyphosate is orders of magnitude higher than concentrations of glyphosate or AMPA normally found in drinking water under usual conditions. The presence of glyphosate and AMPA in drinking water does not represent a hazard to human health. For this reason, the establishment of a formal guideline value for glyphosate and AMPA is not deemed necessary." This also applies to metaldehyde where many millions of pounds have been spent trying to remove totally harmless levels.

SAMPLING AND TESTING

Within the UK there exists a risk based regulatory sampling and inspection system for both drinking water and environmental waters and aquatic emissions.

The analytical laboratories are accredited to ISO/IEC 17025:2005 General Requirements for the Competence of Testing and Calibration Laboratories.

In addition Drinking Water Laboratories are required to comply with the Drinking Water Technical Standards (DWTS) issued by the DWI (in England and Wales) and DWQR (in Scotland). DWTS is necessary in addition to ISO 17025 to ensure fit for purpose results.

These standards also set out the required competencies of people involved in determining if the necessary standards have been met. Demonstration that the competencies have been achieved and verified by a third party can be done by gaining relevant profession accreditations such as Chartered Chemist (CChem) status within the Royal Society of Chemistry. Other scientific based professional registers accreditations include those granted by the Science Council.

The Professional Registers consist of the three designations below:

Chartered Scientist (CSci) is a well-established award, with over 15,000 scientists having achieved it since its launch in 2004. Candidates will typically be in senior scientific or managerial roles, qualified to at least QCF level 7 and applying their knowledge in their roles.

Registered Science Technician (RSciTech) is a new award to provide recognition for those working in technical roles.

Registered Scientist (RSci) is a new award to provide recognition for those working in scientific and higher technical roles.

WATER SECURITY

Water quantity as well as quality (purity) has also to be taken into account when considering water security or sustainability.

For water to be considered renewable it has to be used at less than the regeneration rate. In other words, renewable resources are limited. The faster you use them the quicker they run out. As demand for water rises combined with increasing urbanisation, alternatives to removing water from the environment have to be considered.

> "the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water related risks"
>
> Mike Muller, Graduate School of Public and Development Management University of the Witwatersrand South Africa

The options for increasing water availability in urban areas include:

- Rain water harvesting
- Aquifer recharge
- Affordable sanitation
- Desalination and similar processes
- Reuse and recycling

There are existing regulatory quality standards for:

- Drinking (potable) water standards
- Environmental standards
- Environmental emissions

While there are no regulations covering the quality of reused water, the British Standards Institute (BSI) has produced some guidelines for both greywater and rainwater reuse. For the first time, guidance introduces embedded water quality parameters for water reuse applications. Compliance with these parameters is designed to ensure public health is not compromised.

The guidelines in BS 8525 have taken the standards included in the Bathing Water Directive and developed values based on detailed research into specific applications where greywater is to be used.

The guidance recommends that whilst frequent water sampling is not necessary, it is good practice to observe water quality during maintenance checks. There is more detailed information in the Environment Agency publication *Greywater for domestic users: an information guide.*

The Water Sciences Forum within the RSC role in ensuring water purity and water security is non-partisan and to act as an "honest broker."

Water Scientists should identify the evidence needs and gaps, enable debate, and help influence policy.

CONCLUSION

Water Purity means "not harmful." Scientists and technologists cannot impose solutions on citizens which guarantee water purity. Water Policies need to be based on sound science and evidence to be successful. Consumers, citizens, politicians and scientists must all work together to achieve success.

Reference

1 Aminomethylphosphonic acid

MURKY WATERS: phosphorus mitigation to control river eutrophication

Professor Helen Jarvie
Centre for Ecology & Hydrology, Wallingford.

Professor Helen Jarvie is a Principal Scientist in Water Quality at the Centre for Ecology and Hydrology, Wallingford, and Adjunct Professor in Fluvial Sciences at the University of Arkansas, USA.

Eutrophication (enrichment of waters with phosphorus (P) and nitrogen (N), causing nuisance excessive growth of aquatic plants), is one of the biggest causes of surface water quality impairment, and is of pressing national and global concern. Eutrophication can cause reductions in plant biodiversity and toxic algal blooms; loss of dissolved oxygen (from the death and decay of large amounts of plant biomass), resulting in death of fish and invertebrates; increases in costs of water treatment for potable supply; and reduced amenity value of our rivers, lakes and coastal areas. Of particular concern are nuisance algal blooms and P is often the limiting nutrient for freshwater algal growth. This means that P inputs to rivers from sewage and agriculture can be particularly problematic in stimulating algal growth. Our UK lowland rivers are particularly vulnerable to eutrophication, owing to the high population density and intensive agriculture, which generate large fluxes of nutrients to our rivers. This is exacerbated by high demands for water abstraction for domestic supply, industry and irrigation which, coupled with climate variability and a move to drier summers, reduces river flows and the capacity for rivers to dilute and attenuate these nutrient inputs at times of greatest eutrophication risk. Over the last few decades, reducing P inputs to rivers has become the main international strategy for limiting freshwater eutrophication and is a key target for the EU Water Framework Directive, in order to achieve "Good Ecological Status" in our rivers.

Upgrades to treatment of sewage effluent (which strip P from the final effluent before discharge into rivers) have yielded some dramatic improvements in river P concentrations over the last couple of decades. The Centre for Ecology & Hydrology's River Thames Initiative studies have shown how P stripping from final sewage effluent has reduced P concentrations in rivers across the Thames basin. For example, on the River Kennet in the upper Thames catchment, P stripping at Marlborough sewage works in 1997 resulted in a dramatic reduction in baseline ambient P concentrations from c 0.6 to c 0.08 milligrams per litre.

To mitigate agricultural P inputs, best management practices have been adopted, which address P source controls (eg the rate, method and timing of P applied as fertilisers or manure) and transport controls (eg conservation tillage, contour ploughing and riparian buffers). Although these have been very successful in reducing P concentrations in field runoff, there has often been disappointingly little improvement in downstream water quality as a result of agricultural remediation. More widely, despite decades of P-based mitigation, many restoration programmes have not yet achieved the expected magnitude and extent of water quality and ecological improvements, for example, in Chesapeake Bay, the Great Lakes, or the Gulf of Mexico. This disappointing response to P remediation has puzzled catchment managers, but two important factors are starting to emerge:

> . . . not yet achieved the expected ecological improvements . . .

Firstly, the continued long-term release of P from 'legacy P' stores. Legacy P stores have accumulated in soil, river sediments, wetlands, riparian floodplains, lakes, groundwater and estuaries, as a result of inefficient use of P in past and on-going land-use management. Annually, only around 20-30% of P applied to agricultural land as fertilizer or manure is exported directly out of the watershed (through P loss from the soil in runoff when it rains and removal of P in grain and animal produce). The remaining 70-80% of the applied P enters catchment and water body P stores, which build up over time and release 'legacy' P, as the P storage capacity becomes saturated, or after changes in land use, land management or wastewater treatment. This means that, even when remediation measures reduce P inputs, P release from legacy stores can mask downstream improvements in water quality. The variable residence and recycling times of P within these terrestrial and aquatic stores suggest that the legacies of past land-use management may continue to impair future water quality over timescales of years or decades.

Secondly, ecological responses do not necessarily conform in simple and predictable ways to reduced P concentrations. Algal response can become decoupled from P concentrations during remediation. The example from the River Kennet illustrates the challenges we face: before the upgrades to effluent treatment, the baseline P concentrations in the river downstream were c 0.6 milligrams per litre, but there was healthy chalk stream

ecology, including abundant macrophyte (higher plant) growth which provides an important habitat for fish and invertebrates. However, within a couple of years of effluent remediation (which resulted in a seven-fold decrease in baseline river P concentrations), attached algae had proliferated and shaded out the macrophytes, resulting in a major degradation in the aquatic ecology. This response to dramatically lowered P concentrations seems counter-intuitive, but this is just one of numerous examples, where P remediation does not always yield the desired ecological outcomes, even when targets are met. While increasing P concentrations can increase algal biomass, it does not necessary follow that by, reducing P concentrations, recovery will follow the same trajectory. These are complex and inter-linked ecological systems and it is often difficult to ascertain the cause of these unexpected ecological responses. For example, P concentrations may not have been reduced sufficiently to reach the critical thresholds for algal growth limitation, and there are other ecosystem feedbacks and drivers that can come into play. Grazing by invertebrates provides a 'top-down' control on limiting algal growth. Reducing the invertebrate grazing pressure, for example by stocking rivers with fish (such as brown trout), which predate on the invertebrate grazers, can result in proliferation of algae. There are also important physical habitat controls; for example, cutting down riparian tree cover increases light availability to the river, which can also promote algal growth. Similarly, channel management, which impedes river flow and reduces water flow velocity can also promote algal accrual while standing waters such as lakes and canals may seed algal growth within rivers to which they drain. Correspondingly there are extremes in flow that come with the climate instability that the UK is experiencing. In this context, extreme drought conditions may be particularly problematic and very difficult to address within environmental management. Further, there are other co-limiting nutrients, such as nitrogen, to consider. While P has an important role in promoting nuisance algal growth, if we want to reduce the impacts of eutrophication, we also need to consider a wider range of controls, including physical habitat, other nutrients and top-down controls linked to food web (invertebrate and fish

WHICH DO YOU PREFER?

These photographs challenge our perception about what constitutes 'Good Ecological Status':

(a) This appears to be the cleanest of the three water bodies, and is used for boating and recreation. However, the lack of algal growth is actually a consequence of upstream industrial discharges, which result in the presence of a mix of heavy metals and organic micro-pollutants, including herbicides, which limit algal growth.

(b) This is a canal, which receives very high phosphorus (P) inputs from sewage effluent (with canal water P concentrations at c 2 milligrams per litre), but supports a high diversity of aquatic plants, and is classed as a 'Site of Special Scientific Interest' in terms of reed bed habitat.

(c) Visually, this appears to have the worst water quality. However this highly turbid river, with high levels of phytoplankton (floating algae), actually has the highest ecological classification in terms of macroinvertebrate biodiversity score.

So appearances can be deceptive; these photographs illustrate (i) the divergence between quantitative measures of chemical and ecological status and the aesthetic appearance of our rivers and (ii) the need to open up the dialogue for wider community consultation to assess what sort of river environments we want, that are achievable and that we are willing to pay for.

Source: I. J. Bateman, University of East Anglia; see Bateman, I.J et al. (2006) Journal of Agricultural Economics, Vol. 57, 221–237.

interactions), to promote more resilient ecosystem functioning.

We also need to consider what sort of river environments are desirable to the wider community and also achievable and affordable. Many of our rivers have been physically impacted by human activity over many hundreds of years. The River Basin Management Planning process (required under the EU Water Framework Directive), is helping to engage wider stakeholder involvement in identifying how water quality impairment impacts communities and what constitutes healthy river environment. This dialogue is of great importance because there can be considerable divergence between what is visually perceived as good water quality and an attractive river environment, and the quantitative measures used to define "Good Ecological Status" (see accompanying Figure 'Which do you prefer?'). Initiatives such as the Catchment Restoration Fund and the rise of third sector organisations such as the Rivers Trusts are also helping wider community engagement by promoting campaigns to restore and protect river environments. These include a broader remit of restoring a wider range of ecological functions and services, including aquatic and riparian habitat management. Such approaches not only benefit the aesthetic and amenity value of river environments but also promote more tightly coupled nutrient cycling, and ecosystem resilience to perturbations.

In conclusion, we face an "inconvenient truth" that P-based nutrient mitigation, long regarded as the key strategy in eutrophication management, in many cases has not yet yielded the desired improvements in water quality and reductions in nuisance algal growth in rivers and their associated downstream ecosystems. However, the complex recovery trajectories & lags in response to remediation are not an excuse to do nothing; nor are they an excuse to impose more restrictions on any one stakeholder. To address legacy P, the priority must now be to 'draw-down' existing P legacies and prevent future legacy P build-up through source controls, which balance P inputs and recycling more efficiently. Nutrient (including P) mitigation is just one important part of a larger toolbox of measures to promote more resilient river ecosystem functioning. Simple, pragmatic, and easily applicable management tools linked to public perceptions of "good" water quality are also needed, and policies on eutrophication control need to be based on best-available scientific understanding. However, while science can help decision makers, the decisions cannot be taken within science: decisions about allocation of resources and priorities for remediation need to be made within the context of wider societal goals, and balancing competing demands for environmental improvement, food security, depletion of easily-mined mineral P reserves and increasing costs of fertilizer production, and the development of sustainable and vibrant rural and urban communities and economies.

For more information, see: Jarvie, H.P., Sharpley, A.N, Withers, P.J.A, Scott, J.T., Haggard, B.E., Neal, C. (2013). Phosphorus mitigation to control river eutrophication: murky waters, inconvenient truths and 'post-normal' science. *Journal of Environmental Quality*, 42, p295-304.

HOW WELL IS WATER?

Recently, **Dan Osborn**, from the Natural Environment Research Council spoke to the All Party Parliamentary Group on Water about the global context of water and the progress UKWRIP members are making to address growth and resilience issues associated with water.

Water represents an opportunity for growth because every business, household and person needs water no matter where in the world they are. The UK has an excellent research track record in water and an excellent reputation for delivering high quality drinking water and waste water management. But this is no time to rest on our laurels. The challenges from environmental change, population growth and demographic developments (such as ageing) mean that the UK must examine critically its water security position and take the opportunities presented by a global need to supply water and deploy and refurbish the technologies and infrastructure that does so. Great research needs to be taken up by innovators and innovations need to lead to marketable products and new ways of managing water resources. The new products and services will have to take account of the extreme variations in rainfall that lead to floods on the one hand and droughts on the other that will be a continuing and perhaps increasing feature of the UK "waterscape". Thus, the Government Chief Scientific Adviser chairs the UK Water Research and Innovation Partnership which aims to help private, public and third sectors address both the water security challenge and the national and international economic growth and social development opportunities. Recently, Dan Osborn spoke to the All Party Parliamentary Group on Water about the global context of water and the progress UKWRIP members are making to address growth and resilience issues associated with water.

. . . increasing feature of the UK "waterscape" . . .

THE GLOBAL ECONOMIC AND BUSINESS CONTEXT

The World Economic Forum annually assesses risks to the world economy on an annual basis and water has risen near the top of the tree (see http://www.weforum.org/reports/global-risks-2013-eighth-edition). Water supply is seen as the top societal risk and many of the other top risks are linked to water. Failure to take action to address such issues could cost at least $250bn for water supply alone. Overall, water issues rank alongside the challenges (and opportunities!) that climate change presents. The magnitude of the risk is, in turn, equivalent in many respects to those posed by the lack of liquidity and the financial crisis itself.

. . . global water market is worth about $500bn . . .

Business opportunities in water (and other natural systems on which we depend without often realising the importance of that dependence) have been recognised in the UK by the Ecosystems Market Task Force (EMTF) and the World Business Council for Sustainable Development (WBSCD). In its 2050 Vision (see: http://www.wbcsd.org/vision2050.aspx) WBSCD call for externalities such as carbon, water and ecosystem services more broadly to be incorporated into market thinking and practices. The global water market is worth about $500bn annually and grows as the population and its expectations do.

The EMTF was funded by Defra and for its specialist aspects by the Natural Environment Research Council. EMTF said (recommendation 5) that implementing appropriate measures set out under its section on "Water cycle catchment management: integrating nature into water, waste water and flood management was important to UK businesses and society" could lead to savings of about £5bn. Views of stakeholders and business on such matters can be seen at (http://www.youtube.com/playlist?list=PLDKjigqXww5hWDCKQMVA2CSUhV-DaEkUS).

THE ENVIRONMENTAL CONTEXT

The UK as a whole could not be more aware of the variability in weather and rainfall patterns that have happened over the past few years. There have been dramatic swings from drought to flood, low rainfall to high. Impacts have been many and various with farmers and city-dwellers all suffering shocks as water has disappeared and then reappeared – sometimes in unexpected places.

This variability is something we may have to get used to because of where the UK is located in the flow of global air masses and ocean currents. Research supported by Research Councils UK is helping understand this variability. Recent initiatives cover both flooding, drought and intense rainfall events.

UK WATER RESEARCH AND INNOVATION PARTNERSHIP (UKWRIP)

Despite the importance of water to the UK, the degree to which this resource varies in availability and recent findings showing that about 65% of the water the UK depends on for food and manufactures is water originating overseas, the way UK businesses approach water innovation and the creation of new business opportunities is less well tied into the outputs and outcomes from research than it is in other countries.

. . . growing interest in water and waste-water . . .

UKWRIP (chaired by the Government Chief Scientific Adviser) was formed to see whether links between research, innovation and the market place could be improved. UKWRIP has the twin aim of helping (a) improve the UK's water security and (b) the UK get a larger share of the global water market. UKWRIP members are from the private, public (research and innovation; policy and regulation) and third sectors. Private sector groups cover the utilities, the supply chain and those business sectors that have a major reliance on water (farming, retailers). A full account of UKWRIP set out in 2011 can be found at: (http://www.bis.gov.uk/assets/bispartners/goscience/docs/t/11-1390-taking-responsibility-for-water).

UKWRIP is meeting a range of members' needs as it is the only UK forum in which all interested parties can meet to identify issues and organise actions. There are network opportunities; Action Groups (business, infrastructure, food, water use, climate and environment); ways to lower barriers on the road from research to innovation and a study in hand to see how other countries succeed in getting innovative products and services into the market place. This will recommend what steps the UK needs to take if it wants to emulate best practice.

There is a growing interest in water and waste-water in an urban context where the UK could take a global lead if the right kinds of investments in demonstration facilities can be achieved. This may need support from both the public and private sector and there are models to base action on in other business sectors such as energy. UKWRIP's Infrastructure Action Group (funded by UKWIR – the water utilities research arm) has already reported on where the major priorities should be in this kind of area.

UKWRIP private sector members have pointed to a lack of training opportunities in water and very swiftly this has been addressed by the Research Councils opening opportunities for post-graduate training in water and infrastructure. The strong private sector involvement in multi-disciplinary bids to Doctoral Training Centres funded through the Engineering and Physical Science Research Council signals a new approach to the UK's water security and economic growth is gaining momentum.

. . . dramatic swings from drought to flood . . .

WATER PURITY: Microbial Aspects, Especially Cryptosporidium

Professor Rachel Chalmers
Head, Cryptosporidium Reference Unit, Public Health Wales Microbiology

Despite the fact that the most common and widespread health risk associated with drinking water globally is microbial contamination, water purity is an expectation in the UK: we do not expect our drinking water to transfer infections and make us ill. However, there are occasions and settings where infections may occur; water of poor quality can cause outbreaks, and contributes to background rates of disease, whether this is through water used for drinking, domestic purposes, food production or recreation.

Cryptosporidium is a microbial contaminant, a protozoan, which has caused drinking and recreational waterborne outbreaks of gastrointestinal illness (cryptosporidiosis) in the UK and elsewhere. This protozoan has a complex life cycle and infection can cause cryptosporidiosis in animals (especially young livestock) as well as humans, resulting in large numbers of the "oocyst" stage being shed in their faeces. Although usually self-limiting, symptoms can be prolonged (often 2 weeks, sometimes longer) and unpleasant. There is a growing body of evidence that long-term adverse health effects may also arise following Cryptosporidium infections, such as irritable bowel syndrome. For some severely immunocompromised patients, infection can have devastating results, including chronic diarrhoea and infection of the hepto-biliary tree leading to liver failure. There is no proven specific therapy for cryptosporidiosis in these patients.

Contracted mainly by person-to-person or farm animal contact, Cryptosporidium can also be spread through food or water. Ingestion of even single numbers of oocysts has a high probability of causing illness. Historically, more drinking waterborne outbreaks in the UK were caused by Cryptosporidium than any other pathogen. One reason for this is because it is resistant to chlorine which controls most other pathogens. However, following the introduction of regulatory continuous monitoring for Cryptosporidium at high-risk water treatment works in England and Wales in 1999 the occurrence of drinking waterborne outbreaks of cryptosporidiosis decreased: structured surveillance conducted since 1992 shows that the proportion of Cryptosporidium outbreaks linked to drinking water before the regulatory change (34% of 62 outbreaks) was substantially greater than after (4% of 132 outbreaks) (Figure). There is also evidence of beneficial impact in a reduction of sporadic cases of cryptosporidiosis in the spring, when combinations of rainfall events and seasonal occurrences in animal husbandry (eg calving, lambing) contributed to contamination of water supplies with human-infectious strains. It is notable from the Figure that while drinking waterborne outbreaks have declined, outbreaks linked to recreational waters have increased; swimming pools are now the most common settings associated with Cryptosporidium outbreaks. Here, secondary disinfection (UV, ozone, for example) as well as both swimming pool user and operator awareness of Cryptosporidium are proven interventions that need to be promulgated in the UK. Notably, there are no specific regulations governing swimming pools in the UK.

To return to drinking water, where contamination and outbreaks can have far-reaching

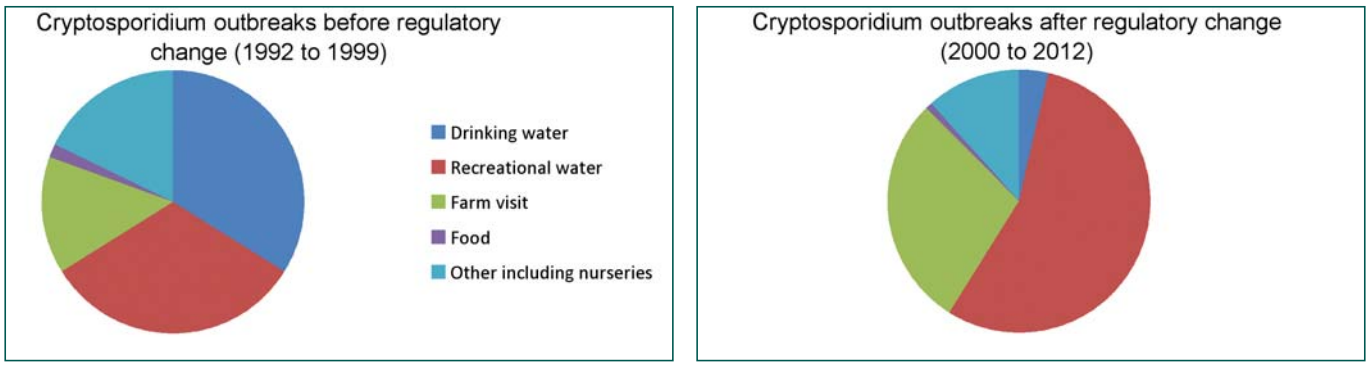


Figure: Proportion of reported Cryptosporidium outbreaks by setting or vehicle (Public Health England and Public Health Wales data)

effects, affecting large numbers of people and industries that use mains water (food and health care to name but two). Those 1999 regulations, which relied heavily on end-point testing, have since been replaced with broader drinking water quality regulations that in 2007 introduced new provisions for risk assessment and risk mangement, based on WHO water safety plan methodology outlined in the WHO water quality guidelines. A fundamental ethos of the WHO guidelines is that water quality should promote public health. This is translated in practical fashion by the adoption of water safety plans, providing a risk-based approach supported by evidence-based awareness of potential vulnerability of the source water and supply to contamination, underpinned by effective preventative management. Water safety plans comprise:

- a system assessment to determine whether the drinking-water supply (from source through treatment to the point of consumption) as a whole can deliver water of a quality that meets the health-based targets;
- operational monitoring of the control measures in the drinking-water supply that are of particular importance in securing drinking-water safety;
- management plans documenting the system assessment and monitoring plans and describing actions to be taken in normal operation and incident conditions, including upgrade and improvement, documentation and communication.

The plans are supported by a system of independent surveillance that verifies that the above are operating properly.

A management approach that places the primary emphasis on preventing or reducing the entry of pathogens into water sources and reducing reliance on treatment processes for their removal is the preferred strategy. As a faecally-derived contaminant, Cryptosporidium can arise from farmed or wild animals through direct contamination of source waters with dung, indirect through slurry and run-off, or from people via sewage. With this in mind, it is critical for Cryptosporidium control that multiple barriers are in place to secure the safety of drinking water supplies. These include protection of water sources, proper selection and operation of a series of treatment steps, mainly effective filtration supplemented by UV disinfection where necessary, and management of distribution systems to maintain and protect treated water quality. Where one or more of these barriers are absent or fail, outbreaks of cryptosporidiosis may, and indeed have, occurred. Current testing identifies the oocysts, only as "genus Cryptosporidium" regardless of whether they are alive or dead, or of a species that infects and causes illness in humans or not. Yet additional tests for the resolution of species, which improve the risk assessment by including infectivity potential for humans, have been shown to be of added-value. This is a specialist molecular test provided by reference laboratories. More aspirational is current research as part of the AQUAVALENS project, led by the University of East Anglia and funded by EU Framework 7 (www.aquavalens.org), investigating the further development of assays based on whole genome sequencing data, to improve the accuracy of testing for waterborne pathogens.

One area of particular difficulty in source water quality management arises as many aspects are often outside the direct responsibility of the water supplier, for example where catchments and source waters are beyond the drinking-water supplier's jurisdiction. Thus, it is essential that a collaborative multiagency approach be adopted to ensure that agencies with responsibility for specific areas within the water cycle are involved in the management of water quality. Communication has been identified by the Chief Inspector of Drinking Water as one area for improvement.

Improved control of drinking waterborne cryptosporidiosis can be, and continues to be, achieved within the current regulatory framework. Nevertheless, there may still be a background risk in some mains supplies requiring a high level of vigilance throughout the system. Furthermore, many private water supplies are poor quality, and recent estimates of risk of Cryptosporidium infection, and likelihood of diarrhoea, from very small supplies are unacceptably high especially among children. There are health benefits to be gained from improving the quality of such supplies, a goal underpinning regulations introduced in England and Wales in 2010.

Globally, the impact of Cryptosporidium has been brought into sharper focus recently. The Global Enteric Multicenter Study (GEMS) has identified that in children under 5 years in sub-Saharan Africa and south Asia, most attributable cases of moderate-to-severe diarrhoea were due to just four pathogens including Cryptosporidium. Interventions targeting these pathogens could substantially reduce the burden of moderate-to-severe diarrhoea. However, the world remains off-track to meet the Millennium Development Goals sanitation target, which requires reducing the proportion of people without access from 51 per cent to 25 per cent by 2015.

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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:

Jim Dowd (Labour, Lewisham West and Penge), Stephen Metcalfe (Conservative, South Basildon and East Thurrock), Andrew Miller (Labour, Ellesmere Port and Neston), David Morris (Conservative, Morecambe and Lunesdale), Stephen Mosley (Conservative, City of Chester), Pamela Nash (Labour, Airdrie and Shotts), Sarah Newton (Conservative, Truro and Falmouth), Graham Stringer (Labour, Blackley and Broughton), David Tredinnick (Bosworth), 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.

CURRENT INQUIRIES

Forensic Science Services (FSS) follow-up

On 22 November 2012, the Committee announced an inquiry: FSS Follow-up. The Committee invited written submissions by 10 January 2013.

On Wednesday 30 January 2013 the Committee took evidence from Alison Fendley, Executive Director, Forensic Archive Ltd, Dr Gill Tully, Consultant, Principal Forensic Services Ltd, and Helen Kenny, Former Branch Secretary for the FSS, Prospect Trade Union.

On Wednesday 6 February 2013 the Committee took evidence from Professor Martin Evison, Director, Northumbria University Centre for Forensic Science (NUCFS), Dr John Manlove, Manlove Forensics Ltd, and David Richardson, Chief Executive, LGC Forensics; and then from Chief Constable Chris Sims, Association of Chief Police Officers (ACPO), Gary Pugh, Director of Forensic Services, Metropolitan Police Service and, Kevin Morton, Director of Scientific Support Services, Yorkshire and the Humber.

On Wednesday 13 February 2013 the Committee took evidence from Karen Squibb-Williams MA, Strategic Policy Adviser, Crown Prosecution Service, Michael Turner QC, Chairman, Criminal Bar Association, and Richard Atkinson, Chair of Criminal Law Committee, Law Society.

On Wednesday 6 March 2013 the Committee took evidence from Professor Bernard Silverman, Chief Scientific Adviser, Home Office and Andrew Rennison, Forensic Science Regulator.

On Wednesday 13 March the Committee took evidence from Jeremy Browne MP, Minister of State for Crime Prevention, Home Office and Stephen Webb, Former Director, Finance and Strategy Directorate, Crime and Policing Group, Home Office.

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

Water Quality

On 19 December 2012, the Committee announced an inquiry: Water Quality. The Committee invited written submissions by 8 February 2013.

On Wednesday 27 February the Committee took evidence from Richard Aylard, Thames Water, Marco Lattughi, Environmental Industries Commission, and Mike Murray, Association of the British Pharmaceutical Industry; and then from Professor Andrew Johnson, Centre for Ecology and Hydrology, Rob Collins, Blueprint for Water Coalition, and NERC; and then from Dr Sue Kinsey, Marine Conservation Society, and Professor Richard Thompson, Plymouth University.

On Monday 4 March 2013 the Committee took evidence from Ian Barker, Head of Water, Land and Biodiversity, Environment Agency, Nick Cartwright, Environment and Business Manager, Environment Agency and Regina Finn, Chief Executive, Ofwat.

On Wednesday 6 March 2013 the Committee took evidence from Peter Gammeltoft, European Commission.

On Wednesday 13 March 2013 the Committee took evidence from Richard Benyon MP, Parliamentary Under-Secretary for Natural Environment, Water and Rural Affairs, Department for Environment, Food and Rural Affairs, Rory Wallace, Head of the Water Framework Directive Team and Dr Caroline Whalley, Priority Substances Policy/Technical Advisor.

The written and oral evidence received in this inquiry is on the Committee's website. A Report was published on 13 June.

Clinical Trials

On 13 December 2012 the Committee announced an inquiry: Clinical Trials. The Committee invited written submissions by 22 February 2013.

On Wednesday 13 March the Committee took evidence from Professor Sir Michael Rawlins, Chair of the Academy of Medical Sciences Regulation and Governance Review, Dr Keith Bragman, President, Faculty of Pharmaceutical Medicine, and Dr Fiona Godlee, Editor in Chief, British Medical Journal.

On Monday 22 April the Committee took evidence from Catherine Elliott, Director, Clinical Research Interests, Medical Research Council, Sharmila Nebhrajani, Chief Executive, Association of Medical Research Charities, Professor Peter Johnson, Chief Clinician, Cancer Research UK and Representative from the Wellcome Trust; and then from Dr Bina Rawal, Director of Research, Medical and Innovation, Association of the British Pharmaceutical Industry, Dr James Shannon, Chief Medical Officer, GlaxoSmithKline and Mr William M. Burns, Member of the Board of Directors, Roche.

On Wednesday 15 May the Committee took evidence from Professor Karol Sikora, Medical Director of Cancer Partners UK and Dean, University of Buckingham Medical School and Simon Denegri, NIHR National Director for Public Participation and Engagement in Research and Chair, INVOLVE; Tracey Brown, Managing Director, Sense About Science and Dr Helen Jamison, Deputy Director, Science Media Centre; and Sir Kent Woods, Chief Executive, Medicines and Healthcare products Regulatory Agency; Dr Janet Wisely, Chief Executive, Health Research Authority; Bill Davidson, Acting Deputy Director and Head of Research Standards and Support, Department of Health and Peter Knight, Deputy Director, Head of Research Information and Intelligence, Department of Health.

On Monday 3 June the Committee took evidence from Rt Hon David Willetts MP, Minister of State for Universities and Science, Department for Business, Innovation and Skills, and the Rt Hon the Earl Howe, Parliamentary Under Secretary of State for Quality, Department of Health.

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

The European and UK Space Agencies

On 15 February 2013, the Committee announced an inquiry: The European and UK Space Agencies. The Committee invited written submissions by 12 April 2013. The Committee expects to hold oral evidence sessions in 2013.

Climate: public understanding and its policy implications

On 28 February 2013 the Committee announced an inquiry: Climate: public understanding and its policy implications. The Committee invited written submissions by 22 April 2013. The Committee expects to hold oral evidence sessions in 2013.

REPORT

Water quality

On 13 June 2013 the Committee published its First Report of Session 2013-14, *Water quality: priority substances*, HC 272

GOVERNMENT RESPONSE

Government Response to the Committee's report 'Educating tomorrow's engineers: the impact of Government reforms on 14-19 education: Government Response to the Committee's Seventh Report of Session 2012-13'

On 15 May 2013 the Committee published the Government Response to the Committee's report on Educating tomorrow's engineers.

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 16 May 2013) are Lord Dixon-Smith, Baroness Hilton of Eggardon, Lord O'Neill of Clackmannan, Lord Krebs (Chairman), Baroness Manningham-Buller, Lord Patel, Lord Peston, Baroness Perry of Southwark, Lord Rees of Ludlow, the Earl of Selborne, Baroness Sharp of Guildford, Lord Wade of Chorlton, Lord Willis of Knaresborough and Lord Winston.

Scientific infrastructure

The Committee has launched an inquiry into scientific infrastructure. The call for evidence closed on Friday 21 June 2013. The inquiry will collect evidence on the large and medium-sized scientific infrastructure currently available in the UK. It will consider: future needs and strategic planning, funding and governance arrangements, international partnerships and partnerships with industry. Oral evidence will be taken up to the summer recess and the Committee hopes to publish its report in the Autumn.

Open access

The Committee undertook an inquiry into the implementation of the Government's open access policy. It issued a targeted call for evidence to key stakeholders for this short inquiry. The Committee took oral evidence in January 2013 and published its findings in February 2013 (http://www.publications.parliament.uk/pa/ld201213/ldselect/ldsctech/122/12202.htm)

The report was debated on 28 February (http://www.publications.parliament.uk/pa/ld201213/ldhansrd/text/130228-0002.htm).

It followed this up with a letter to RCUK expressing concern about its revised open access policy in March (http://www.parliament.uk/business/committees/committees-a-z/lords-select/science-and-technology-committee/news/open-access-response-to-rcuk/).

Regenerative medicine

The Committee launched an inquiry into regenerative medicine before the summer recess. A group from the Committee visited the California Institute for Regenerative Medicine. Oral evidence was taken from October 2012 to March 2013. Transcripts of these sessions and written submissions made are available on the Committee's website. The Committee expects to report on 1 July 2013.

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

The Committee's report was debated on the floor of the House on 21 March (http://www.publications.parliament.uk/pa/ld201213/ldhansrd/text/130321-0003.htm).

Sports and exercise science and medicine

In May 2012, the Select Committee launched a short inquiry into sports and exercise science and medicine. It wished to consider how the legacy of London 2012 could be used to improve understanding of the benefits exercise can provide, and in treating chronic conditions. The Committee explored how robust this science is and how lessons learnt from the study of athletes can be applied to improve the health of the population generally. The Committee held a seminar on 29 May 2012, and took oral evidence during June from sports and exercise scientists and clinicians, UK Sport, and officials and Ministers from the Department of Health and the Department for Culture, Media and Sport. The Committee published its report on 17 July 2012. The Government response was received in October 2012. The report will be debated in the House.

FURTHER INFORMATION

The written and oral evidence to the Committee's inquiries mentioned above, as well as the Calls for Evidence and other documents can be found on the Committee's website. Further information about the work of the Committee can be obtained from Chris Clarke, Committee Clerk, clarkechr@parliament.uk or 020 7219 4963. The Committee Office email address is hlscience@parliament.uk .

HOUSE OF COMMONS LIBRARY SCIENCE AND ENVIRONMENT SECTION

Scientists and other staff in the Science and Environment Section provide confidential, bespoke briefing to Members and their offices on a daily basis. They also provide support to Commons Select Committees, and produce longer notes and research papers which can be accessed on line at http://www.parliament.uk/topics/topical-issues.htm

Opposite are summaries of some recently updated published briefings.

For further information contact:
Dr Patsy Richards
Head of Section
Tel: 020 7219 1665
email: richardspa@parliament.uk

RECENT PUBLICATIONS

Badger Culling

SN/SC/5873

The previous Government decided in 2008 not to introduce a badger cull as part of bovine TB control measures in the light of findings of the UK Randomised Badger Culling Trial. This concluded that a reactive cull of badgers resulted in significant increases in bovine TB and a proactive cull, while controlling TB in the cull area, contributed to an increase in TB in surrounding areas, and would not be cost effective. Not all agreed. Sir David King, the chief Scientific Adviser at the time, reviewed the findings and concluded that a proactive cull would be cost effective.

After the election the Government indicated that a badger cull would be introduced as part of TB control measures. It announced a consultation in September 2010, which set out its proposals. These include introducing proactive culls over 150km^2 areas where farmers would be licensed to control badgers by shooting. Farmers would bear the costs of culls. The Government would bear the costs of licensing and monitoring. The consultation also included proposals on TB monitoring in cattle and further biosecurity measures. In December 2011 the Government announced that it intended to go forward with a badger cull trial. The trial will be carried out in two pilot areas. Results from the trial will be considered before culling is rolled-out more widely. The two trial areas, in West Gloucestershire and West Somerset, were announced in January 2012. Licences were granted by Natural England for the two areas in autumn 2012. Following concerns from the NFU on the late start of the cull and the potentially increased costs to farmers, a cull was postponed until 2013. The announcement was made in February that the cull would go ahead from 1st June 2013, following a new estimate of badger numbers in the two areas being published.

Bees and Neonicotinoids

SN/SC/6656

Based on the findings of a May 2012 European Food Safety Authority assessment (a literature review), the European Commission will soon be bringing forward the detail of a proposal to suspend the use of three common neonicotinoids (Imidacloprid, Thiamethoxam and Clothianidin) for two years from December 2013. This follows the Commission's successful appeal after its plans failed to achieve the required qualified majority in the Standing Committee on the Food Chain and Health (SCoFCH).

The UK abstained in the initial vote in the Standing Committee and then voted against the measure in the appeals Committee. The UK Government does not believe that field trial evidence supports the Commission's ban or that there has been sufficient analysis of the impacts of the alternatives that will be used. However, Defra's field trials, run by the UK Food and Environment Research Agency (FERA), have been publicly criticised by the European Food Safety Authority (EFSA) as containing "several weaknesses", "deficiencies" and "contradictory statements". The Authority has therefore concluded that the study does not affect its January 2013 conclusions.

Environmental groups such as Buglife and Friends of the Earth have welcomed the ban but cautioned that a two-year suspension is not sufficient for bee colonies to recover and that other impacts on bees need to be considered as part of a national plan. The British Bee Keepers Association is particularly concerned about the impacts of the replacement insecticides and farming methods which will be used. The Humboldt Forum for Food and Agriculture recently estimated that the overall cost of a ban could be as high as €4.5 billion and, over a five-year period, put 1 million arable production jobs at risk across the EU.

A range of DIY retailers have already removed products containing the three neonicotinoids and Waitrose has removed neonicotinoid products from its supply chain.

Nuclear power

SN/SC/6228

The July 2011 white paper on electricity market reform, now being implemented through the Energy Bill, outlines government policy towards nuclear power. This acknowledges: "The reforms set out in this White Paper will drive increased levels of intermittent renewable generation, and higher levels of inflexible generation, such as nuclear." There is therefore broad continuity in nuclear policy by recent UK governments. In March 2013 planning consent was granted for a new nuclear power station at Hinkley Point, Somerset – the first project to be granted a nuclear site licence for 25 years.

Safety considerations will always be much to the fore, prompted by memories of Chernobyl and Fukushima. A report by the Chief Nuclear Inspector, Dr Mike Weightman, provided some reassurance on the safety of existing and future nuclear stations, while counselling against complacency. However, disposal of radioactive waste remains an issue, and work is still under way to identify a suitable site for long-term geological storage of waste.

Nuclear power currently contributes 19% of the UK's electricity supply and recent studies of its economics appear favourable – at least when future carbon costs are factored in, which are low for nuclear power and some renewables and comparatively high for fossil fuels. Nuclear decommissioning costs can appear relatively small, at least when substantial discounting of future costs is included in the economics. Nevertheless, negotiations between the Government and EDF over the price to be paid for electricity generated by Hinkley C have not yet been concluded.

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

Energy Bill 2013 - update for Report stage

SN/SC/6653

The Energy Bill 2012-13 to 2013-14 is a 'carry-over' Bill, which means it has been continued from the previous Parliamentary session in the Commons. This short note provided an update to some of its more controversial areas for the Bill's Report and Third Reading stage in the Commons on 3 and 4 June 2013. It updated Library research briefings following Committee Stage and for Second Reading, as well as on the draft Bill. The issues covered include a decarbonisation target, energy tariffs, biomass, new nuclear, demand reduction and community energy schemes.

Carbon capture and storage

SN/SC/5086

Carbon capture and storage (CCS) is a potential way of 'decarbonising' electricity generation, through capturing and storing the carbon dioxide (CO_2) produced. As a form of 'low-carbon' generation under the current Energy Bill, CCS would allow the continued burning of fossil fuels. However, the 'emissions performance standard' introduced by the Bill also allows unabated gas to 2045; some feel this is not set low enough to incentivise CCS.

CCS generation is not yet proven on a large scale, and nor is storage long-term, despite a series of UK Government and EU initiatives aimed at incentivising its development. In March 2013 Peterhead (Aberdeenshire) and the White Rose Project (Yorkshire) were named as the two preferred bidders in the latest UK CCS Commercialisation Programme Competition.

Food Banks and Food Poverty

SN/SC/6657

Food banks (or "foodbanks") provide free food to people in acute need, including some who have been referred by health and social care professionals. In the UK, food banks are run by a range of volunteer-based organisations redistributing food donated by consumers, retailers and the food industry. The largest network of food banks is organised by The Trussell Trust which has over 345 banks UK-wide. Food bank use has been increasing steadily since 2005, with figures from The Trussell Trust showing that their bank use has increased from 128,000 users in 2011/12 to almost 350,000 in 2012-13.

A variety of factors are likely to have contributed to this growth. Global food prices hit an all-time high in early January 2011 and have remained relatively high since that time, making food in the UK proportionately less affordable for low-income households. Combined with this, the recession has seen unemployment increase significantly and earnings grew at less than the rate of inflation last year. The number of people claiming benefits has increased, but the eligibility rules have been tightened and the level and number of emergency Crisis Loans reduced. Many commentators have speculated that these benefit reforms are having the biggest impact on the growth of food banks, but the Government has refuted any link.

ACTIVITIES

The Science Section is currently undertaking a co-location pilot with both the House of Commons Energy & Climate Change Select Committee and the Science & Technology Select Committee. The specialists on each of the three teams have been able to share knowledge, expertise and briefings, benefiting the Members whom these teams advise and brief, and the outputs of the teams.

Two library clerks met the French President's Special Envoy on the Protection of the Planet, Mr Nicolas Hulot, to discuss issues surrounding international environmental negotiations.

The section organised a tour of the Natural History Museum for the Parliament's scientists and engineers group, which included meeting the head of zoological collections, discussing the research conducted on the collection, and meeting scientists and archaeologists working in the Department of Palaeontology.

Members of the section conduct outreach activities, such as speaking to NHS consultants, and to the public, in a Parliamentary Outreach event on how to interact with Parliament, in a Public Bill Workshop held in Central Hall, Westminster.

First POST fellow in the Library

UCL Energy Institute PhD student Mike Fell has been based in the Science and Environment Section since March this year. Funded through the POST/EPSRC fellowship programme, he has been working on answering Members' enquiries and writing/updating Standard Notes.

"This has been a great opportunity for me to get some insight into the day-to-day workings of Parliament. In this section I am constantly seeing examples of how science and environment issues impact on the lives of people and the Members who represent them. I've enjoyed providing briefings which will help resolve real problems and inform evidence-based policy."

PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY (POST)

RECENT POST PUBLICATIONS

Livestock Vaccines

May 2013 *POSTnote 433*

UK agriculture is constantly faced with the threats and economic consequences of various diseases of livestock. Vaccination of livestock is one approach to disease prevention and control. This POSTnote examines the use of vaccines and outlines the pros and cons of using vaccination in livestock.

Managing Online Identity

May 2013 *POSTnote 434*

The Government plans to digitise more public services by 2015 to improve efficiency and reduce costs. As more daily activities, services and transactions are conducted online, increasing amounts of personal data are used on the internet. This POSTnote describes online identity, government projects to secure online access to public services and the issues arising from a more online society.

Environmental Impact of Tidal Energy Barrages

June 2013 *POSTnote 435*

A tidal energy barrage across the Severn Estuary could produce up to 5% of the UK's electricity demand. It would help meet renewable energy targets but would have significant environmental impacts. This POSTnote summarises evidence on environmental impacts associated with the operation of tidal energy barrages and the effectiveness of compensatory measures.

Monitoring Internet Communications

June 2013 *POSTnote 436*

Internet communications are often monitored to investigate criminal activity. Recent attempts to update UK regulation of investigatory powers have generated controversy. This POSTnote explains the use of different internet monitoring methods and discusses the impact of evolving technologies.

Selection of Marine Conservation Zones

June 2013 *POSTnote 437*

Marine Conservation Zones may contribute to the protection and recovery of the marine environment. This POSTnote examines the process and approach used to select and designate zones, and difficulties in identifying and managing suitable areas.

Uncertainty in Population Projections

June 2013 *POSTnote 438*

Population projections inform policy formulation across a wide range of areas. While short-term projections are generally reliable, longer-term figures are subject to ever greater uncertainties. This POSTnote examines the sources of these uncertainties and explores projection methods which aim to take them into account.

CURRENT WORK

Biological Sciences – HIV Prevention in the UK, Minimum Age of Criminal Responsibility, Epigenetics and Health, Khat, Greenhouse Gas Emissions from livestock, Cosmetic Procedures, Organ Transplants and Regulation of Pre-Implantation Genetic Diagnosis.

Environment and Energy – Invasive Non-native Plant Species, Intermittent Electricity Generation, Demand Side Response, Urban Green Infrastructure, Insect Pollinator Declines, Antimicrobial Resistance in the Environment and Negative Emissions Technologies.

Physical sciences and IT – Autonomous Road Vehicles, Big Data, Computer Science Education.

CONFERENCES AND SEMINARS

Integrated Approaches to Managing Floods and Droughts in a Changing Climate

On 24th April, POST organised a parliamentary seminar to discuss the opportunities and challenges for more integrated approaches to managing floods and water resources given changing flood and drought risks. The event was chaired by Lord Whitty. Presentations were made by: Professor Ed Maltby, Emeritus Professor of Wetland Science, Water and Ecosystem Management, University of Liverpool, Richard Benyon MP, Defra Parliamentary Under-Secretary for Natural Environment and Fisheries, Professor Jim Hall, Director of the Environmental Change Institute, University of Oxford and Member of the Adaptation Sub-Committee of the UK independent Committee on Climate Change, Professor Alan Jenkins, Deputy Director of the Centre for Ecology & Hydrology and Science and Director for the Water Research Programme and Ian Barker, Head of Land and Water at the Environment Agency.

Future Environmental Applications and Implications of Synthetic Biology

On 30th April, POST hosted a Foresight Action Network spring meeting in conjunction with the Natural Environment Research Council (NERC) to explore and develop a better understanding of where these technologies may be used to the benefit of the environment, and also where there might be negative impacts and identify where further research is needed to protect the environment from identifiable risks. The outputs from the workshop will be made available on the NERC website. To inform the group discussions, presentations were made by: Professor Richard Owen, University of Exeter, Professor Bill Adams, University of Cambridge and Dr Marco Palomino, University of Exeter.

Special Educational Needs

On 14th May, POST organised a parliamentary seminar in conjunction with the All Party Parliamentary Group on Education to discuss an overview of how children and young people with special educational needs are defined and identified, where and how their needs are being met and the roles of those who are responsible for their education and training. Research from various disciplines has recorded significant shifts in the profile of children's needs, often resulting from new causal bases including premature birth. Presentations also covered the likely outcomes and impacts of the Children and Families Bill on provision for children with special educational needs. The event was chaired by Fabian Hamilton MP. Presentations were made by: Professor Barry Carpenter, University of Oxford, Dr Rhona Tutt, SEN Consultant and Sharon Godden.

Science of Bovine Tuberculosis Disease Control

On 20th May, POST organised a private briefing session to give parliamentarians the opportunity to debate bovine TB control with relevant experts prior to the proposed cull. The event was chaired by Lord Oxburgh. Brief presentations were made by Professor Ian Boyd, the Defra Chief Scientific Adviser, Mr Nigel Gibbens, the Defra Chief Veterinary Officer and two independent scientists, Professor Christl Donnelly, Imperial College and Professor Rosie Woodroffe, Zoological Society London, prior to an extended Q&A session. Professor Donnelly and Professor Woodroffe were members of the Independent Scientific Group on Cattle TB.

The Science of Health and Wellbeing

On 4th June, POST organised a parliamentary exhibition in collaboration with seven of the leading public sector bodies that fund research on health and wellbeing in the UK. All research disciplines – from physics to philosophy – are relevant to health and wellbeing and experts were on hand to discuss their latest research and their exhibits with parliamentarians. The event was chaired by Adam Afriyie MP. Presentations were made by: Professor Rick Rylance, Chief Executive, Arts and Humanities Research Council and Chair of Research Councils UK and Professor David Walker, Deputy Chief Medical Officer, Department of Health.

STAFF, FELLOWS AND INTERNS AT POST

Fellows

Brett Edwards, Bath University, Wellcome Trust
Dave Parker, University of Bristol, Royal Society of Chemistry
Luke Gibbon, University of Strathclyde, Wellcome Trust
Amy Zhang, University of Cambridge, Royal Society of Chemistry
Paul Coleman, BBSRC
Rory O'Connor, Centre for Ecology and Hydrology, British Ecological Society
Steve Aston, NERC
Eleanor Walton, York University, BBSRC
Becky Wilebore, University of Cambridge, NERC
Anne Claire Pawsey, University of Edinburgh, EPSRC
Christophe Mazur, Imperial College London, Grantham Institute

Staff

Dr Martin Griffiths, POST Physical Sciences and ICT adviser, is leaving POST in August 2013.

INTERNATIONAL ACTIVITIES

Dr Aaron Goater was invited to the annual meeting of the PISCES bioenergy consortium in Mombasa, Kenya, from 10th to 14th June.

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, House of Lords or Westminster Hall between 7th January and 27th March.

EDUCATION

AS-levels and A-levels	16.4.13	HoC 33WH	Seema Malhotra
Educating Engineers	16.5.13	HoC 26WH	Andrew Miller
Student Visas	6.6.13	HoC 1707	Adrian Bailey

ENERGY AND CLIMATE CHANGE

Energy Generation	17.4.13	HoC 102WH	Andrew George
Nuclear Power	22.4.13	HoL GC312	Viscount Hanworth
Off-gas Grid Households	16.4.13	HoC 1WH	Sarah Newton
Severn Barrage	22.4.13	HoL GC329	Lord Cope of Berkeley
UN Framework Convention on Climate Change	18.4.13	HoC 141WH	Tim Yeo

ENVIRONMENT, FOOD AND AGRICULTURE

Badger Cull	5.6.13	HoC 1519	Mary Creagh
Common Agricultural Policy	18.6.13	HoC 763	David Heath
Food Waste	24.4.13	HoC 327WH	Mark Pawsey
Marine Management Organisation (Data Accuracy)	20.5.13	HoC 1023	Alison Seabeck
Marine Conservation Zones	20.5.13	HoC 116WH	Damian Collins
Pollinators and Pesticides	6.6.13	HoC 1745	Joan Walley

HEALTH

Accident and Emergency Waiting Times	5.6.13	HoC 1586	Andy Burnham
Drug-resistant Tuberculosis (Developing Countries)	4.6.13	HoC 191WH	Jim Fitzpatrick
Genetic Medicine	13.6.13	HoC 595	George Freeman
Global Fund to Fight AIDS, TB and Malaria	4.6.13	HoL 1127	Lord Fowler
Herbal Medicines	24.4.13	HoL GC442	Lord Pearson of Rannoch

MISCELLANEOUS

Economy: Culture and the Arts	13.6.13	HoL 1741	Baroness Wheatcroft
European Commission's 4th Railway Package	25.4.13	HoC 1035	Simon Burns
Girls and ICT Careers	24.4.13	HoC 978	Chi Onwurah
Intellectual Property Bill (Second Reading)	22.5.13	HoL 848	Viscount Younger of Leckie
Lethal Autonomous Robotics	17.6.13	HoC 729	Nia Griffith
Plug-in Vehicles (Select Committee Report)	25.4.13	HoC 375WH	Louise Ellman
Science and Research	4.6.13	HoC 158WH	Dr Julian Huppert

SCIENCE DIRECTORY

THE FOLLOWING ORGANISATIONS HAVE ENTRIES IN THE SCIENCE DIRECTORY:

Association of the British Pharmaceutical Industry
AIRTO
AMPS
Biochemical Society
The British Ecological Society
British In Vitro Diagnostics Association (BIVDA)
British Measurement and Testing Association (BMTA)
British Nutrition Foundation
British Pharmacological Society
British Psychological Society
British Science Association
British Society for Antimicrobial Chemotherapy
British Society for Immunology
Cavendish Laboratory
Chartered Institute of Patent Attorneys
Clifton Scientific Trust
The Council for the Mathematical Sciences
Eli Lilly and Company Ltd
EngineeringUK
The Food and Environment Research Agency
GAMBICA Association Ltd
The Geological Society
Institute of Food Science & Technology
Institute of Marine Engineering, Science and Technology (IMarEST)
The Institute of Measurement & Control
Institute of Physics
Institute of Physics and Engineering in Medicine
Institution of Chemical Engineers
Institution of Civil Engineers
Institution of Engineering Designers
The Institution of Engineering and Technology
Institution of Mechanical Engineers
LGC
The Linnean Society
L'Oréal
Marine Biological Association
Met Office
MSD
National Physical Laboratory
Natural History Museum
NEF: The Innovation Institute
Nesta
PHARMAQ Ltd
The Physiological Society
Prospect
The Royal Academy of Engineering
Royal Botanic Gardens, Kew
The Royal Institution
The Royal Society
The Royal Society of Chemistry
Society for Applied Microbiology
Society for General Microbiology
Society of Biology
Society of Chemical Industry
Society of Cosmetic Scientists
Society of Maritime Industries
Universities Federation for Animal Welfare
The Welding Institute

Research Councils UK
Biotechnology and Biological Sciences Research Council (BBSRC)
Economic and Social Research Council (ESRC)
Engineering and Physical Sciences Research Council (EPSRC)
Medical Research Council (MRC0
Natural Environment Research Council (NERC)
Science and Technology Facilities Council (STFC)

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 over 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/
Twitter: @BESPolicy

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 Measurement & Testing Association (BMTA)

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BMTA is the trade and technology association for laboratory-based organisations and testing and calibration service providers. We have over 100 member companies representing the interests of over 450 UKAS accredited laboratories. BMTA provides its members with a wide range of liaison, lobbying, technical event and information services. BMTA is also very active in training initiatives and provides its members with access to European issues through our membership of EUROLAB.

British Nutrition Foundation

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

BRITISH PHARMACOLOGICAL SOCIETY

Today's science, tomorrow's medicines

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The British Pharmacological Society is the primary UK learned society concerned with research into drugs and the way they work. Our 3000+ members work in academia, industry, regulatory agencies and the health services, and many are medically qualified. We cover the whole spectrum of pharmacology, including laboratory, clinical, and toxicological aspects. Inquiries about the discovery, development and application of drugs 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 very welcome.

British Science Association

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Imran Khan will be Chief Executive from 2.4.13

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 immunology

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The BSI is one of the oldest, largest and most active immunology societies in the world. We have over 4,000 members who work in all areas of immunology, including research and clinical practice.

The BSI runs major scientific meetings, education programmes and events for all ages. We disseminate top quality scientific research through our journals and meetings and we are committed to bringing the wonders and achievements of immunology to as many audiences as possible.

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.

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

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Members of CIPA 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

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

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Clifton Scientific Trust Ltd is registered charity 1086933

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

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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, 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

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

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

GAMBICA Association Ltd

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

The Geological Society

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

Institute of Food Science & Technology

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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)

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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. We are a charitable organisation with a worldwide membership of around 50,000, working together to advance physics education, research and application.

We engage with policymakers and the general public to develop awareness and understanding of the value of physics and, through IOP Publishing, we are world leaders in professional scientific communications. Visit us at www.iop.org.

Institute of Physics and Engineering in Medicine

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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 membership approaching 38,000 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

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Representing over 80,000 professional civil engineers around the world, ICE actively contributes to the development of public policy at all levels of government in areas concerning infrastructure, engineering and our quality of life.

Established in 1818, ICE is recognised worldwide for its excellence as a centre of learning, as a qualifying body and as a public voice for the profession. Our members design, build and maintain the infrastructure that keeps our country running.

Under our Royal Charter, we have a duty to provide independent, expert advice on infrastructure issues for the benefit of the public and to serve wider society. We are seen by Parliament and industry alike as the authoritative voice of infrastructure.

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.

IET

The Institution of Engineering and Technology

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

Institution of Mechanical Engineers

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

LGC *Setting standards in analytical science*

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Website: www.lgcgroup.com

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

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

With headquarters in Teddington, South West London, LGC has 36 laboratories and centres across Europe and at sites in China, Brazil, India, South Africa 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

L'Oréal UK and Ireland

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Website: www.loreal.co.uk

L'Oréal employs more than 3,500 scientists around the world and dedicates over 500 million euros each year to research and innovation in the field of healthy skin and hair. The company collaborates with a vast number of institutions in the UK and globally.

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.

Met Office

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The Met Office doesn't just forecast the weather on television. Our forecasts and warnings protect UK communities and infrastructure from severe weather and environmental hazards every day – they save lives and money. Our Climate Programme delivers evidence to underpin Government policy. Our Mobile Meteorological Unit supports the Armed Forces around the world. We build capacity overseas in support of international development. All of this built on world-class environmental science.

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.

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

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Website: www.nhm.ac.uk

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

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

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

NEF: The Innovation Institute

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The Innovation Institute is the leading provider of innovation and growth solutions to business, education and government. Through our strategic programmes we help our clients and stakeholders to:

- Achieve performance excellence
- Drive entrepreneurship
- Diversify products and markets
- Develop innovative cultures
- Influence policy to stimulate innovation

Our charitable arm, the New Engineering Foundation, supports vocational scientific and technical skills development at strategic level. In addition, our Institute of Innovation and Knowledge Exchange is a professional body and "do tank", led by the Innovation Council to support the role of innovation in society.

Nesta

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Nesta is the UK's innovation foundation with a mission to help people and organisations bring great ideas to life. We do this by providing investments and grants and mobilising research, networks and skills.

Nesta doesn't work alone. We rely on the strength of the partnerships we form with other innovators, community organisations, educators and investors too.

We are an independent charity and our work is enabled by an endowment from the National Lottery.

Nesta Operating Company is a registered charity in England and Wales with a company number 7706036 and charity number 1144091. Registered as a charity in Scotland number SC042833. Registered office: 1 Plough Place, London, EC4A 1DE.

www.nesta.org.uk

PHARMAQ Ltd

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PHARMAQ is the only global pharmaceutical company with a primary focus on aquaculture. We provide environmentally sound, safe and efficacious health products to the global aquaculture industry through targeted research and the commitment of dedicated people. Our product range includes vaccines, anaesthetics, antibiotics, sea lice treatments and biocide disinfectants. We also recently acquired a diagnostics company, PHARMAQ Analytiq, which offers a range of diagnostics services that help to safeguard fish welfare and improve productivity in the global aquaculture industry.

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 120,000 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.

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

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RBG Kew is a centre of global scientific expertise in plant and fungal diversity, conservation and sustainable use, housed in two world-class gardens. Kew is a non-departmental public body with exempt charitable status and receives approximately half 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 of plants and fungi
- Banking seed from 25% of plant species in the Millennium Seed Bank Partnership
- Restoring and repairing habitats
- Inspiring through botanic gardens

Kew's mission is to inspire and deliver science-based plant conservation worldwide, enhancing the quality of life.

The Royal Institution Science Lives Here

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Twitter: ri_science

The core activities of the Royal Institution centre around four main themes: science education, science communication, research and heritage. It is perhaps best known for the Ri Christmas Lectures, but it also has a public events programme and an online science short-film channel, as well as a UK-wide Young People's Programme of science and mathematics enrichment activities. Internationally recognised research programmes in bio- and nanomagnetism take place in the Davy Faraday Research Laboratory.

The Royal Society

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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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http://www.chemsoc.org

The Royal Society of Chemistry is a learned, professional and scientific body of over 48,000 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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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

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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 Chemical Industry (SCI)

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SCI is an inclusive, multi-disciplinary forum connecting scientists and business people to advance the commercial application of chemistry and related sciences for public benefit. SCI is open to all to join and share information, ideas, innovations and research. Members can network with specialists from sectors as diverse as food and bio-renewables, water, waste and environment, energy, materials, manufacturing and health.

Society of Cosmetic Scientists

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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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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

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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 is the leading engineering institution with expertise in solving problems in all aspects of manufacturing, fabrication and whole-life integrity management.

Personal membership provides professional development for engineers and technicians, and registration as Chartered or Incorporated Engineer, or Engineering Technician.

Industrial membership provides access to one of the world's foremost independent research and technology organisations.

TWI 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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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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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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Over the past century, the MRC has been at the forefront of scientific discovery to improve human health. Founded in 1913 to tackle tuberculosis, the MRC now invests taxpayers' money in the highest quality medical research across every area of health. Twenty-nine MRC-funded researchers have won Nobel prizes in a wide range of disciplines, and MRC scientists have been behind such diverse discoveries as vitamins, the structure of DNA and the link between smoking and cancer, as well as achievements such as pioneering the use of randomised controlled trials, the invention of MRI scanning, and the development of therapeutic antibodies. We also 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.

Natural Environment Research Council

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The NERC invests public money in cutting-edge research, training and knowledge transfer in the environmental sciences – through Universities and our own research centres. We work from the poles to the ocean depths and to the edge of space, researching critical issues such as biodiversity loss, climate change and natural hazards. Through collaboration with other science disciplines, with UK business and with policy-makers, we deliver knowledge and skills to support sustainable economic growth and public wellbeing – reducing risks to health, infrastructure and supply chains, and the natural environment on which we all depend.

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
www.scienceinparliament.org.uk

Tuesday 22 October
Smart Buildings

Tuesday 5 November
Annual Lunch
Guest of Honour: Sir Mark Walport FRS
Government Chief Scientific Adviser

Tuesday 19 November
A Good Immigration Policy for Science

Tuesday 10 December
Deep Sea Mining to include Protection of the Seabed

THE ROYAL SOCIETY

Website: royalsociety.org

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

Many past events are available to watch or listen to online at http://royalsociety.tv The collection includes events with speakers such as Jocelyn Bell Burnell FRS, Val McDermid and Professor Brian Cox OBE.

Details of all our events can be found on our website at royalsociety.org/events

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THE ROYAL INSTITUTION

21 Albemarle Street
London W1S 4BS.

Details of future events can be found at www.rigb.org
Booking is essential. For more information and to book visit www.rigb.org
There is a charge for tickets. Members go free.

PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY

For details of events organised by POST visit http://www.parliament.uk/mps-lords-and-offices/offices/bicameral/post/post-events/

BRITISH SCIENCE ASSOCIATION

The British Science Festival will be taking place in Newcastle upon Tyne, celebrating all the North East has to offer.
The full programme will be available online in July, when the booking system will open.

Many of the events are free, but may require tickets to be booked in advance. For more information visit:
http://www.britishscienceassociation.org/british-science-festival

The British Science Festival is working in partnership with Corylus Learning to host thousands of young people at the Festival as part of the schools' programme. For more information visit:

http://www.britishscienceassociation.org/british-science-festival/schools-programme

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THE INSTITUTION OF MECHANICAL ENGINEERS

The Institution of Mechanical Engineers plays a leading role in the international engineering community in providing advice to governments, industry and global society. Each year it organise some 300 technical conferences, seminars, lectures, debates and workshops around the UK and internationally, on key updates, developments or new techniques across 18 engineering and manufacturing sectors.

For details visit: www.imeche.org/events

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British Ecological Society

CELEBRATING 100 YEARS

The British Ecological Society Celebrates its Centenary in 2013 with:

Launch of Ecological Issues report on the impact of extreme events on freshwater ecology

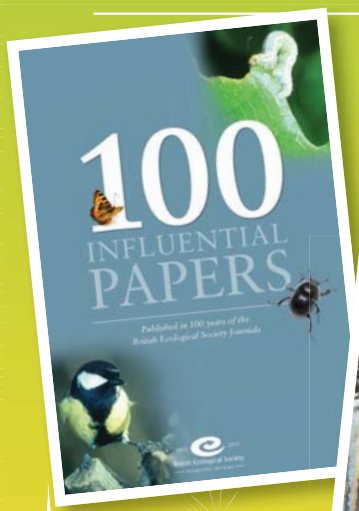
World's largest gathering of academic ecologists at the 11th INTECOL conference

125 ecological themed events for the public

Four educational wall charts on cross curricula ecological issues

Three cross disciplinary scientific meetings on topical ecological issues, marine science, global change & biosphere interactions and disease

Publication of 100 Influential Papers published in 100 years of British Ecological Society journals

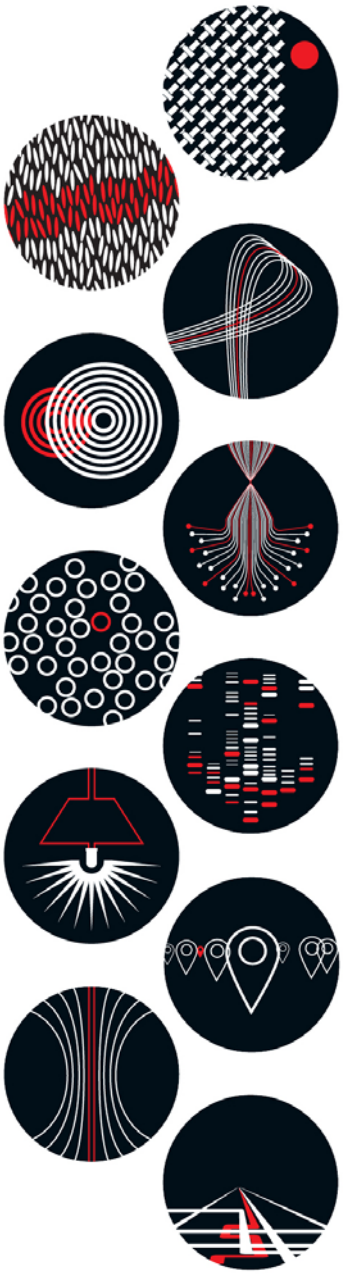


Festival of Ecology

www.britishecologicalsociety.org

Case studies prepared by IOP in partnership with EPSRC and STFC | June 2013

Physics: transforming lives



Case studies prepared by the Institute of Physics in partnership with the Engineering and Physical Sciences Research Council and the Science and Technology Facilities Council

IOP Institute of Physics

EPSRC
Engineering and Physical Sciences Research Council

Science & Technology Facilities Council

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Charity registration number 293851
Scottish Charity Register number SC040092

The report is available to download from our website and if you require an alternative format please contact us to discuss your requirements.