

# fst *journal*

The Journal of The Foundation for Science and Technology

Volume 21 Number 8 June 2016 [www.foundation.org.uk](http://www.foundation.org.uk)

---

## Editorial

**Sir Paul Nurse:** In defence of doubt

---

## The pros and cons of EU membership

**Lord Hennessy:** Collaboration – a better way to nurture science

**Viscount Ridley:** British science should look outwards to the world

**Dame Jocelyn Bell Burnell:** The benefits of membership to UK science

**Sir Emyr Jones Parry:** Collaborating to create a better future

---

## Using science to authenticate, verify and assure

**Sir Mark Walport:** The potential of forensic science for the UK

**Dr Derek Craston:** Forensic science beyond the courtroom

**Dame Sue Black:** The power of the Medici Effect

**Baroness Neville-Jones:** Meeting the challenge of new technology

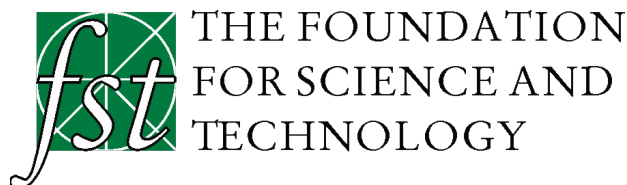
---

## Building infrastructure for the UK

**Tony Meggs:** Delivering infrastructure effectively and efficiently

**Lord Adonis:** Creating the framework for effective infrastructure delivery

**Sir Terry Morgan:** Infrastructure as the nursery for tomorrow's skills base



### COUNCIL

#### *Chairman*

The Earl of Selborne GBE FRS

#### *Deputy Chairman*

Dr Mike Lynch OBE FRS FREng

#### *President, The Royal Society*

Sir Venki Ramakrishnan PRS FMedSci

#### *President, Royal Academy of Engineering*

Professor Dame Ann Dowling DBE FRS FREng

#### *President, British Academy*

The Lord Stern of Brentford PBA FRS

#### *President, The Academy of Medical Sciences*

Professor Sir Robert Lechler PMedSci

#### *President, The Royal Society of Edinburgh*

Professor Dame Jocelyn Bell Burnell DBE FRS FRSE FRAS FInstP

#### *President, The Learned Society of Wales*

Sir Emyr Jones Parry GCMG FInstP PLSW

#### *Chair, Arts & Humanities Research Council*

Sir Drummond Bone FRSE

#### *Chair, Biotechnology and Biological Sciences Research Council*

Sir Gordon Duff FRCP FRCPE FMedSci FRSE

#### *Chair, Economic and Social Research Council*

Dr Alan Gillespie CBE

#### *Chair, Engineering and Physical Sciences Research Council*

Dr Paul Golby CBE FREng

#### *Chair, Medical Research Council*

Donald Brydon CBE

#### *Chair, Natural Environment Research Council*

Sir Anthony Cleaver HonFREng

#### *Chair, Science and Technology Facilities Council*

Sir Michael Sterling FREng

#### *Chair, EngineeringUK*

Dr Paul Golby CBE FREng

#### *Chair, Innovate UK*

Phil Smith

#### *Chair, Steering Board, UK Space Agency*

Post Vacant

#### *President, The Science Council*

Post Vacant

Professor Polina Bayvel FRS FREng

Sir John Beddington CMG FRS FRSE HonFREng

Sir Leszek Borysiewicz FRS FRCP FMedSci

The Lord Broers FRS FREng

Sir Geoffrey Chipperfield KCB

The Lord Haskel

Dr Julian Huppert\*

Sir David King ScD FRS HonFREng

The Lord Krebs FRS FMedSci

Sir Rob Margetts CBE FREng

The Lord Mair CBE FRS FREng

The Lord May of Oxford OM AC FRS

The Rt Hon Sir Brian Neill\*

The Rt Hon the Baroness Neville-Jones\* DCMG

The Baroness O'Neill of Bengarve CH CBE FBA FRS

Sir Paul Nurse FRS FMedSci HonFREng

The Lord Oxburgh KBE FRS

The Lord Rees of Ludlow OM FRS HonFREng

Dr Peter Ringrose

The Baroness Sharp of Guildford\*

Sir Adrian Smith FRS

Dr Graham Spittle CBE

The Lord Trees\*

The Baroness Wilcox\*

The Rt Hon the Lord Willetts\*

Sir Peter Williams CBE FREng FRS

The Lord Willis of Knaresborough

#### *Honorary Treasurer*

Tony Quigley

#### *Honorary Secretary*

Patrick McHugh

### CHIEF EXECUTIVE

Dr Dougal Goodman OBE FREng

\* Associate Member

---

### The Foundation for Science and Technology

10 Carlton House Terrace

London SW1Y 5AH

Tel: 020 7321 2220

Email: [fstjournal@foundation.org.uk](mailto:fstjournal@foundation.org.uk)

**Editor** Dr Dougal Goodman OBE FREng

**Production Editor** Simon Napper

**Layout** Simon Clarke

*FST Journal* redesigned in 2015 by IOP Publishing's Design Studio, under the art direction of Andrew Giaquinto.

IOP Publishing provides publications through which leading-edge scientific research is distributed worldwide and is central to the Institute of Physics, a not-for-profit society.

Neither the Foundation nor the Editor is responsible for the opinions of the contributors to *FST Journal*.



©2016 The Foundation for Science and Technology

ISSN 1475-1704

Charity Number: 00274727 Company Number: 01327814

# fst *journal*

Volume 21 Number 8 June 2016

## THE COUNCIL OF THE FOUNDATION

Inside front cover

## UPDATE

Call for action on 'devastating problem' of antimicrobial resistance • Higher education White Paper sets out plans for competition • Computer science employability review • Africa Prize for tablet-based heart monitor • New facilities at Culham Science Centre • A joined-up approach to urban living • Royal Society launches GM guide • UKRI interim chair • RCUK inclusion plan

## EDITORIAL

In defence of doubt **Sir Paul Nurse** 4

## THE PROS AND CONS OF EU MEMBERSHIP

Collaboration: a better way to nurture science **Lord Hennessy** 6  
 British science should look outwards to the world **Viscount Ridley** 8  
 The benefits of membership to UK science **Dame Jocelyn Bell Burnell** 11  
 Collaborating to create a better future **Sir Emyr Jones Parry** 12

## THE VALUE OF EU MEMBERSHIP

Findings of the report from the House of Lords Science and Technology Select Committee 15

## USING SCIENCE TO AUTHENTICATE, VERIFY AND ASSURE

The potential of forensic science **Sir Mark Walport** 16  
 Forensic science beyond the courtroom **Dr Derek Craston** 18  
 The power of the Medici Effect **Dame Sue Black** 20  
 Meeting the challenge of new technology **Baroness Neville-Jones** 22

## BUILDING INFRASTRUCTURE FOR THE UK

Delivering infrastructure effectively and efficiently **Tony Meggs** 24  
 Creating the framework for effective infrastructure delivery **Lord Adonis** 26  
 Infrastructure as the nursery of tomorrow's skills base **Sir Terry Morgan** 29

## EVENTS

Foundation events held since 3 June 2015 32



## Higher education White Paper sets out plans for competition

A White Paper setting out the Government's plans to reform the higher education and research system was published in mid-May. Entitled *Success as a Knowledge Economy: teaching excellence, social mobility and student choice*, the document says: "Higher education continues to be a sound financial and personal investment with a wide range of societal benefits. But there is more to be done for our university system to fulfil its potential as an engine of social mobility, a driver of economic growth and cornerstone of our cultural landscape."

It notes that access remains uneven, with young people from the most dis-

advantaged backgrounds 2.4 times less likely to go into higher education than the most advantaged. Courses are inflexible, based on the traditional three-year undergraduate model, with insufficient innovation and provision of two-year degrees and degree apprenticeships.

The Government says there is no compelling reason for incumbents to be protected from high quality competition. It wants a globally competitive market that supports diversity, where anyone who demonstrates they have the potential to offer excellent teaching and clears a high quality bar can compete on a level playing field.

In order to enable greater competition, it plans to simplify the regulatory landscape, creating a level playing field with a single route to entry and a risk-based approach to regulation. It will seek to reduce unnecessary barriers to entry, but, recognising the public interest in ensuring the quality and sustainability of the system, will ensure quality is built into the reforms at every stage, from the way new entrants are regulated to the incentives on incumbents.

[www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/523546/bis-16-265-success-as-a-knowledge-economy-web.pdf](http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/523546/bis-16-265-success-as-a-knowledge-economy-web.pdf)

## UKRI interim chair

Sir John Kingman has been appointed interim Chair of UK Research and Innovation (UKRI), to set up the organisation in shadow form. This will be the strategic body bringing together the seven Research Councils, Innovate UK and the research funding from the Higher Education Funding Council for England.

Sir John will provide advice to ministers on recruiting a leading scientist to take the reins as UKRI Chief Executive.

As second permanent secretary to HM Treasury, Sir John was at the helm of HM Treasury during successive administrations that prioritised investment in science and innovation. He was responsible for five science spending reviews.

## RCUK inclusion plan

Research Councils UK (RCUK) has launched an action plan to promote equality, diversity and inclusion in research, recognising its own leadership role in driving a change in culture.

The plan outlines an ambition to lead by example to ensure a diverse workforce, challenge bias and work towards fair and inclusive funding processes; as well as lead and support change in the research community. Work has already begun with the roll-out of training for peer reviewers and funding decision-makers concerning unconscious bias.

[www.rcuk.ac.uk/documents/documents/actionplan2016-pdf](http://www.rcuk.ac.uk/documents/documents/actionplan2016-pdf)

## Computer science employability review

Computer science graduates are more likely to be unemployed six months after graduating than the average graduate, and STEM graduates in particular. Employment outcomes significantly improve 3.5 years after graduation, although they are still lower compared to other graduates. These findings seemingly contradict evidence of increasing employer demand for digital skills and above-average levels of recruitment difficulties in the ICT sector.

There is evidence that computer science is one of the least competitive degree-level subjects to apply for; also, computer science graduates have comparatively low levels of prior attainment and are less likely to achieve first class honours.

In response, the Government asked Professor Sir Nigel Shadbolt to conduct

a review of computer science degree accreditation and graduate employability. His report, *Computer Science Graduate Employability: qualitative interviews with graduates*, was published in May.

Among the conclusions is that "graduate transitions from unemployment at six months to employment three-and-a-half years later are mostly driven by graduates taking the necessary steps that they feel they should have undertaken while on their course. The delay in doing so is largely a result of a misguided perception that computer science graduates are in demand and that they will have a relatively smooth transition into employment."

[www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/523079/bis-16-114-computer-science-graduate-employability.pdf](http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/523079/bis-16-114-computer-science-graduate-employability.pdf)

## Africa Prize for tablet-based heart monitor

Cameroonian innovator Arthur Zang has won the second Africa Prize for Engineering Innovation for his heart-monitoring device, the Cardio-Pad. His invention could change the way that Africans access treatment for heart disease, a critical illness on the continent.

The Cardio-Pad is a small tablet device that allows any medical professional to perform heart diagnostics at any location. These diagnostics, sent to a cardiologist via a mobile phone network, are interpreted in under 20 minutes.

Nearly one in two Africans over the age of 25 has undiagnosed hypertension, and an estimated 20 million Africans suffer from a cardiovascular disease. A further 80 million Africans are estimated to have abnormally high blood pressure, which can lead to heart failure.

The Africa Prize for Engineering Innovation, founded by the Royal Academy of Engineering in the UK, encourages talented sub-Saharan African engineers, from all disciplines, to develop local solutions to challenges in their communities.

## Call for action on ‘devastating problem’ of antimicrobial resistance

A review commissioned by the UK Government says wide-ranging action is required at a global level to prevent a post-antibiotic future.

The review panel, chaired by economist Jim O’Neill, warns that, without global action, antibiotic resistance will become a “devastating problem” by 2050, responsible for an estimated 10 million deaths a year. Surgery could also carry a much higher risk of complications because of the possibility of infection.

Following 19 months of consultation and eight interim papers, each focusing on a specific aspect of antimicrobial resistance (AMR), the report

sets out the Review on Antimicrobial Resistance’s final recommendations to tackle AMR in a global way.

The magnitude of the problem is now accepted. Research estimates that, by 2050, 10 million lives a year and a cumulative \$100 trillion of economic output are at risk due to the rise of drug-resistant infections if solutions are not found now to slow this down. Even today, 700,000 people die of resistant infections every year.

Antibiotics are a special category of antimicrobial drugs that underpin modern medicine. If they lose their effectiveness, key medical procedures could become too dangerous to per-

form. These include gut surgery, caesarean sections and joint replacements, as well as treatments that depress the immune system, such as chemotherapy for cancer. Most of the direct and much of the indirect impact of AMR will fall on low and middle-income countries.

It does not have to be this way, says the Review. It is in policy makers’ and governments’ hands to take steps to change this situation and the report makes a series of recommendations to address the challenge.

[amr-review.org/sites/default/files/160518\\_Final%20paper\\_with%20cover.pdf](http://amr-review.org/sites/default/files/160518_Final%20paper_with%20cover.pdf)

## New facilities at Culham Science Centre

Two specialist hi-tech facilities developed by the UK Atomic Energy Authority (UKAEA) have been formally opened at the Culham Science Centre in Oxfordshire.

RACE (Remote Applications in Challenging Environments) is a robotics test centre for UK industry. Robotics is one of the Government’s ‘eight great technologies’ for growth. RACE applies knowledge in robotics developed over two decades at the Joint European Torus (JET) fusion experiment at Culham, so companies in other areas, such as space, deep sea, nuclear, construction and autonomous vehicles, can benefit. RACE has already helped British firms secure £100 million in contracts.

The Materials Research Facility (MRF) is a laboratory for scientists designing the nuclear power stations of the future – both

fission and fusion. MRF is a key part of the Government-backed National Nuclear User Facility which aims to improve the UK’s nuclear research base and long-term options for generating low-carbon energy.

Funding for Oxford Advanced Skills has also been announced. This is a new apprentice training facility for Oxfordshire hi-tech businesses, also to be located at Culham. Oxford Advanced Skills is a partnership between UKAEA and training providers JTL – it will train 150 engineering apprentices per year when completed in 2019 and aims to address the skills shortage which threatens Oxfordshire’s booming technology sector.

RACE and MRF are UKAEA’s first new research facilities at Culham for over 30 years.

## Royal Society launches GM guide

The Royal Society has launched *GM Plants: questions and answers*, a fact-based Q&A-style guide to answer questions that the UK public have about genetically modified (GM) crops. The online booklet is accompanied by an animation explaining the basic science of GM, compared to conventional plant breeding.

An extensive study published in May by the National Academies of Sciences, Engineering, and Medicine in the USA found no evidence of risks to human health or the environment from GM crops.

The World Bank says that the world needs to produce at least 50% more food by 2050 to keep up with population growth. As part of the debate about what kind of agriculture and food systems can provide the food that we need, the Royal Society has drawn on the expertise of its Fellows and other authorities in plant science to summarise the scientific and technological evidence about GM.

In the UK half of the population do not feel well informed about genetically modified crops and a further 6% have never heard of them.

To identify the topics people most wanted to know about, Ipsos MORI carried out a series of focus group discussions around the UK, the result of which was a set of 18 priority questions.

[royalsociety.org/topics-policy/projects/gm-plants](http://royalsociety.org/topics-policy/projects/gm-plants)

## A joined-up approach to urban living

People living in the cities of Birmingham, Bristol, Leeds, Newcastle & Gateshead and York will benefit from a new research and innovation initiative to help improve their cities’ health, wellbeing and prosperity as they face up to challenges of modern urban living.

Phase one of the Urban Living Partnership, a first-of-its-kind investment by the seven UK Research Councils and the Government’s innovation agency, Innovate UK, brings citizens together with university researchers, local authorities and over 70 partners from business and

the third sector, in five multidisciplinary pilot initiatives aimed at rewriting the blueprint for the evolution of city living.

The Urban Living Partnership brings together a body of expertise across over 20 disciplines including civil engineering, computer science, planning, psychology, management, arts and humanities, the creative industries and health sciences.

Partners to the first phase of the initiative include: IBM UK, Arup, Atkins Global, the Environment Agency, Natural England and the Future Cities Catapult.



## In defence of doubt

Paul Nurse



Sir Paul Nurse FRS FMedSci is a geneticist and cell biologist who has worked on how cell reproduction is controlled. He is Director of the Francis Crick Institute in London, and has served as President of the Royal Society, Chief Executive of Cancer Research UK and President of Rockefeller University. He shared the 2001 Nobel Prize in Physiology or Medicine.

**T**his theme might seem unusual for a scientist concerned with the way sciences – and indeed all academic disciplines – can lead to the advancement of knowledge. It might be imagined that academics should be arguing to reduce doubt rather than defend it. My intent is to argue that doubt should be encouraged. It is a critical step in the progress of knowledge, particularly scientific knowledge. A recognition of the significance of doubt is important for the pursuit of science, for interactions between science and society, and for that matter for society as a whole.

### A crucial step

My starting point is the 11th century French monastic scholar Peter Abelard, who identified doubt as a crucial step in the pursuit of truth when he stated that: “By doubting we come to inquiry, and through inquiry we perceive truth.” What Abelard meant was the need to recognise that all is not known with certainty about the world. Doubting embraces a sceptical approach, challenging the views of established opinions and authorities about knowledge and understanding. Indeed, doubt together with curiosity form the mainsprings of the pursuit of knowledge.

Maintaining a sceptical approach during inquiry also leads to an absolute respect for observation, experiment and consistency in results. It underpins the need to develop ideas that can be tested and which are therefore capable of refutation. All of these are core attributes of science.

### A contrast

This focus on doubt and scepticism contrasts with views of the world which emphasise ideologies, faith and beliefs, since these do not depend on empirical support derived from direct evidence or proof, but rather depend on testimony or authority, and so some consider doubt of little value or even as a weakness.

An obvious example, less of an issue in the UK but important in the USA and Muslim countries, is the promotion of creationism as an explanation for the diversity of life. Creationism essentially depends upon received authority for its support and therefore is not subject to doubt or refutation, both of which are central to scientific enquiry.

Doubts can also become marginalised when grand ideologies are too zealously embraced,

becoming excessively self-referential and incapable of refutation. Two examples of ideologies which many have argued suffer these problems are Marxism and Freudianism. Ideologies such as these, as well as other more faith-based thinking, have and will continue to provide important insights, but when they are used as the only prism through which the world should be observed and understood, then intellectual impoverishment is generally the outcome.

Doubt also encourages both a diversity of ideas and a healthy sceptical approach, which helps test the validity of those ideas – a surer way to arrive at reliable knowledge.

### The view of society

Doubt and scepticism are crucial for scientific enquiry, but that is not how society always views science. The great ideas of science have usually been subject to prolonged investigation and testing and, having survived such intense interrogation, they become accepted as highly reliable explanations for the world around us. This is how we teach science at school and how we scientists often portray science in the media, encouraging society to view science as always dealing in certain knowledge.

Long-standing and well-tested ideas of science should have a high status for reliability, but this does not always apply to many of the problems of science under current investigation, problems in which society often has great interest. Good examples are biomedical problems, such as the causes, treatment and prevention of disease, the genetic basis of behaviour, and the influence of diet and pollution on health. Frequently research in these areas falls into the category of tentative knowledge, but such hesitant understanding is thought to be unsatisfactory when society and its leaders are seeking, quite understandably, greater certainty.

A frequently occurring example is whether a newly-discovered infectious agent – a virus, a bacterium or a parasite – will cause a major human pandemic, a question which most scientists working in this area often find very difficult to answer at early stages of disease outbreak. Yet clear advice about whether this is likely or not is of great importance to governments and the public, who are wrestling with how to manage a potential major threat to public health.

### A disconnect

This disconnection between the need and desire for sure knowledge on the one hand, and uncertain scientific understanding on the other, is a major cause of problems in interactions between science and society. Society looks for certainties and believes science can usually provide them, while science can be in a state of tentative knowledge which cannot always provide the certainties required in the timeframe within which they are needed. The problem is exacerbated when less-scrupulous political leaders or ideologists shelter behind poor science or criticise high quality science when trying to bolster a particular political or ideological opinion, or when attempting to support specific commercial activities.

As an example of the latter, take those who deny the evidence of climate change by arguing that the majority of climate scientists should be ignored, when the real motives of such denialists are perhaps more to do with promoting libertarian ideology or with protecting specific commercial interests. I believe that the future will judge this debate in much the same way as we now view the tobacco industry's denial that smoking causes cancer.

How can this mismatch between what society expects and what science can deliver be dealt with? I would argue that the way forward is to encourage effective public dialogue, openness, and honesty. This requires: a willingness of engaged scientists to talk with, and listen to, the public about the issues; an openness to explain the true nature of scientific inquiry and the knowledge it produces (which can range from understanding of great reliability to explanations which are far more tentative); and an honesty to admit when we are in doubt and cannot provide the clarity required.

This last point can be a real issue with the coverage of science in the media, where the wish to provide differing views and perhaps, less laudably, the entertainment of promoting a confrontation between individuals at polar opposites, can lead to the excessive exposure of fallacious ideas, held and presented by zealous individuals who lack both doubt and also any significant scientific support for their positions.

### The healthy functioning of society

I want to take my defence of doubt one step further, to the healthy functioning of society on a more global scale. Real dangers threaten the world when those with intolerant fundamentalist religious or ideological beliefs come to political power or have too much influence on those in political power. Their lack of doubt leads them to believe that they are always in the right, producing



© Marie-Lan Nguyen / Wikimedia Commons

**“By doubting we come to inquiry, and through inquiry we perceive truth.”  
Peter Abelard**

groups, governments and regimes which do not listen to the opinions of others, which are not interested in dialogue, and which turn all too readily to violent interventions to impose their orthodoxies on others.

We are in real need of greater doubt in today's world, not only for the advancement of knowledge and its effective use for the benefit of humanity, but also to make the world a safer place.

Francis Bacon, the seventeenth century English architect of the scientific revolution, eloquently summed up this argument when he wrote in *The Advancement of Learning*: “If a man will begin with certainties, he shall end in doubts; but if he will be content to begin with doubts, he shall end in certainties.”

I commend this passage to us all. □

In the lead-up to the UK referendum on continued membership of the European Union, the Foundation for Science and Technology held a meeting on 3 May 2016 looking at the pros and cons of membership for UK research programmes.

## Collaboration: a better way to nurture science

Peter Hennessy



The Lord Hennessy of Nympsfield FBA is a member of the House of Lords Select Committee on Science and Technology. He is a journalist and historian who has sought to unpick the inner workings of the machinery of Government. He has worked for *The Times*, the *Financial Times* and *The Economist*, and has written a number of popular books on the history of modern politics in Britain. (Photo © Layton Thompson [www.laytonthompson.com](http://www.laytonthompson.com))

The life of the mind should have little or nothing to do with customs unions – and that is what the European Union in its various forms since 1952 has been and will remain. For free trade comes no freer than the global intellectual trade in ideas and research. A free trade of the mind is something we can all sign up to, wherever we stand on the Great European Debate currently gnawing at the vitals of the British body politic. This free trade of the mind should never be combined or confined by anyone be they politician, bureaucrat or priest. There can be no tariff on thought, it is borderless.

The UK was a very considerable player in the worlds of research, science, technology, the arts and humanities before we joined what was then the European Economic Community (EEC) in January 1973. It will still remain so in 2018 if next month's referendum requires the UK to leave the EU and the timetable for ejection prescribed by the Lisbon Treaty is achieved.

As a country we have always 'thought heavier than our weight' in the world since at least the seventeenth century and I am confident we will continue to do so, whatever the British people reveal as their collective wisdom when the voting result is announced in Manchester on Friday 24 June. The reasons for our global prowess in the little-grey-cells department – our 'cultural world service', as Melvyn Bragg describes it – are multiple and I am pleased to say the British Academy will soon be mounting a study of the ingredients with the encouragement of the House of Lords Select Committee on Science and Technology.

All that having been said, research needs fructifying institutions and funding streams to irrigate the life of the mind, both at the national and international levels. It is my belief that our 43-year membership of the European Community has, on balance, been positive to this end.

It is, though, impossible to demonstrate such an assertion. After all, in January 1973 we could not have set up a control group of universities and

### SUMMARY

- UK has always 'thought heavier than its weight'.
- It is not possible to scientifically test the assertion that membership of the EU has been better or worse than existence outside.
- If the UK had engaged after the war, 'Europe' would look quite different.
- Certain aspects of EU scientific policy need to be addressed.
- The UK may have a real opportunity to provide leadership.

research labs that would not be eligible for EEC largesse. Nor could we have set aside, say Warwickshire, from our EEC membership to see if it flourished more or less than other parts of the UK.

From the evidence sessions of the Lords Committee in pursuit of its inquiry into 'EU Membership and UK Science'<sup>1</sup>, I acquired impressions that had not dawned on me before. For example, it strikes me that this aspect of our 43-year old relationship with Europe has been the least jagged of all the linkages which, taken together, amount to a formidable emotional deficit with the European Community (which will likely endure even if we vote to remain).

### UK not involved at the start

This is partly because we did not invent this phenomenon. The Coal and Steel Community in the early 1950s came not from a UK view of the world but out of the minds of clever, Catholic, left-wing, French bureaucrats: most Brits have a problem with at least three of those five characteristics (though I am not among them)!

If the UK had invented post-war European integration it would be so very different – all run by a tiny secretariat from a small office located in an area of high unemployment producing about three letters a year saying: "Would you mind



awfully doing a bit more on free trade here, here and here, but only if you've got time."

For we are not a 'Directives' people. If we had shaped the Community there would probably have been no science or R&D element in it at all. Yet that feature exists. It matters. It is, as the Select Committee says, "a major component of the UK's membership of the EU. Nearly one fifth (18.3%) of EU funding to the UK is spent on research and development."

As that great man Michael Caine might put it: not many people know that. The science and R&D element is not – and will not become – a make-or-break issue in the great European debate. In fact, it will be barely a squeak amidst the great cacophony of claim and counter-claim that assails us.

There would, I believe, be a loss to the UK on this front if we leave. It was put to the Committee that the EU funding stream is the equivalent to an extra Research Council for the UK. We might also lose some of the human flows into and out of our labs which the free movement of people with the EU permits; and this in an era where increasingly the prizes go to international and collaborative projects.

Switzerland does not offer a happy exemplar, for example. Among the witnesses we heard, Professor Siegfried Russwurm, Chief Technology Officer of Siemens, and Professor Philippe Moreillon, Vice Rector for Research and International Relations at the University of Lausanne, were especially eloquent.

### The experience of Switzerland

Switzerland, a country which, quite rightly, prizes its science base and prides itself on thinking heavier than its weight in the world, is not an exact guide to how UK scientific and R&D life might be if we leave. It cannot be: we are very different countries however you look at it.

But how Switzerland has fared as an 'Associated Country' with the EU is instructive. Along with a dozen other non-EU countries it participates in the funding schemes of the EU Framework Programme and puts money into the EU Budget. Yet such countries lack the level of influence within decision-making processes and advisory panels that EU members enjoy. These countries do, however, commit to freedom of movement of people. However, when in 2014 Switzerland narrowly voted to restrict freedom of movement in a referendum, it was suspended from access to what was then called the EU's Horizon 2020 programme – which plainly hurt its research efforts.

Professor Moreillon in his evidence to the

**We might be prouder and more independent if we depart from the EU, but we will very likely be poorer in terms of science and R&D funding.**

Select Committee was eloquent on the limits to the Swiss position: "When we became an Associate, it was much, much easier, of course, but we are still not sitting at the decision table or on the consultative committees where the decisions are made. We have a number of ways to interact, such as through university associations. We are still on the corridor, but at least we are part of the whole programme."

The implication is that, if the UK leaves, it will become a corridor nation. We might be prouder, sturdier and more independent if we depart from the EU, but we will very likely be poorer in terms of science and R&D funding.

There are, however, a number of unsatisfactory elements within the existing scientific relationship which the Select Committee inquiry illuminated. It is not all an 'ode to joy' to allude to the EU's signature hymn.

Harmonisation and EU regulations can bite into that prime principle of intellectual free trade with which I began. For example, we concluded that in the area of genetic modification and clinical trials, UK business and research were placed at a disadvantage compared to non-EU competitors because of EU regulations.

And on the business front, compared to the universities, UK companies have not proved adept at siphoning off EU science and R&D funding. Businesses, unlike the universities and the Learned Societies, were reluctant to give evidence to the Select Committee – which is a pity as well as a bit of a mystery to me.

We did, however, pick up an impression that excessive EU bureaucracy and a low-level of support from Government (especially compared to Germany) were at work here – plus the fact that structural EU funding tends to go more to poorer EU members rather than those with more mature economies.

### A genuine possibility?

So, there is a 'can do better' theme within the wider picture of our relationship with the EU on the science and R&D front. Yet, perhaps a genuine possibility exists here.

If we remain, how about the UK Government crafting an initiative on this terrain? More money for science and R&D as a proportion of the EU Budget as a whole. An attack on bureaucracy. A serious look at those regulations that restrict research in certain areas.

Such an initiative would have an attractive air of novelty – even of shock – about it. Because, to borrow from P.G. Wodehouse, if you work in the Commission, it is easy to distinguish between a ray of sunshine and a British Prime Minister bearing a grievance.

An obvious – but important – final thought. Towards the end of the Second World War, the great Labour politician and orator, Nye Bevan, took on the gloom-mongers about Britain's post-war economic prospects. "This island," he said "is

almost made of coal and surrounded by fish." In other words, how can we be poor? Well, we know what happened to our cod and to our great industry based on 'black gold'.

In modern Nye Bevan terms, our one, fixed national capital asset is our collective cluster of little grey cells. We must nurture them, feed them with both love and money and bring in the best from the four corners of the earth to stimulate them! □

<sup>1</sup> [www.parliament.uk/hls/science](http://www.parliament.uk/hls/science)

# British science should look outwards to the world

Matt Ridley



The Viscount Ridley FMedSci FRSL worked for *The Economist* for nine years as science editor, Washington correspondent and American editor, before becoming a self-employed writer and businessman. He was non-executive chairman of Northern Rock plc and Northern 2 VCT plc. He has been a weekly columnist for *The Telegraph* and *The Times*. He sits in the House of Lords as a Conservative and is a member of Science and Technology Select Committee.

I am enthusiastically in favour of international collaboration, international funding and international organisation in science. I love the way science is a global activity, that every time you go to a lab you meet people who originated everywhere and anywhere, yet all speak the same language, by which I mean reason, a love of evidence and a passion for truth.

Discovery and invention are collective processes that happen in networks, not in ivory towers. They arise in conversation, not in isolation.

Britain has traditionally been a welcoming country for scientists and I want it to be even more so in the future (our labs have more diversity than Premier League teams). We must get the best and the brightest wherever they come from, mix them together and generate results. That way we will promote economic growth and – even more important – generate knowledge.

Consider the career of Britain's greatest 20th century scientist, born 100 years ago: Francis Crick. His main collaborators were Kreisel, Perutz, Watson, Brenner and Koch – not one of them British. The only Brit he collaborated with at length was Leslie Orgel, who was based in California.

## European science programmes

So while international collaboration is vital, the question is whether our place within the EU aids that process or not. I believe membership does not help British science and technology overall, and may actually be a hindrance.

Now, until recently, I was under the impression that the main EU science programmes (Framework Programme 7 and Horizon 2020)

## SUMMARY

- Science succeeds best in the context of international collaboration.
- Brussels does not have a good record of supporting science.
- Focussing on regional markets instead of global ones makes no sense today.
- Free movement of scientists and technologists is at threat if we remain.
- At present, less-qualified EU citizens have greater immigration rights than better-qualified people from other parts of the world.

were only accessible to member states. I thought that if we left the EU we would lose access to those programmes, which provide 3% of our R&D budget. Then it dawned on me that Switzerland, Norway and Iceland were in these programmes too – and indeed Israel, Tunisia and Turkey.

Altogether, 15 countries in the EU science funding programmes are not member states. The three countries with the greatest funding per head of population from Horizon 2020 – Iceland, Norway and Switzerland – are not members (the country with the most project coordinators per head of population is Iceland).

The idea that we have to be in the EU to be part of this programme is a myth, an urban legend. Everyone pays money in to get money out; these are simply membership clubs.

The same is true of the main scientific collaborations. The European Molecular Biology

Organisation, the European Space Agency, EUMETSAT – these are pan-European projects, not EU ventures.

The particle accelerator at CERN actually straddles the border between an EU and a non-EU country. The Higgs bosons do not have to show their passports or pay tariffs as they pass. In fact, CERN gets less than 2% of its budget from the EU.

So when people refer to ‘Europe’ do they mean the EU, the European Economic Area (EEA), the European Research Area or simply the Continent?

### Political interference

At one point in the recent Select Committee Inquiry, we interviewed witnesses from different programmes: EMBO, ITER, and the LERU. All three of them have non-EU members.

I was told that non-EU countries can have European money, join European organisations, and coordinate European projects, but they cannot set policy. Really? Why?

I was told it was because these countries are not represented on the Commission or in the European Parliament. Does that mean the European Parliament or the Commission is deciding how the money gets spent in Horizon 2020, in EMBO, in CERN, in the European Space Agency? If so, that’s a scandal. In Britain we have the Haldane Principle which holds that scientists set their own priorities. Is that principle abandoned at the European level? If so, I am really worried.

Brussels has significantly affected British science. There was the Clinical Trials Directive, which destroyed clinical trials in this country and, according to Morris Brown of Cambridge University, “threatened patients’ lives”. We used to have 12% of world clinical trials, but we now have 1%. The Directive was eventually reformed so it was more reasonable, but that took 10 years and the clinical trials industry had long since fled to India and elsewhere by then.

There was the Data Protection Directive, which made many kinds of research much harder here than on other continents. There was the Deliberate Release Directive, which has killed off this country’s leading role in agricultural biotech. True, homegrown green fanatics started it, led by lords in white boiler suits. Yet ask scientists what is holding their efforts back now and they will say that the EU approval process for releasing GM crops or GM insects is so cumbersome, so uncertain and so unscientific, that most of them have given up even applying.

And now there is the Tobacco Products Directive, which contains a disastrous own-goal for public health, making it harder for smokers to quit by taking up vaping.



**Straddling borders: the particle accelerator at CERN runs under both France and Switzerland and gets less than 2% of its budget from the EU**

How has this happened? Well, big pharmaceutical companies lobbied hard in Brussels in favour of their prescription-medicine alternatives, patches and gums. Subsidised tobacco growers and the tobacco industry lobbied hard to have vaping devices included in a tobacco directive, even though they are not tobacco products.

Some 15 years ago, diesel car makers successfully lobbied for the European Commission to favour diesel cars as a way of cutting CO<sub>2</sub> emissions, with the result that particulate and NOx emissions are far worse than they could be – resulting in thousands of unnecessary deaths.

Homeopaths have successfully lobbied Brussels to be excused from the need to prove their medicines are efficacious.

Big green pressure groups have lobbied the Commission to get neonicotinoid pesticides banned, despite clear scientific evidence that they are less of a risk to bees than the alternatives. Greens lobbied the Parliament recently to get Roundup herbicide banned, despite clear scientific evidence that it is one-tenth as carcinogenic as coffee.

If science policy is left to the European Parliament, a hotbed of anti-scientific gullibility and big business lobbying, then science will be set back.

Our witnesses mostly agreed with me on this. They said the Parliament is often anti-scientific. They added that the Commission’s interpretation of the precautionary principle is stifling innovation by holding the new to a higher standard than the old, while ignoring the potential benefits of innovation by focussing only on the hazard.

Brussels is not very good at evidence-based policy making, but it is great at policy-based evidence making. The centralised, top-down, lobby-ready nature of the European system is one

If science policy is left to the European Parliament, a hotbed of anti-scientific gullibility and big business lobbying, then science will be set back.



In the end, it is all about innovation. The European Union is bad at doing it, good at discouraging it, repeatedly sides with those who have vested interests in resisting it, and holds Britain back from achieving it.

of the main reasons that BASF is abandoning Europe for America.

New EU internet rules, which *The Economist* says will hurt the Continent's start-ups, are one reason that Spotify – one of the very few European digital start-ups of any size – is threatening to abandon Europe for America. Under pressure from big publishers, the Commission is preparing a frontal attack on the hyperlink, the basic building block of the Internet.

## A brake on innovation

For me, in the end, it is all about innovation. The European Union is bad at doing it, good at discouraging it, repeatedly sides with those who have vested interests in resisting it, and holds Britain back from achieving it. Where are the European digital giants to rival Apple and Amazon, Google, Facebook and Wikipedia?

Britain needs to be setting the scientific pace at the global, not the regional level. It needs to be an international scientific superstar like Singapore – only 13 times bigger. Singapore left the Malaysian federation and thrived.

Britain – for its size – is probably the world's leading scientific country. We have less than 1% of the world's population, but 15% of the most highly cited scientific papers, and more Nobel prize winners than any other European country. Our biggest science collaborator is America. The only EU universities in the world's top 20 are British.

We are world leaders in biotechnology and digital technology and our greatest potential collaborators – and potential rivals – in both fields are in Asia and America, not Europe.

So it is vital that we remain open to the world. A regional customs union protected by tariff walls and run from a central bureaucracy is a 1950s idea – an 'analogue project in a digital era', as Michael Gove puts it.

In an age when container shipping has collapsed the cost of intercontinental trade; when the internet and budget airlines and Skype have made it as easy to collaborate with Asia and America and Africa as in Europe, regionalism makes less sense.

Harmonising standards is a good idea, yes, but doing so at the regional level makes no sense. In fintech, in car making, in agritech, in digital, in biotech – the action is at the global level, where our voice is just 1/28th of a seat. We could be chairing these bodies.

I suggest that continuing membership of the EU, not departure from it, carries the greater threat to free movement of scientists and technologists. That belief is based not on speculation but on what is already happening now.

Universities are quite rightly complaining

about how much harder it is to get visas for students and professors to come here from India, China, America, Australia and elsewhere. The academic world is rife with stories about us missing out the best talent because of visa problems.

I recently heard tell of a brilliant New Zealand physicist at Oxford who wanted to stay, partly because he loves cricket, but has had to go to Stanford because it is just too hard to get a visa to stay here.

I talked to another scientist who advertised for a post-doc under a European funding grant and had one outstanding and several mediocre replies, but the outstanding one was holding out for a higher salary than advertised. My friend was told by his university that he could pay more than the advertised salary if the applicant was European, but not if he was not. The applicant has an Indian passport. That is discrimination.

I talked to a friend in India who was barely able to contain his rage at Theresa May for making it so hard for his most talented students to get to UK institutions.

Why is the Home Secretary making it so hard for scientists from outside the EU? It is really very simple. The Government promised to reduce net migration below 100,000 and is failing to meet its targets. Since it cannot by law stop unqualified Poles and Romanians coming here seeking work, then instead it is trying to stifle entries by non-EU citizens.

## A dearth of talent

So the difficulty universities are finding in attracting talented people from the rest of the world is directly related to our membership of the EU. The connection could not be clearer. We have clamped down on Indian scientists because we cannot clamp down on Romanian fruit pickers.

The same is true for students. The least-qualified Spanish student has more right to subsidised fees than the most-qualified Argentinian student. America, Canada and Australia have a higher proportion of overseas researchers than Britain, Germany or France – and have stricter general immigration policies. If we left, took control of immigration and adopted a points system like Australia we would be able to open up to more skilled migrants from America, Asia and just as many from Europe. Or we could have an expedited academic talent visa, like America has.

There is no likelihood that Brexit would be followed by restrictive visas for European scientists: nobody is calling for that. By 2030, 90% of the STEM graduates in the world will be from outside the EU. Do we really want to be isolationist little-Europeans and turn our backs on them? □

Continuing membership of the EU, not departure from it, carries the greater threat to free movement of scientists and technologists.



# The benefits of EU membership to UK science

Jocelyn Bell Burnell

The views I am sharing here are those of an astrophysicist from Oxford University. My experience is in academic, scientific research; not business, not innovation. I have, however, chaired European Commission physics panels – awarding grants, fellowships, prizes, etc.

Oxford Astrophysics Group has 130 people – secretarial, computer support staff right through to the professoriate. That is 130 people and 30 nationalities. Such a mix is the norm in top-rank science research today. We recruit the best from all over Europe and beyond. Incidentally, it turns out that many Europeans have had a more rigorous mathematics and physics training than their UK counterparts.

Membership of the EU facilitates mobility of researchers and of students. The mixing and the diversity are good. It is well-established in both business and academic centres that diversity in a group adds robustness and flexibility and therefore it is normally more successful. The more diverse groups are, the more successful they are.

## Research funding success

UK research has been remarkably successful. In the 2014 Horizon 2020 grants, 45 are held in the UK. Then Germany has 29 and France 23. We get more than 20% of the European Research Council grants while we put in only 11% of the funding. The grants are typically of the order of €2 million or more.

Between 2007 and 2013, the UK received 50% more funding than Germany and twice as much as France. We have been extremely successful at getting European Research Council awards.

I have often wondered why this should be so. It is certainly the case in astrophysics that the competition here in the UK is enormous and the opportunities are so limited in the UK that all but the best go to the wall. Those who remain are absolutely brilliant at making their case, be they in Britain or in Europe – and so we gain European money. In the past, the fact that the working language for these grants is English may have worked in our favour, but many more people now have good English so that no longer affects the results.

Nearly 50% of UK scientific publications have non-UK authors in the list. Indeed, those

## SUMMARY

- The UK does very well from European science programmes.
- UK research has been remarkably successful.
- EU authorities are prepared to listen and learn.
- EU pressure has helped to enhance the position of women in science.
- Multi-nationalism is the way forward.



Professor Dame Jocelyn Bell Burnell DBE FRS PRSE is the President of the Royal Society of Edinburgh (RSE). She is best known for discovering pulsars, one of the most significant scientific achievements of the twentieth century. At the time, she was a PhD student in radio astronomy at the University of Cambridge. She has been an influential campaigner in efforts to raise the number and profile of women in professional and academic science posts.

papers have higher impact than the ones with just UK authors. A recent case study showed that 93% of scientists want to stay in Europe. Oxford University gets £66 million a year from European funding – that is about 10% of all the UK's European funding.

UK university research funding from EU grants has grown 68% over the past four years. That is significant growth.

## Astrophysics

In my own area of astrophysics, the most exciting results in the last few years have been the discovery of the Higgs boson and the recent announcement of the detection of gravitational radiation. The Higgs boson was discovered at CERN – a multi-national organisation, albeit outside of Europe. The gravitational radiation work was done jointly by the USA, the UK, Germany and Italy.

Neither of these discoveries was physically made in the EU, but they are multi-national projects. We have many grand challenges ahead of us (the environment, climate change, sustainability, energy, water, food) and will need multi-national collaboration in order to solve them. Now, if we are already in one multi-national collaboration, why quit? It does not stop us collaborating with other people as well.

Multi-national collaborations also allow harmonisation of regulations. So, for instance, animal welfare standards are now common

**UK university research funding from EU grants has grown 68% over the past four years. That is significant growth.**

throughout Europe. There are also some areas where regulation is not working so well – GMO regulation protocols, for example, are too ponderous, too expensive, too complicated and counter-productive with perverse incentives.

Another area that interests me is gender. The EU forced us to have maternity leave. Before 1973 we did not have maternity leave, let alone the right to return to a job. The European Community made us in the UK adopt that, as well as policies in the fields of human rights and working conditions. These have shone a spotlight on the number of women in the scientific workplace, and on their progress.

I for one am very grateful for that focus because we were not doing enough in Britain. Whether we are yet doing enough is another issue, but a lot of the gains so far have been due to European pressure. For that reason, I give them a lot of credit and forgive them a lot of sins.

### A listening ear

The EU authorities undoubtedly can be incredibly ponderous and complicated, but they also listen. The Horizon 2020 research programme is a lot easier for scientists to apply to than its predecessors, although the UK did not make things easy for itself! A number of my colleagues refused to get involved, claiming it was just too complicated.

On balance I am pro the European Union, although it is far from perfect. I am encouraged that the administrators have started to listen to complaints from ordinary people about their procedures and have taken steps to modify them.

I see multi-nationalism as the way forward. Given that we are in one 'consortium', I do not think it is doing more harm than any other option. So I am inclined to say stay with it – it is not exclusive, it is not restrictive and we can continue to work with whomever we want. □

# Collaborating to create a better future

Emyr Jones Parry



Sir Emyr Jones Parry GCMG FInstP is President of the Learned Society of Wales and Chancellor of Aberystwyth University. After being awarded a PhD in Physics from Cambridge, he became a career diplomat from 1973-2007. His last postings were as Ambassador to the United Nations in New York, Permanent Representative to NATO, and Political Director of the Foreign Office. From 2007-2009 he chaired the All Wales Convention on the Future Powers of the National Assembly for Wales.

Let us start with three assertions which should not be controversial. The first is that the UK could manage perfectly well outside of the European Union. Second, that the EU is far from perfect. The third is that the UK is one of the world's leading scientific nations and has always worked with international collaborators.

Within the Royal Society, the post of Foreign Secretary was always one of the most influential. As the recent House of Lords report has shown, European cooperation has been much enhanced since 1973 when we joined the EU. It has been good for universities, for research and for the student experience. EU membership has fostered a greater openness – to staff, to students, to ideas and to research collaboration with European institutions and universities. The results are set out in the report. Some 18.3% of EU funding in the UK is spent on R&D, which represents 3% of total R&D spend in the UK.

Free movement has led to the employment of more researchers from other member states – that is perfectly true and actually desirable. The student movement Erasmus has proved very successful: it would have been even more successful in the UK if we had more students with the language skills to

## SUMMARY

- Membership of the EU has been good for universities, for research and for the student experience.
- It makes no sense to abandon a framework which reflected UK priorities from its inception.
- The EU allows us to work collaboratively on major issues that have to be tackled at an international level.
- Membership of the EU enhances UK security in its wider sense of tackling terrorism, climate change, energy security.
- The EU is not perfect, but we should take a leading role and improve it from the inside.

study in universities in other countries.

Of course, given the UK's net contribution to the EU budget, it can be argued that we are merely recovering some of our own money. Outside of the EU, indeed, we could keep all our own money and spend it as we wished. We could even increase what is spent on R&D. I heard one Minister arguing that farmers need not worry

about being outside of the Common Agricultural Policy because of all the money we can hypothecate to agricultural support. That money will have to go a very long way given all the reassurances to different groups!

For researchers, there is a simple question to answer. If it were left to Westminster to decide, could you maintain the level of funding you currently get from the EU? Is there any certainty about the level of funding? Would it be ring-fenced? How sustainable would that income be? This would be a particularly acute problem for peripheral regions in the UK and for smaller universities. In addition, the financial incentive to collaborate with European universities would be reduced.

### Lack of influence

It is argued that we could continue, as non-members, to participate in EU research programmes. Yes, many countries do already. But they have no influence on the formulation of those programmes.

As someone who has sat on the Research Committee of the EU, I am conscious of just how much effort went into ensuring that the policies we wanted the EU to pursue were the policies that suited us and would meet the priorities of the British Government and of UK researchers. And we were successful.

Now, having succeeded, why walk away? Why form a new arrangement outside and expect the same degree of influence we currently enjoy? It is a bit like resigning from a club on Friday, pitching up on Monday and expecting to take advantage of exactly the same facilities as you had enjoyed the previous week.

The EU Horizon 2020 programme scales up university cooperation to tackle the most critical global problems, all of which are better dealt with multilaterally. It also aims to create more competitive, productive and innovative economies. These priorities are difficult to argue against and they will benefit the UK.

Some have said that the EU stifles innovation. It was in 1981 that the EU produced its first communication on innovation, a concept scorned by the then UK Department of Industry.

What, then, are the advantages of being in the EU? Firstly, global challenges require multilateral cooperation – whether terrorism, environment, climate change, energy, food security. They cannot be tackled as effectively at nation-state level.

The British Government opposed the inclusion of the environment within the EU treaties. Yet, I remember my horror, when I was in Canada in 1975, that the province of Quebec put its sewage into the Ottawa River. Later, in 1980, I went back to the little port in West Wales where I had swum as a

child and realised that all the sewage went straight out, 100 m behind the pier, completely untreated. We still lived like this at that time.

Now, good sense and EU regulation led to an improvement, but there was also a dawning realisation that pollution and other environmental issues do not respect national boundaries. Tackling those must be done together.

I believe that the EU enhances our security, but not just in military terms. Include terrorism, food security, climate change and then it is clear that the EU has a very strong role to play in making us more secure. The economic advantages have been demonstrated over the years, but without a 'control' to measure this against, it is difficult to prove absolutely.

### The value of 'sovereignty'

There is a belief among some that the UK can prosper on its own because we belong to so many organisations and exert so much influence. A variation of this is to be a passionate European, but against the EU. In both cases: "Well, we're better outside."

If you replaced the provisions of the treaties of the EU by bilateral agreements to produce the same effect between 28 countries, that would require 378 bilateral agreements. The challenge of negotiating those and trying to get a degree of consistency among each of them is, I think, impossible. But we could recover our sovereignty in the process!

What is sovereignty worth in today's world? It is actually curbed by individual choice and by external events. We should be able to defend ourselves without interference from Brussels. Yes, but not from NATO, of course. When we signed up (and we actually moulded the NATO treaty) we agreed that 'an attack on one is an attack on all' and we are obliged to respond. That certainly affects our sovereignty!

On the other hand, consider the impact of external events on sovereignty: a 2008 financial crisis or a 1992 run on the pound. The price of oil has also had a significant impact on the UK and is completely outside our control.

Norway and Switzerland are often mentioned. All their agreements with the EU presume and require free movement of people. They also require budget contributions. When Norway opted for membership of the European Economic Area, it still ended up the ninth biggest contributor to the EU budget. In a two-day debate in the Storting, something in excess of a thousand pieces of legislation were summarily voted through, because that was the price of joining the European Economic Area. So the idea that there is some better

What is sovereignty worth in today's world? It is actually curbed by individual choice and by external events.

It is a bit like resigning from a club on Friday, pitching up on Monday and expecting to take advantage of exactly the same facilities as you had enjoyed the previous week.

place outside, with greater freedom and no conditions, is – to a very large extent – an illusion.

### A prize worth keeping

The UK outside could probably conclude a free trade agreement with the EU. But access to the Single Market is the real prize, especially for services. That is only possible if you accept the regulations of the Single Market, which permit unhindered movement. But Brexit will have nothing of those rules.

People really ought to understand that most of the big decisions in the EU have involved the consent of successive British governments that were involved at the heart of negotiations.

To finish where I started: I am not for a moment going to claim that the EU is some sort of panacea

– manifestly, it is not. However, in an increasingly insecure world, we would be better working with our allies and friends in the EU. Churchill commented: “There is only one thing worse than actually negotiating with your allies, and that is having no allies with whom to negotiate.”

I reject the concept of ‘Brave old Blighty’, off alone to mid-Atlantic to find some new relationship in an uncertain world. I do not believe those relationships will be any better. In fact, I am very dubious about whether they could exist. Do we have confidence that there is a Special Relationship with the USA, especially as we view the next Presidential election? We should appreciate what we have and take a leading role in the EU, making it a better place to tackle the common problems we confront. □

## The debate

Issues covered in the debate included the method of determining research priorities, the role of the European Parliament and the increasingly international character of scientific research.

The procedure for allocating grants in the EU is complex. It starts with Ministers on the Competition Council deciding broad areas, but then Research Committees advise the Commission on specific subjects. Those with experience of EU negotiations were clear that it is vital to be ‘in the room’ when Ministers take decisions. This is not just about having a voice, it is also being involved in the informal discussions with individuals and the negotiating tactics that make the difference in formulating policies and, if necessary, working to mitigate their disadvantages.

Because of the involvement of democratically elected Ministers, there is no ‘democratic deficit’. It is not only Ministers who need to learn negotiation techniques, though; if the UK is to get full benefit from negotiations, officials must work to master them.

The European Parliament responds to populist clamour (as over GMOs), but it is for Ministers to work with MEPs to develop greater responsibility. The way forward with the EU Parliament is to recognise its importance and develop the co-decision procedures between it and the Council.

As science evolves, there is an increasing demand for large international technological or scientific capital projects. We must negotiate to bring some to sites in the UK. We will be more likely to succeed if we are in the EU where Ministers can make the case.

It is clear that majority of universities want to remain in the EU for the benefit of scientists, other academics and students. Staying in does not affect the range of international contacts and the

global range of their interests. It is a pity, but understandable, that the same clear view has not been heard from business.

Will the conclusions of the House of Lords report, the views of universities and the flow of funds to R&D affect public opinion on the referendum? Probably not. The public are more likely to focus on controlling immigration; but would getting out would mean fewer immigrants? It was unlikely they would think it beneficial to have fewer EU immigrants, if it meant having more Indian or Chinese immigrants instead, even if these were highly skilled. The UK’s immigration policy is set by the UK government, not the EU.

Participants noted the interest in other countries about the relations of the UK with the EU. President Obama has said it is in the US interest for us to remain in; Canada is watching with interest.

Social sciences are important research areas and it is important that they are included in discussions. A group of four academies (including the British Academy) is working to ensure this. Indeed, collaboration in all areas is one benefit of being in the EU; being outside will make this more difficult.

We should not be looking at EU policies in terms of country against country, but in terms of competition against the rest of the world, but also how it benefits the world.

Being part of a bigger group has benefits; one example is the Canadian referendum on Quebec separation. Quebec is a distinct culture, but it still thought being part of Canada was worthwhile. Scotland also decided not to go it alone. □



# The value of EU membership

UK businesses are lagging behind competitor nations seeking EU funding, while UK universities are reaping rewards, concludes the House of Lords Science and Technology Committee's report on the influence of EU membership on UK science.

The status of the funding relationship between the UK and the EU is a complex one, notes the report, but also one that bestows significant value to UK science from the European Union. Nearly a fifth (18.3%) of all the UK's incoming EU funding goes on scientific research and development.

The European Union's main funding system for science rewards excellence and the inquiry heard that the UK is one of the EU's top performers in terms of securing these competitive funding streams. The situation is different though when funds for building capacity in science and research are considered.

## Business funding

The Committee is concerned about the poor level of engagement by large businesses in securing EU funding. The UK is below the EU average and lags behind competitor nations such as Germany and France. Given that 64% of research and development in the UK is conducted by businesses, this is a serious failing in the current set-up.

## Collaboration

The inquiry heard that collaborative opportunities are perhaps the most significant benefit that EU membership affords science and research in the UK. The Committee heard of one example, a pan-European bioscience research project called ELIXIR, which witnesses believed was headquartered in the UK as a result of our EU membership. However, it should be noted that of the UK's top five collaborative partners, two are outside the EU (the USA and Australia).

## Freedom of movement

The Committee heard many assertions that the ease with which talented researchers and scientists can move

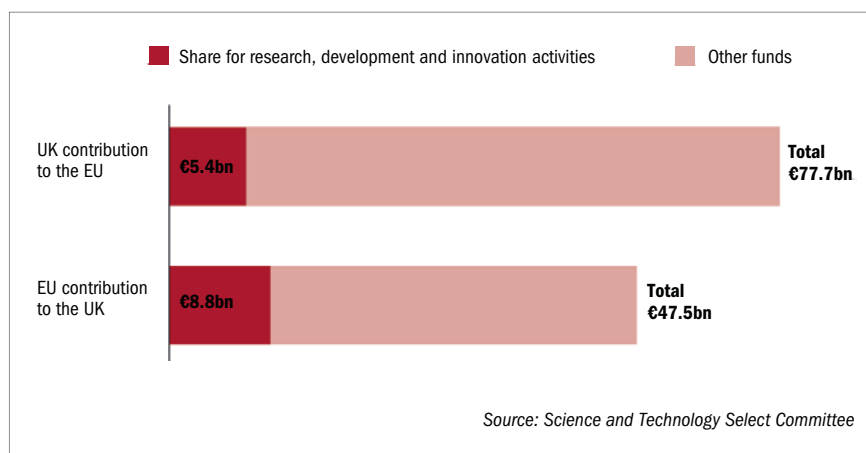


Figure 1. Total flow of funds between the UK and the EU, 2007-2013

between the UK and across the rest of the EU is an enormous advantage to our country's science community. The report agrees that this freedom of movement is an absolutely key benefit to the UK, and every effort should be made to preserve it.

## Brexit

The Committee examined the implications of alternatives to the UK being a full EU Member State. One example would be becoming an Associated Country. The inquiry heard that the UK would still be able to receive EU funds, and would continue with involvement in European and international scientific projects, but many thought that it would no longer have the same level of high-level strategic influence. The Committee concluded that further investigation is necessary to ascertain how Brexit might impact our currently influential position in Europe.

The chairman of the Select Committee,

Lord Selborne, commented: "Our aim was to present a much clearer picture of the position of UK science within the EU, but we had to cut through a dense 'Eurofog' of claim and counter-claim on many aspects of membership.

"Many witnesses claimed that the UK is a top performer in the race for R&D funding when that is only part of the picture. UK universities have outstanding performance in EU funding competitions while UK businesses, in particular large businesses, have low levels of participation and the UK, understandably, does not receive a high level of funding for scientific capacity building.

"We urge the Government to benchmark the level of support it provides for businesses, large and small, wishing to participate in EU programmes against that available in other member states. We want to see Government plans for raising UK performance."

## EU MEMBERSHIP AND UK SCIENCE REPORT

The report from the House of Lords Science and Technology Select Committee, entitled *EU membership and UK science*, was issued on 20 April and focusses on the influence of EU membership on UK science. It also looks at other aspects of EU membership, such as freedom of movement of researchers and the ability to collaborate on major projects, concluding that these in particular are significant aspects of membership. The report describes some negative aspects of the UK's EU membership, such as restrictive EU regulations that could prohibit innovative research. The report concludes that the UK could lose strategic influence on EU science policy in the event of a vote to leave.

[www.publications.parliament.uk/pa/ld201516/ldselect/ldsctech/127/12702.htm](http://www.publications.parliament.uk/pa/ld201516/ldselect/ldsctech/127/12702.htm)

# FORENSIC SCIENCE

The theme of the 2015 Annual Report by the Government's Chief Scientific Adviser is the ways in which science can authenticate, verify or assure the identity of people and things. The report and its findings were the subject of a meeting of the Foundation held at the Royal Society on 2 March 2016.

## The potential of forensic science for the UK

Mark Walport



Sir Mark Walport FRS FMedSci is Government Chief Scientific Adviser at the Government Office for Science. Previously, he was Director of the Wellcome Trust, which is a global charitable foundation dedicated to achieving extraordinary improvements in human and animal health by supporting the brightest minds. Before joining the Trust he was Professor of Medicine and Head of the Division of Medicine at Imperial College London. Sir Mark is Co-chair of the Prime Minister's Council for Science and Technology.

What is forensic science? I would define it as 'the sciences as applied to the justice system'. These sciences have very broad applicability and can be applied both to solving a crime that has taken place and to preventing one happening in the first place. And, indeed, some of these techniques have uses far beyond the justice system.

Last year, in my first annual report as Government Chief Scientific Adviser, I addressed the issues of innovation and how to manage risk rather than avoiding it. In many ways, forensic science, the subject of my second annual report<sup>1</sup> is very innovative and carries risks which we have to weigh up – deciding how to use these advances in the most beneficial way, while reducing those risks.

### A changing landscape

There is no question that modern forensics is changing. Analytical tools mean more accurate and sensitive measurement. The number of domains within which we can measure things has increased spectacularly as well.

Today's digital world allows our movements to be tracked in ways that were never possible before. This gives rise to new debates such as the one taking place in the US court system concerning the forensic evidence held on an encrypted app on an iPhone.

As markets globalise there are other issues. People buy items from a wide variety of locations: when they arrive on the doorstep, how does the consumer know whether the goods are authentic: are they really 'what they say they are on the tin'?

In cyberspace, how can an individual determine whether another person or organisation is being truthful? The number of phishing attacks illustrates how easy it is to pretend in the virtual world. Questions about identity, authentication and assurance in the online world have become increasingly important.

### SUMMARY

- Forensic science is highly innovative and is changing fast.
- This has relevance for a wide range of issues, including governance, privacy, authenticity and assurance.
- Cyberspace is the fastest growing domain of criminal activity in the world.
- Forensic science can be used to help assure supply chains, designing out counterfeit products.
- The UK is good at forensic science and this area offers our country significant opportunities.

### Questions of governance

Then there are questions about governance. Cyberspace, in particular, is a very complex environment which is not governed by any single nation. Different criminal justice systems are grappling with ways in which governments may access information held in another sovereign territory, or where crimes have been committed in multiple jurisdictions simultaneously. So, forensics is developing in a landscape that is also changing rapidly.

The analytical techniques that are important in the courtroom are equally important outside, though. When, for example, water is claimed to be 'pure', what does that mean? We are becoming increasingly interested in the claims that products make. Water used to be water, but now it makes claims – that it has come from particular volcanic lakes, for example – so how do we actually know that those products are what they say and, indeed, do the other chemicals in this particular brand of water actually matter?

Assuring provenance and authenticity is more important today, partly because the technology now exists to make the necessary connections. Yet the connections have to be validated, too. In the criminal justice sphere, just because a

particular piece of DNA turns up in a particular place, that does not mean a specific person was physically there themselves. There is the whole challenge of working out whether the apparent associations are in reality true or false.

Additionally, the technologies can also be used in efforts to prevent crime occurring in the first place.

### Challenges

The Report poses a series of challenges to policy-makers. For example: what is the best forum for discussions between different participants in the justice system about the nature and the significance of the applications, as well as the interpretation of forensic approaches and tests?

Forensic science is applied in various ways before it even gets to the courtroom. A sample is collected, but how exactly and which parts are analysed? There is a long trail from the collection of the sample all the way to its presentation in court. There are many suppliers of forensic services, so how can they work together in a way that ensures consistency?

A particular difficulty revolves around communication: how should information, especially relating to measurement and the inherent uncertainties, be provided to a court in a manner that is clear and can be understood by all of the participants in the legal process?

What new technologies are on the horizon and how might they be relevant and applicable? Importantly, who is horizon-scanning for these developments and assessing their potential?

What should be the approach when a new technology or a new application of an existing technology arrives in the court system? In the world of medicine, there is a regulated approach with Phase 1 studies and clinical trials. Should there be something similar here?

### Areas of interest

Cyberspace is the fastest growing domain of criminal activity in the world. The amount of evidence even on an individual hard disk may be enormous. How to deal with it when it is damaged? And are there enough people to carry out this work? I would argue that there is a real cyber-skills shortage today.

The International Medicines Products Counterfeiting Taskforce of the World Health Organisation (WHO) estimates that up to 25% of the medicines supplied in some economically less-developed countries is counterfeit. I vividly remember in Vietnam a number of years ago, being shown a whole array of Artemisinin (anti-malarial tablets) in packs and being asked

What should be the approach when a new technology, or a new application of an existing technology, arrives in the court system?

which were fake and which genuine. Not only could I not do so, neither could the physician working with this medication every day! This is potentially a death sentence if you receive a counterfeit anti-malarial drug.

Currency has been subject to forensic approaches of different sorts over centuries, in an effort to make coins less susceptible to counterfeiting. Crosses were made on the edges of medieval coins to prevent clipping. If one or more were cut off, then the coin was not legal tender. The introduction of milling was very important in terms of developing approaches to actually prevent currency crime. It is much better to prevent the crime than to inflict the terrible punishments of those times!

Identifying and addressing early opportunities for temptation as well as making objects less valuable when they are stolen indicates the potential for forensic techniques to design out crime. As a case in point, a significant fraction of pound coins in circulation at the moment are forged and the Mint is designing new versions – so new pound coinage incorporating new techniques will be introduced very soon.

### Disruptive technology

The Government Office for Science recently produced a report on distributed ledgers. This is a disruptive technology which can help design out crime. Essentially, it is an electronic ledger where a legitimate change in one copy made by someone who is authorised to do so (or in an un-permissioned system, a person who solves the cryptographic puzzle), results in changes to all copies of the ledger, virtually simultaneously. If someone illegitimately tries to change one copy, it is rejected.

The great thing about distributed ledgers is that you can build in algorithms, smart contracts, consent and so on. Health records are one area where ledger technology has great potential, because it can potentially hold records very securely, while also recording the fact that I have consented to particular courses of treatment, etc. So there are all sorts of opportunities for this technology: one early commercial implementation was by a company called Everledger, using

How should information, especially relating to measurement and the inherent uncertainties, be understood by all of the participants?

The challenge for forensic techniques is to increase confidence and trust in the many markets where it can be applied and not solely the justice system.

distributed ledger technology to track diamonds through the supply chain. In principle, that could be used to keep 'blood diamonds' out of the supply chain and trace them where they do occur.

The technology is still at an early stage of development – it was created to enable the digital currency bitcoin, but its potential is much broader. It has the potential to assure critical infrastructure by working out, for example, whether a control system has been tampered with.

In summary, forensic science is a very fast-moving environment. The UK is good at forensic science so there is an opportunity for us to exploit. But how can we best support emerging forensic techniques? How can we ensure there is sufficient

public trust in order to do this to allow this support? Again, what forum do we have or can we create where we can debate these and other issues?

Forensic science draws on many scientific disciplines, going far beyond the justice system. To stay at the leading edge of technology, innovation will be essential and this can come from almost anywhere. The challenge for forensic techniques is to increase confidence and trust in the many markets where it can be applied and not solely the justice system. □

<sup>1</sup> [www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/506461/gs-15-37a-forensic-science-beyond-report.pdf](http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/506461/gs-15-37a-forensic-science-beyond-report.pdf)

# Forensic science beyond the courtroom

Derek Craston



Dr Derek Craston FRSC is the Government Chemist and Managing Director of Science and Innovation at LGC. LGC is a life sciences research and testing company. As the Government Chemist he is responsible for overseeing the statutory function of referee analyst, resolving disputes over analytical measurements, particularly in relation to food regulatory enforcement. The role also includes promotion of analytical science and technology and providing advice to Government on policy, standards and regulation based on research carried out by him and his team.

Provenance and authenticity issues are not new. Forensics is not a subject that has just emerged; it has been required since goods were first traded. There is a treatise dating back to 160BC dealing with concerns over the adulteration of wine. The genesis of the role of Government Chemist dates back to the 1840s, when tobacco and alcohol were being adulterated in order to avoid paying taxes. The Government Chemist was established to support related regulations, which were difficult to enforce due to the complexity of the analysis given the scientific tools available at that time.

The horsemeat scandal in 2013 created massive consumer concern, and initiated a report that was prepared on behalf of Government by Professor Elliot from Queen's University Belfast. This report has had a number of ramifications, including the establishment of the Food Crime Unit within the Food Standards Agency. Yet this was not the first example of this issue.

There were crises in the 1940s and 1980s around similar subjects, while at the turn of the 19th Century laws were put in place because people were importing unhealthy horsemeat from Holland and France.

While provenance and authenticity are not new issues, there are novel aspects today that forensic science needs to take into account, particularly in terms of the complexity of identification and control.

## SUMMARY

- Fraud (and forensic/measurement science to identify this) has been in existence for many centuries.
- There is a continuing need to determine the authenticity and the provenance of products.
- Counterfeit goods put lives at risk as well as impacting ethical businesses.
- Forensic approaches are applicable across many sectors.
- Forensics can also be a vital weapon in preventing crime, not just in solving it.

## The scale of the challenge

It is very difficult to give an accurate estimate of an illicit market, but in 2009 the OECD wrote a report on levels of counterfeiting. It estimated the counterfeit market to be worth around \$250 billion. It broke this figure down into different sub-sections, the largest being pharmaceuticals. Food came next and then electronic products, clothes and cosmetics. In reality, of course, there is evidence of this type of behaviour in every sector.

There are safety as well as economic implications to counterfeiting. A statistic quoted in the 'Evidence and Case Studies' that supported Sir Mark Walport's Forensic Science report indicates that "in 2014 over 35 million fakes were detained



at European borders” and of those “25% were potentially dangerous”. The area of pharmaceuticals is particularly problematic, especially in the emerging world where countries do not have the regulatory system or infrastructure upon which to base or perform the necessary analytical work.

Statistics suggest that food fraud is worth tens of billions of pounds a year. The report records that it is high-value products such as wine, organic foods and honey, as well as more common things like milk, that are the prime targets.

At the moment, of course, the internet and its global trading reach are affecting markets. Around 15% of retail in the UK is now carried out online and this causes very significant challenges to those in enforcement. Organised crime has distribution networks and the ability to establish websites. So when people are trawling the net looking for bargains they can easily stumble on these sites and end up purchasing counterfeit goods.

### **Innovation in forensics**

Given the changing nature of the challenge, innovation becomes vitally important if forensic science is to keep pace with the issues of the day. In the chapter of the Report that I contributed, I talk about three facets of forensic science innovation that are very important in the fight against counterfeiting.

The first of those is today’s ability to take a complex product and break it down – ‘de-formulating’ it in order to understand its constituent parts. The second is an ability to detect very low levels of constituents. The third is the ability to apply technology in the field.

Forensic science has benefited from developments in other areas of science. The Report itself, as well as the Evidence document, discusses a range of technologies which enable researchers to build ‘fingerprints’ of the small-molecule content of a product. This will help to identify particular signatures and enable us to tell the difference between a product that is authentic and one that is counterfeit.

Another technique is called isotope ratio mass spectrometry. Developed for geological applications, this looks at variations at origin in isotope ratios of light atoms such as hydrogen, oxygen, nitrogen and sulphur. By applying this technique to food, ratios resulting from such analysis provide information about the place of origin of a product – is it Scottish beef, does the wine come from this particular region? Some very sophisticated methods are now available to tackle some of the more complex issues involving authenticity.

Just as forensic science has benefited from developments beyond its sphere, so have other

areas of science benefited from innovation in forensics. For example, techniques for DNA identification can now be used by scientists doing very basic and fundamental research and who need to demonstrate the authenticity of cell lines they are employing.

Similarly, forensic science has been a driving force for measurement science out in the field, where technologies such as RAMAN and infra-red spectroscopy have been used to detect counterfeits.

A significant development in forensic science has been the ability to measure things at low concentrations. A century ago, it would have been a struggle to analyse a quantity as small as 6 gm – say a small lump of sugar – in a vat of water. Today that sensitivity of measurement is routine. Indeed, it is possible to analyse that same small amount in a whole reservoir of water. However, just because we can, does that mean we should?

Amongst others, Professor Ian Boyd, Chief Scientific Adviser at Defra, addresses this in the Report in a section on environmental forensics. He asks the question: “Just because we can measure something, should we measure it, what does it mean and how does that information impact on what we want to achieve?”

### **The importance of quality**

If forensic measurement is to be meaningfully interpreted it has to be done well. Quality is vital and this requires an understanding of the factors affecting measurement variability.

That is why metrology institutes like ours and the National Physical Laboratory, for example, aim to provide the infrastructure which helps people understand the uncertainties associated with measurement. They can then put in place the necessary controls to ensure that they can rely on the values their instruments give them.

Once quality data is obtained then the values need to be interpreted in the right context and with a proper understanding of natural variation. For example, it is not possible to know if a product has been diluted with water if the natural variations in water content are not understood.

How does one know if honey is produced largely from a particular type of pollen without knowing the variations in this natural product across years and seasons? The only real way of knowing is to have good quality datasets that can be relied on for comparison. Not only is the

**Forensic measurement has to be done well. Quality is vital and this requires an understanding of the factors affecting measurement variability.**

The real solution is to make it as difficult as possible for people to put counterfeit or sub-standard products into the supply chain.

creation of these datasets important but so too is their curation and availability.

### Prevention, not just detection

While forensic science helps to protect the safety and security of the products that we use and eat and take for medical purposes, it is often called into use after an event. The real solution to this age-old problem is to make it as difficult as possible for people to put counterfeit or sub-standard products into the supply chain. This is something that requires really good management and monitoring of supply chains. For example, ethical pharmaceutical companies have developed

mechanisms for monitoring their processes and managing their entire supply chains. These can involve strategies to make sure that products are difficult to counterfeit, using things like water-marks on packaging, or the addition of harmless trace compounds or fluorescent tags that people can easily detect. Such countermeasures are also deployed by the food industry.

The solution must ultimately lie in prevention rather than detection. While we still need to develop our analytical tool box so that we are better able to react to threats, we should continue to strive for products that are more difficult to counterfeit. □

# The power of the Medici Effect

Sue Black



Professor Dame Susan Black DBE FRSE is a forensic anthropologist and Director of the Centre for Anatomy and Human Identification at Dundee University. Her forensic expertise has been crucial to a number of high-profile criminal cases. In 1999 she headed the British Forensic Team's exhumation of mass graves in Kosovo. She founded the British Association of Human Identification in 2001, the same year in which she received an OBE for her services to forensic anthropology in Kosovo.

Anyone can become enthralled by murder or by any aspect of criminality and, because forensic science is so accessible, the public believe they understand it. Agreeing a definition of 'forensic science', though, is a bit more difficult. We all think we know what it is, but start to look at it more closely and it begins to lose its clarity, like a ghost in the mist. Probably the only way to define it is as "the scientific disciplines that are sometimes used by a courtroom".

The Chief Scientific Adviser's Report poses the question of how forensic science can translate to Government policy, as well as to private sector growth.

Forensic science is not, by and large, a discovery area science. To borrow a definition from Sir Paul Nurse in his report on research funding, scientists in this field are not a rigid, discipline-specific set of individuals, but rather a tapestry of practitioners and researchers, engaging in multi-disciplinary endeavours that have the potential to break down the barriers we find at the intersections between more traditional silos of science.

### The Medici Effect

In the business modelling world there is a phenomenon known as the Medici Effect. It refers to the remarkable burst of creativity in 15th century Italy, instigated by one rather formidable Florentine banking family. They created an environment within which sculptors, architects, scientists, painters, philosophers, bankers and poets could all converge. We still speak the names with reverence today: Galileo, Da Vinci, Rubens, Michelangelo.

### SUMMARY

- Forensic science is a multi-disciplinary zone within science.
- It is an example of the Medici Effect where discoveries occur at intersections between disciplines.
- It innovates, drawing on discoveries in other areas and applying them in new ways.
- Its field of application goes far beyond the courtroom.
- Forensic science comprises a very flexible, agile set of sciences.

How can we create a Medici Effect today? If we stay on the same road with the same passengers every single day, our chances of innovation, our chances of changing a culture or of embracing risk are completely deadened. Innovation is supposed to be uncomfortable. Yet going outside our normal networks to meet new people and situations is to introduce a Medici intersection – the intersection between disciplines, which is where change occurs. This is productive, while if we stay within the same value networks we will not be productive.

The Medici Effect does not guarantee success, though. We may fail but even failures can be wonderful – everybody should fail many, many times. Forensic science fails many times, because to get it right we have to understand where the points of failure are.

Anybody who is good at innovation – and forensic science is good at innovation – has a

diverse and deep network. Stepping into an intersection that occurs in a Medici Effect between disciplines, you combine areas of different expertise and integrate them into a new area. Creativity, innovation and invention do not lie in silos. Forensic science is not a silo but a 'discipline of disciplines'. So if there was any group of individuals that were in the best possible position to innovate, surely it has to be the forensic scientists?

### An extensive array

Forensic science is already an area of fluidity. It contains an extensive array of subjects. Fingerprints, if you like, is a specific area, but each such area has a translation capacity and there is awareness of other subjects circling around. There is an agility of approach that comes with being the 'new kid on the block' compared with the more established sciences.

Believe it or not, forensic science is not encumbered by restrictions associated with investment and finance, because there is no funding stream for forensic science research. I would argue that the challenging competitive environment in which we have to operate is the reason that forensic science has thrived. It is adept at valuing agility, inter-disciplinarity, honest, open, transparent collaboration and cooperation. In that, forensic science offers a freedom upon which we are now ready to capitalise.

Forensic scientists will look to translate something which already exists. We will look around at what everybody else is doing and modify it just a little bit. So if the food industry is developing packaging that allows us to see when food is going off, the forensic scientist may think of using this to determine the age of blood stains, for example. We will take everybody else's technology and adapt it. Forensic scientists have no shame whatsoever!

### Chameleon conduits

We are chameleons – or matchmakers, if you like – the conduit between sciences that allows movement between disciplines. It is a very underestimated secret weapon.

Those who view forensic science purely as the application of science to the courtroom are missing a tremendous trick. If we only consider it from that angle, we might as well be looking at just one face of the Eiger. Open up its translational potential and you start to see the other faces of the mountain, in this case the intersections between pharma, medicine and any of the global problems that our society faces.

Forensic science is a new kid on the block, but its ability and flexibility at this time offers a Medici moment.



**Marvellous magpies: Forensic science often takes existing technology, such as colour-change packaging, and adapts it for its own purposes**

A member of the press, commenting on this Report, said: "This is one of the first reports I have ever seen from the Government which isn't asking for more money. Isn't it refreshing to read a report that isn't saying 'we need more money', but is much more inventive and innovative than that? It is asking us to change our behaviour. To change our culture."

Indeed, that is the challenge: to hunt down the intersections between the different disciplines, break down barriers between different sciences and exploit the opportunities. That is much more important than asking for more money.

Genuine innovation takes us out of our comfort zones – it takes us out of the silos of science and challenges us: if we really believe in innovation, then it happens in the Medici intersections between disciplines.

Forensic science does not thrive in lofty academic portals or ivory towers. It has been referred to as a 'dirty' science because of its role in the courtroom. Yet it comprises a very flexible, agile set of sciences and there is a huge opportunity here.

People change culture and it is culture that changes innovation. I firmly believe that this Report has given us the permission and the pathway, as well as the guidance, to be able to change that culture. For me, that is an incredibly empowering situation.



# Meeting the challenge of new technology

The **Rt Hon the Baroness Neville-Jones DCMG**, a former Foreign Office diplomat who served at the highest levels of the diplomatic service, who was at one time Chair of the Joint Intelligence Committee and a security Minister in the Government, made some initial comments at the start of the discussion period.

**F**orensic technologies and their uses could be a source of new wealth for our society through greater security and more resilience, but how exactly can that be achieved?

Ten years ago, the Government provided funding to turn internet technologies from a promise 'glimmering on the horizon' into a major aid to Government services, a source of wealth for the private sector and a source of security to society as a whole. Those goals are effectively the same today.

In that programme it was decided at the very start that it had to be a cooperative enter-

prise encapsulated in the notion of the public/private partnership. In reality, the academic institutions had to be there as well. There had to be a recognition that things are always changing – finding antidotes to new threats, closing doors to new vulnerabilities and so on. The triangular relationship between public and private sectors together with academia is an ongoing feature of the way new technologies are launched and maintained in society.

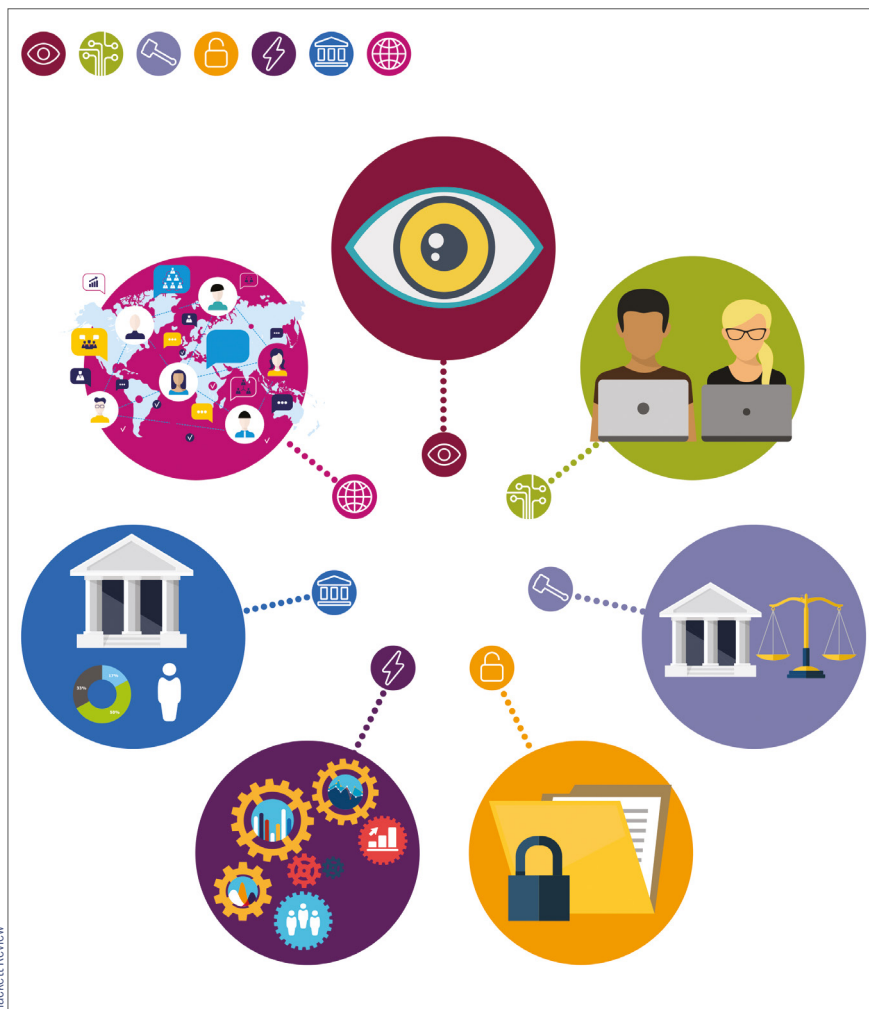
Looking at the technologies highlighted in the Chief Scientific Adviser's report, it seems to me that distributed ledgers could be a major

contribution to both increased security and to trust in internet activity. Ten years ago, the programme relied on some of the big battalions – the defence companies, telecoms operators and banks – to start the process off. Today, however, the necessary innovations are likely to come from small companies. The challenge is that Government has never found it easy to coordinate activities with SMEs.

Many of these technologies, if they really are as bold and adventurous, will also be immature. Developing regulation in an immature market is quite difficult. There will be setbacks, things will go wrong, but that should not deter us.

Finally, there is the whole question of crime. Prevention is always unglamorous, but very important and we certainly need to do more on that front. However, it is clear that criminals are going to get through and use these technologies for illegitimate purposes.

In such circumstances, how can trust in these technologies be engendered? How can we develop system-wide, social acceptance and agreements whereby we are prepared to trust the new technologies and trust each other's use of them in daily life? □



**Distributed ledger technology is an important area of internet security research**



# The debate

There is a continuing absence of common understanding and trust between scientists and judges – it is as if the ‘two cultures’ identified by C.P. Snow still exist. The Royal Society is working with the judiciary to bring together judges and scientists to discuss scientific issues and their use in the courts. Neuroscience, probability and capacity are among the subjects.

People still work in silos far too often. Businesses also have an interest in reducing crime and in securing convictions. Yet managers do not often meet scientists, although it is important to bring them into the circle. Scientists do not meet non-scientists, or indeed scientists working in other disciplines. Opportunities for interaction should be encouraged and they should be as open as possible, both to develop trust between different groups in society and to enable new ideas to be discussed.

Although the higher judiciary are sympathetic and welcoming of innovative forensic techniques, many other judges remain over-cautious when advising juries on their acceptability, while the Crown Prosecution Service is nervous about using them in prosecution. France has a system of regulating forensic techniques, which pre-empts discussion in court of their suitability.

To set up such a regulatory framework would take time and money; who will pay? The answer may lie in the global market. Forensic techniques do not apply only to the courtroom, but are vital to all businesses worldwide. There must be companies wanting to help pay for their development.

The trail between evidence and its use in court is long. The evidence must be collected, kept, transported, ensured to be of good and consistent quality and explicable to judge and jury. Firm oversight is needed at every step; the scientific justification for its use should always be evident.

Using innovative forensic techniques could delay or complicate proceedings, just as much as benefit them. The police are now well aware of crime in cyberspace, but need to achieve a higher level of detection and conviction. The use of valuable biometric techniques raises questions of compatibility with public values such as privacy.

New technology can authenticate drugs at the point of sale to decrease the proportion of counterfeit products in circulation. The UK has been slow in adopting such technology.

Indeed, technology is evolving faster than the legal framework. A new industrial revolution is under way that needs ‘smart’ regulation. □

Issues raised in the debate included how to encourage cross-disciplinary collaboration, the need for smarter regulation and the question of who should pay for it



West Midlands Police (CC BY-SA 2.0)

## FURTHER INFORMATION

### **Distributed Ledger Technology: beyond block chain**

[www.gov.uk/government/publications/distributed-ledger-technology-blackett-review](http://www.gov.uk/government/publications/distributed-ledger-technology-blackett-review)

### **Forensic Science and Beyond: Authenticity, Provenance and Assurance. Annual Report of the Government Chief Scientific Adviser 2015**

[www.gov.uk/government/publications/forensic-science-and-beyond](http://www.gov.uk/government/publications/forensic-science-and-beyond)

### **Government Office for Science**

[www.gov.uk/government/organisations/government-office-for-science](http://www.gov.uk/government/organisations/government-office-for-science)

### **Home Office Centre for Applied Science & Technology**

[www.gov.uk/government/collections/centre-for-applied-science-and-technology-information](http://www.gov.uk/government/collections/centre-for-applied-science-and-technology-information)

### **House of Commons Select Committee on Science and Technology: Forensic Science**

[www.publications.parliament.uk/pa/cm201314/cmselect/cmsctech/610/610.pdf](http://www.publications.parliament.uk/pa/cm201314/cmselect/cmsctech/610/610.pdf)

### **Ministry of Justice**

[www.justice.gov.uk](http://www.justice.gov.uk)

### **National Audit Office Report on The Home Office's oversight of forensic services**

[www.nao.org.uk/wp-content/uploads/2015/01/The-Home-Office's-oversight-of-forensic-services.pdf](http://www.nao.org.uk/wp-content/uploads/2015/01/The-Home-Office's-oversight-of-forensic-services.pdf)

### **Research and Development in Forensic Science Review, Professor**

**Bernard Silverman** [www.gov.uk/government/publications/research-and-development-in-forensic-science-review](http://www.gov.uk/government/publications/research-and-development-in-forensic-science-review)

# INFRASTRUCTURE

How can the UK encourage long-term strategic decision-making, with political consensus, in order to build infrastructure effectively and efficiently? The challenge was debated at a meeting of the Foundation held at the Royal Society on 27 April 2016.

## Delivering infrastructure – effectively and efficiently

Tony Meggs



Tony Meggs is Chief Executive of the Infrastructure and Projects Authority in the Cabinet Office. He was a senior manager in the energy sector before joining the Civil Service. He has led collaborations between businesses and universities, and co-founded the BP Project Leadership Programme that was the inspiration for the Civil Service Major Projects Leadership Academy.

The Infrastructure and Projects Authority (IPA) complements the role of the National Infrastructure Commission. We work side-by-side and hand-in-hand, in order to create an environment for successful infrastructure delivery in the UK with the NIC focussing on long term infrastructure needs, and the IPA focussed on shorter term delivery. There seems to be increased confidence today in both Government and industry about the UK's ability to deliver extraordinarily complex, world-scale and world-class programmes.

The IPA has been created from two existing bodies. Infrastructure UK was primarily focussed on finance for infrastructure projects, and on creating and propagating the Government's infrastructure pipeline. That has been merged with the Major Projects Authority, which was concerned with the Government's wider portfolio of large projects and programmes, ensuring that they were delivered in the most effective way possible.

### A single centre of expertise

The organisation therefore constitutes a single centre of expertise for project development, project financing, assurance and support. Our purpose is very simple: to help Government and industry to deliver better projects and programmes. Table 1 lists our strategic objectives, covering the critical elements in infrastructure development (page 26).

One of our priorities is to create some certainty about the future flow of activity. Confidence about future continuity can greatly enhance productivity. This certainty about the future is something the IPA is trying to create through its pipeline.

Then, there is the universal challenge of ensuring that projects are initiated in such a way as to create success. There is a propensity to make a policy announcement and then go away and figure out if it can actually be delivered. That involves traversing the 'valley of death' that exists between policymakers and those that have

### SUMMARY

- The Infrastructure and Projects Authority provides a single centre of expertise within Government for infrastructure development.
- It aims to provide longer term certainty regarding the continuity of infrastructure investment in the UK.
- Over the next five years, Government and industry will invest some £300 billion.
- UK infrastructure delivery is relatively expensive – a focus on cost reduction is essential.
- Productivity remains a concern in infrastructure projects.

the difficult job of implementing their decisions. This is an issue that we are working hard to address.

The Government has a Major Projects Portfolio, comprising the top 150 to 200 projects and programmes across Government which the Infrastructure and Projects Authority pays special attention to. There is an extraordinary programme under way right now to transform the way that government services are delivered to the public and to reduce cost. It really is the most ambitious set of programmes one can imagine, with some serious challenges around delivering all of it.

### National Infrastructure Delivery Plan

As part of our work in building market confidence, we recently produced a National Infrastructure Delivery Plan for the coming Parliament. It aims to give a view into the future that offers some idea of the opportunities already out there and tries to create some relative certainty about future developments. Priority projects in a whole suite of different areas are identified.

The first such plan was produced in 2010, and well over 95% of all of the projects and pro-

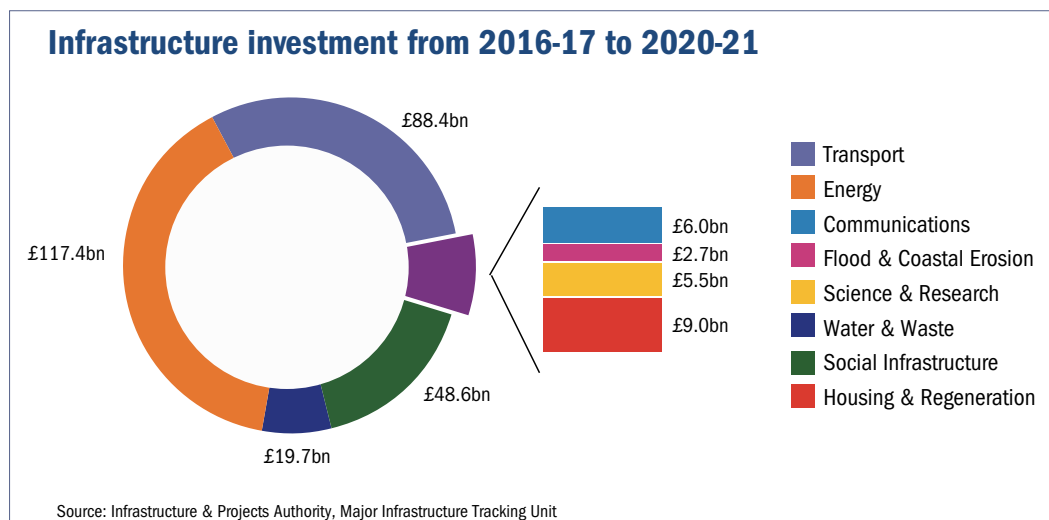


Figure 1. Overview of infrastructure investment from 2016-17 to 2020-21

grammes defined in that original plan have either been – or are in the process of being – delivered. So there is real rigour and honesty in this pipeline – it is not just a wish list.

Figure 1 (above) gives an overview of the investment. There is a great deal in the energy and transport sectors, and for the first time we have also included social infrastructure. We also have a mixed funding model. Over the next five years we expect to spend, jointly between Government and industry, in the order of £300 billion on all of the programmes contained in our pipeline. There is a mixture of funding across different sectors. Transport infrastructure is primarily delivered through Government funding, while water and waste rely predominantly on private capital – but all sectors have a mix. Slightly less than 50% of the total is Government spending.

So there are some very encouraging developments in the world of infrastructure. We are demonstrating a capacity and capability to undertake extraordinary things with a level of

confidence. We have developed a cadre of extraordinary leaders of great projects who have worked their way up through Terminal 5, through the Olympics, Crossrail, etc – a generation of people who know how to make these things happen.

#### The productivity challenge

All that notwithstanding, productivity remains a major challenge, particularly in the construction sector. Despite some progress in the past few years, there is a lot of work still to be done.

We have drawn up a number of areas to be tackled. Project appraisal and selection is concerned with making sure we select the right projects through the right assessment process. Second, we must set projects up for success at the point of initiation. Better planning in general is needed with a focus on reducing costs. UK infrastructure costs are, on average, expensive. The projects are of high quality when built, but relatively expensive. And the final crucial area is the current shortage of skills.

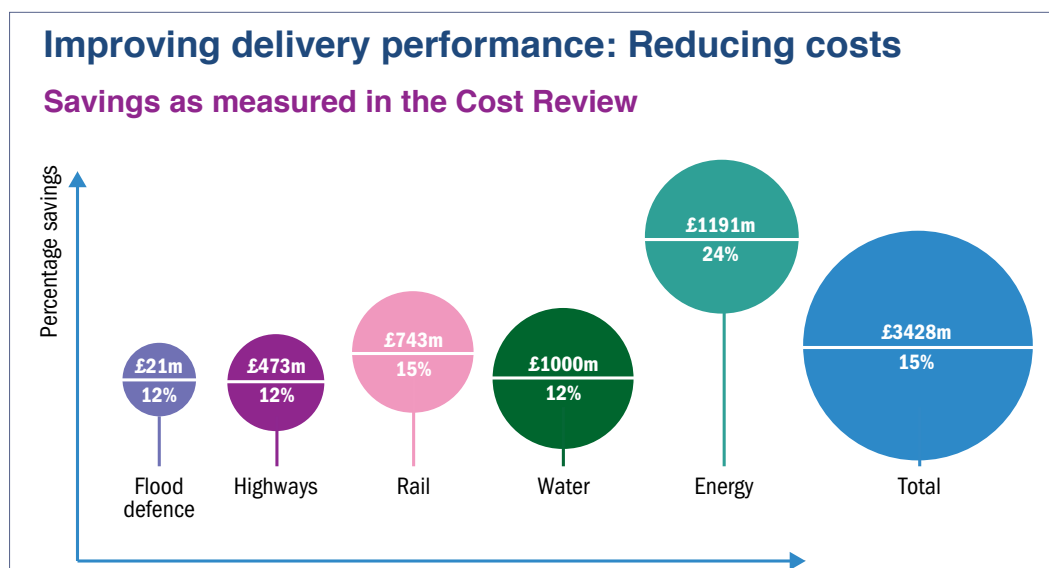


Figure 2. Improving delivery performance: reducing costs

The IPA is continually improving the way that we assess the value of infrastructure and its contribution to both the economy and the environment at large. So there is an ongoing focus on making sure we have the best possible methodology so that we do the best job in the right way. In this context a roadmap has been developed with industry and academia. It describes a pretty rigorous process.

Figure 2 (previous page) gives an indication of the cost savings that have been identified through a cost review that took place during the last Parliament. It started in 2010 and by 2014 the industry group had identified a number of significant savings across various sectors.

The priorities of the Infrastructure and Projects Authority are to extend the horizon of planning and to increase the levels of certainty around future opportunities in the infrastructure space. There is good progress being made in many areas of delivery. Productivity remains a challenge, but there is a limit to what Government can do in this

### IPA STRATEGIC OBJECTIVES

1. Setting the right policy environment for projects to succeed.
2. Giving the market confidence to deliver infrastructure.
3. Setting up projects and programmes for success
4. Ensuring projects and programmes deliver the intended benefits.
5. Promoting the right operating environment for project delivery.
6. Developing world-class project delivery and project finance capabilities across Government.

area. It ultimately comes down to fruitful collaborations between Government and industry, which can help us continue to build great infrastructure, but to do it ever more effectively and ever more efficiently. □

# Creating the framework for effective infrastructure delivery

Andrew Adonis



The Rt Hon the Lord Adonis has at the invitation of the Government set up an independent National Infrastructure Commission to enable long-term strategic decision-making with political consensus. He sits in the House as a non-affiliated peer to emphasise the political neutrality of the Commission. Lord Adonis has been head of the policy unit at No 10, Secretary of State for Transport and Minister for Schools. Prior to entering Parliament he was a journalist working for the *Financial Times* and *The Guardian*.

Most of the UK's major infrastructure projects, even if they are financed and delivered by the private sector, need the consent of the State and usually the State is intimately involved in the planning. Unfortunately, that has not been a great success over the past few decades.

### Crossrail

Crossrail itself is a salutary tale of transport planning. It is now 42 years since publication of the first plan – and cancellation. When Tony Crosland became Environment Secretary in 1974 he gave it little support, so in due course it was cancelled. He cancelled the Channel Tunnel. He cancelled the third London airport, which was in the process of being constructed at Maplin Sands, off Foulness (the piles are still there). He said that projections for future aviation had been grossly exaggerated despite an exhaustive process of planning, with a Royal Commission established in the 1960s. The Royal Commission had reported in the late 60s and recommended a site in the Chilterns for the new London airport. The Heath

### SUMMARY

- The State is – and has to be – intimately involved in the delivery of major infrastructure.
- With long term projects, cross-party consensus is vital.
- UK infrastructure has too often been the result of serendipity instead of foresight.
- The UK creates infrastructure that compares with the best in the world.
- The UK is developing a framework that will enable it to deliver essential infrastructure in a more timely and efficient manner.

Government rejected that, but a minority report recommended a site in the Thames estuary. Legislation was prepared, but it failed to win cross-party support and was cancelled in 1974.

When the Crossrail plans were drawn up, the Victoria Line had just been completed. The cost-benefit ratio for this new Underground line was poor and it very nearly did not proceed.



Eventually it was significantly 'de-scoped', due not simply because of the shortage of money at the time, but also because the traffic projections were considered far too optimistic (this is part of the reason why the stations are all very small on the Victoria Line).

Crossrail came in the wake of that and no action was taken. The first two proposals were cancelled by the Treasury at different stages and only the third iteration gained consent.

The moral I draw from that and other similar stories is that longer term infrastructure planning needs to bring two elements to bear. The first is an objective fact base that is wider than the statistics presented by Governments when they announce projects. The second is to gain some cross-party consensus, because without this it is not possible to progress many of these projects that span more than one Parliament.

### Cross-party commitment

The reason why Crossrail is proceeding is because the cross-party consensus enabled it to survive both a change of Government and a change of Mayor. Otherwise it certainly would have been cancelled in 2010 because the large price tag would have provided a very big and immediate saving for the incoming Government. Construction was just starting which would have been the ideal time for the Treasury to cancel a project as this was the stage at which Maplin was cancelled in 1974.

With cross-party consensus, it is possible to move as rapidly as any other democratic nation. HS2 was announced six years ago. The legislation is now in the House of Lords and will be passed by the end of this year. Construction will start next year.

The Infrastructure and Projects Authority is examining it closely because there is an ongoing concern about how costs are best managed and reduced. This is a huge issue. Why are our infrastructure costs so much more than equivalent projects elsewhere? HS2 is, as I understand it, significantly higher in mileage (allowing for tunnels and other factors) than any other high speed line in the world and around twice of the equivalent schemes in France. It will probably turn out, adjusting for costs, to be the most expensive high speed rail scheme ever developed.

Yet the consensus has held. The result is that we will construct the biggest infrastructure project in Europe (and an extremely complex project with massive attendant controversy) within 16 years of it being first announced. That includes 100 miles of completely new track going out of London, with the construction of four major stations and a

## Longer term infrastructure planning needs to bring two elements to bear: an objective fact base and cross-party consensus

hugely contested planning process. The timescale is about as fast as it is possible to do this.

Once the project gets to Birmingham, the pressure to get to Manchester and Leeds will be unstoppable. This should have been achieved by 2033 – only another seven years.

### HS2

From the outset, HS2 was geared to achieving cross-party consensus. I had asked Gordon Brown if I could go to Transport from Education. He was astounded as Transport was not considered a frontline department. Yet it seemed to me that the moment had arrived to take big rail infrastructure investment forward (this was in 2008-9), because the opposition Conservatives had just come out for high speed rail in principle.

Now in infrastructure there is a yawning gap between agreeing things in principle and actually having a plan. Nobody had a plan for HS2, but if somebody came forward with one (and it needed to be from the Government – i.e. Labour) this could get moving fast. The irony of the situation was that the Conservatives had committed themselves to high speed rail on the rebound from opposing Heathrow expansion. Support for a high speed line, so the argument went, would lead to a significant reduction in the need for domestic aviation because this would all move to rail.

Unfortunately, the one thing that HS2 does not do is lead to much change in domestic aviation – there are very few people who fly between London and Manchester since the modernisation of the West Coast Mainline. There are no flights from Birmingham to Heathrow. To get any significant reduction in domestic aviation as a result of high speed rail you have to look at Edinburgh and Glasgow but that is going to take a very long time.

So it was all very contingent. To look at it in terms of the planning of national infrastructure, this is not a great way to take decisions about the medium to long term – just hoping that the contingent factors come together. We should have started building our intercity high speed rail, linking up the major conurbations like London, Birmingham, Manchester and Leeds, at the same time as the Italians and French – which was in the 1970s. It should have been planned then and delivered over the following 20 years. Not only would the national payback have been significantly greater, transforming the connectivity of the major cities, but we would also have avoided

Ultimately we create infrastructure that is as good as any developed elsewhere. Our problem is that we do not do this in a sufficiently timely fashion.

successive upgrades of the West Coast Mainline and many of the associated costs, which have come to tens of billions. Indeed, if you add up the investments entailed as a result of not doing high speed rail as well as the welfare forgone, I suspect the overall costs are not that different.

### **An independent commission**

Having an independent body make recommendations which Government can then accept or reject, but which creates a body of support to make acceptance more likely, is not a panacea – but it can help. Such an independent body over time can also take a role in monitoring the total infrastructure pipeline. In doing so, it can bring some edge into the system in holding Ministers and the State to account for actually delivering projects.

As with all things, understanding the past is so important for understanding the future. Many of our big infrastructure projects have been serendipitous and have depended on a range of contingent factors. But by definition it is impossible to do anything of this scale without planning and most of our planning is actually sound. The question is whether and when it is implemented.

A whole generation of energy capacity was planned and delivered over a reasonable period and was a great testament to the modernisation and success of energy infrastructure planning in the 1960s and 1970s. The airports have been planned. Heathrow is not where it is because of serendipity, but because it was planned that way. The Abercrombie Report of 1944, which looked at post-war planning in London, has a whole section looking at options for London's international airport.

There were ten potential sites, such as Croydon which was then the international airport, but also others including what are now Gatwick and Stanstead as well as sites further west. The Report settled on Heathrow as the best site, optimising proximity to the economic heart of the capital with inconvenience to local residents.

Although the inconvenience to local residents has been the problem which has beset Heathrow ever since, a good part of the reason why it is so successful is because it is located very close to the economic heart and hinterland that it serves.

Abercrombie also recommended that there should be a fast rail link from the airport to the city centre. Well, it only took 45 years to construct that! But today, there is no major airport serving a city anything like London's size which has such good

connectivity routes with its city centre. He also recommended that there should be a motorway box and hub that connected to it as well. That took slightly less time – only took 35 years to complete. Yet, that again was all part of the Abercrombie plan.

Successive modernisations and expansions of Heathrow have basically accepted the Abercrombie plan and rationale of the mid-1940s. The War Cabinet in the mid-1940s planned the motorway system, and the one that was finally constructed was remarkably similar to the plans laid before them in 1943. Transport Minister Sir Leslie Hore-Belisha had rejected the idea of motorways in the 1930s, saying they were inherently fascist because they were straight and England did not do straight roads.

So the plans were not properly developed until the time of the War Cabinet, and then it took until the late 1950s. It was Ernest Marples who, in the course of five years as Transport Minister, got the whole of what is now the modern motorway system either in construction or in an advanced stage of planning. That would not have happened, though, had it not been for the plans that had been drawn up over the previous 15 years. Ultimately we do create infrastructure that is as good as any developed elsewhere. Our problem is that we do not do this in a sufficiently timely fashion.

### **London**

London is starting to show how we can tackle these issues more systematically. There is a London Infrastructure Plan. The Mayor of London commands significant resources and can therefore himself prioritise projects. There is the Thames Tideway Tunnel, the Silvertown Tunnel and Crossrail. We even have Crossrail 2, which the Government has just committed to, following recommendations made by the National Infrastructure Commission. The commitment is to legislate by the end of this Parliament, which would make it all a much smoother process than Crossrail 1. The Mayor of London and the Greater London Authority constitute a regional infrastructure planning authority with real teeth, real political clout and real resources.

Looking at our success in delivering major projects over the past 15 years, I am optimistic that we might do this all somewhat better and faster over the next generation. The acid test, though, is whether we can ultimately take a decision on the biggest single infrastructure constraint which we face as a country: the expansion of our major hub airports. If that can be resolved over the next year or 18 months then I believe people will think we are capable of grappling with these big issues, and that none are 'off-limits'. □

# Infrastructure as the nursery for tomorrow's skills base

Terry Morgan



Sir Terry Morgan CBE is the Chairman of Crossrail. Prior to his current appointment he was Chief Executive of Tube Lines, a company contracted to maintain and upgrade the infrastructure of the Jubilee, Northern and Piccadilly lines. He has also been Group Managing Director, Operations, and Group HR Director for BAE Systems, Managing Director at Royal Ordnance, Managing Director of Land Rover and Operations Director of the Rover Group. In addition, he led a skills review for the transport sector.

Seven years ago, the first pilings went into Canary Wharf, physically putting value into the ground in the project which became Crossrail. At the same time, the organisation was still working with HM Treasury to obtain approval that we were competent to manage this project!

The Government arrangements for a programme like Crossrail are, in their detail, substantially different from what might be imagined. We went through the Major Projects Review Group (MPRG) process, as it was then, and we made it work for us. We worked really hard at making sure that we could demonstrate our competency and our capability, showing that we had both the people and the systems to deliver this project.

The project is funded to £14.8 billion (with another £1 billion for the rolling stock). We remain confident that we can deliver on time in 2018, which was always the plan, and that we can deliver it inside the funding level that has been set.

## Regeneration

We have always said that Crossrail is more than just a railway. Railways have always brought regeneration along with them and indeed Crossrail has continued in that spirit. We are in existence because London is due to grow by another 1.5 million people by 2030 – we will have to add more than 10% capacity to transport in London. It is already desperately needed today.

Early on, Crossrail undertook a skills review. Government had made a commitment to three million apprentices by 2020. To put that into context, that means that every school leaver between now and 2020 becomes an apprentice – very unlikely to happen! Yet it does show there is an increasing recognition that we need skills that match the needs of the economy if it is to grow.

The review identified that the infrastructure sector could sustain 30,000 apprenticeships by 2020 – that is five times the current level. Some very clear objectives were set. One priority was to be able to transfer lessons learned. The National Infrastructure Commission was very important here. It ensures that we can take the learning from programme to programme.

Take the challenge of productivity. I am in no doubt that part of the productivity problem is

## SUMMARY

- Crossrail is more than just a railway.
- Apprenticeships are a key element in the Crossrail strategy.
- These skills must transfer if productivity is to be improved.
- The lessons about skills are being learned and applied across the sector.
- Investment brings both innovation and new opportunities.

that we keep stopping and starting. Crossrail is a phenomenal programme. The skills that we have developed are second to none. Having confidence that those skills will carry on to the next infrastructure project will help with the productivity gains that are essential for this type of investment.

As an example, Crossrail had a determination to use its procurement power to make a difference. Companies that wanted a contract had to commit not only to deliver within time and cost, but also had to either employ an apprentice for every £3 million worth of contract value, or else employ somebody who was currently unemployed.

## A skills academy

A skills academy was built in East London. The goal was to have 400 apprentices by 2018. In early 2016, we already have 550 apprentices, so the objective set six or seven years ago has already been beaten. It took a while to get everyone engaged, but the best contractors invest in their people as a matter of course.

Why was this programme important to Crossrail? As an example, the project needed about 1,200 people with the skills to work in underground construction. Of those, 700 resided in the UK. So, even if we were able to capture everyone who had that skill, there was still a significant shortfall. There is no long-term skills shortage. Skills shortage will get sorted out by the market, meaning immigration has to some extent filled the gap. But what a lost opportunity that would be to develop young people with the skills we need in order to support the UK economy.

On apprenticeship programmes one in five come from a NEET background – Not in Employment, Education or Training.

The more compelling reason for this investment in skills was the average age. The workforce is dominated by males, with an average age of 55. In an industry with such a great potential future, something had to be done. Hence, we leveraged our procurement power, a strategy now agreed across the transport sector. Network Rail, Highways England, HS2, DfT, Crossrail, TFL: all have committed to using procurement power as a means to prioritise the skills agenda in order to achieve the 30,000 goal.

Another strategic target is for females to make up 20% of our intake by 2020. I wonder if we have actually underestimated the potential for change in Crossrail. The skills agenda has been a relentless campaign and in the past 12 months 27% of our apprentices have been female. That is against a national average of about 6-7%. It can be done, but it has to be done relentlessly.

One of the reasons politicians should – and do – like infrastructure projects is that on apprenticeship programmes one in five come from a NEET background – Not in Employment, Education or Training. On Crossrail, 40% of the apprentices were NEETs. Again, a big infrastructure project delivering real value for the economy, but also having a big social impact across our nation.

There has often been a debate about ‘why London?’ Why does London always get priority in terms of infrastructure investment? Part of the reason is because London is actually paying for quite a significant proportion of Crossrail. Yet it is also true to say that the benefits of infrastructure investment are spread around the UK economy. Some 95% of our contracts have been let in the UK. Then 60% of spending has been with SMEs. A full 60% of the spend has actually been outside London and the South East. So this kind of project does benefit the whole of the UK economy. I do appreciate, of course, that there will be pressure to ensure that infrastructure projects such as HS2 will spread that benefit even more widely across the UK economy.

The skills agenda is very real. Careers guidance needs to talk not just about universities as a destination, but about worthwhile careers that can be delivered through an apprenticeship programme.

The landscape is changing. People come onto the Crossrail programme for a multitude of reasons. It is a great project, it creates real satisfaction, enhances career prospects and gives people a pride in creating something that is significantly different.

The only major items that we bought on Crossrail that were not manufactured in the UK were the tunnel-boring machines. They came from a small village in Germany. Mr Herrenknecht owns the firm. He set up the business 50 years ago and it

dominates the village, employing 2,500 people, including 500 apprentices. There you have got a real example of engagement between state and local enterprise. One of the things he said was how grateful he was to have the London contract. He said: “I know I build the best tunnel-boring machines in the world, but I can only prove that if their capability is really tested, which means you need the very best engineers. Be in no doubt, as far as I am concerned, some of the best engineers in my career have been British.”

Crossrail has 550 apprentices. Many of them have learned how to do tunnelling in a way that would have been quite unthinkable in another era. People in their 20s are being given the opportunity right now. So, for me there is a bigger picture. Not only are we seeing infrastructure improvements in the UK economy, but this creates new opportunities to export that capability around the world.

### Lessons learned

The lessons about skills are being learned. Two national colleges are being built for HS2 technologies – one in Birmingham and one in Doncaster – even before railway construction begins. A similar situation exists in new nuclear. There are colleges being built in Somerset and in North Wales, even though the final decision about the facilities themselves have not been confirmed. We are developing the skills that will enable us to maximise the opportunity for the UK economy.

Everywhere you look on Crossrail, it brings new opportunities. Seven million tonnes of waste were moved out of London. It was recognised that moving that amount of material by road was reputationally very difficult. It would probably have created gridlock in certain parts of London as well. Instead, much of it was moved by rail and then shipped to a location just east of Southend – a place called Wallasea.

We had an agreement with the RSPB and together we created a wetland bird reserve – the largest in Europe. It is now a tourist centre for people who are interested in bird-watching. Who could have imagined that tourism would result from infrastructure investment?

We should be really proud of what we have achieved. Innovation is very much part and parcel of the benefits that come with continued investment in this type of project. I am extremely confident that, if the investment can continue and we can convey the message that projects like Crossrail can be delivered on time and within agreed funding levels, then we will not provide any excuses for politicians to decide that there are higher priorities elsewhere in the economy. □



# The debate

Issues raised in the debate included concerns about ‘white elephant’ engineering projects, freight versus passenger rail and the need for infrastructure projects to contribute to skills development

Is there too much emphasis on large engineering projects, with the risk that some of them could turn out to be white elephants? Significant benefits to the economy and to society could flow from smaller projects designed to remove bottlenecks as well as from projects outside the field of engineering. As for white elephants, the backlog of essential investment is so great that the risks of useless projects are insignificant.

What could the UK learn from other countries? Of course, they have their problems too. In Germany, for example, there had been a major and sudden change in energy policy. In France, some apparently successful infrastructure policies have produced unfortunate social consequences as a result of inadequate foresight and planning (e.g. the Paris RER train system connecting central Paris to the suburbs and the social problems that has created).

There are a number of areas of infrastructure which need more attention, for example flood prevention, as well as higher speed and better broadband coverage.

The debate included discussion of the emphasis on high speed passenger railways. Perhaps it was more important to cater for freight than for passengers?

However, it was pointed out that one of the benefits from the HS2 project was the freeing up of capacity on existing rail routes, thus giving greater scope for freight traffic. Speakers also suggested that in fact more innovative and appropriate ways of handling freight might be “freight trains” on roads.

It is important that other infrastructure projects should seek to match Crossrail’s contribution to skills development. There needs to be

more attention given to capital provision and the cost of capital. This varies markedly from sector to sector, but much of the variability could be due to different risks which could not be eliminated. There is also a need for more radical innovation in construction processes.

The Government sometimes lacks the necessary competences to be an effective customer for projects. Not only are the right professional skills absent but rapid staff turnover results in an overall lack of experience. □

## FURTHER INFORMATION

### Armitt Review

[www.yourbritain.org.uk/uploads/editor/files/The\\_Armitt\\_Review\\_Final\\_Report.pdf](http://www.yourbritain.org.uk/uploads/editor/files/The_Armitt_Review_Final_Report.pdf)

### Crossrail

[www.crossrail.co.uk](http://www.crossrail.co.uk)

### Department for Transport

[www.gov.uk/government/organisations/department-for-transport](http://www.gov.uk/government/organisations/department-for-transport)

### Highways England

[www.gov.uk/highways-england](http://www.gov.uk/highways-england)

### Infrastructure and Projects Authority

[www.gov.uk/government/organisations/infrastructure-and-projects-authority](http://www.gov.uk/government/organisations/infrastructure-and-projects-authority)

### National Infrastructure Commission

[www.gov.uk/government/organisations/national-infrastructure-commission](http://www.gov.uk/government/organisations/national-infrastructure-commission)

### Transport for London

[www.tfl.gov.uk](http://www.tfl.gov.uk)

## Professor H Peter Jost



Professor H Peter Jost CBE, a frequent contributor to the debates, and a long-time supporter of the work of The Foundation for Science and Technology, passed away on 7th June at the age of 95. Professor Jost was generally regarded as the founding father of Tribology. In 1966, he chaired a committee that published a report which became known as the *Jost Report*.

The report changed how the industry and science communities approached the question of friction and wear. It was acclaimed worldwide.

In addition to his appointment as a Commander of the British Empire, he received honours from the heads of state of France, Germany, Poland, Austria and Japan. He was an honorary fellow of the Institute of Materials, Minerals and Mining and of the Institution of Mechanical Engineers. □

## EVENTS

### **Is a paradigm shift taking place in the ways individuals and organisations access, analyse and protect data?**

**25 May 2016**

**Professor Sir Nigel Shadbolt** FREng, Chairman and Co-Founder, The Open Data Institute

**Dr Mike Lynch** OBE FRS FREng, Founder, Invoke Capital

**Professor David Hand** OBE FBA, Chief Scientific Adviser, Winton Capital

**Baroness O'Neill of Bengarve** CH CBE FBA  
**HonFRS FMedSci**, House of Lords [Panellist]

### **The pros and cons of EU membership for UK research programmes in private enterprises and public sector organisations**

**3 May 2016**

**The Lord Hennessy of Nympsfield** FBA, Member, House of Lords Science and Technology Select Committee, House of Lords

**Viscount Ridley** FMedSci FRSL, Member, House of Lords Science and Technology Select Committee, House of Lords

**Professor Dame Jocelyn Bell Burnell** DBE FRS FRSE FRAS FInstP, President, The Royal Society of Edinburgh

**Sir Emyr Jones Parry** GCMG FInstP FLSW, President, The Learned Society of Wales

### **Building effective and efficient infrastructure for the UK**

**27 April 2016**

**Tony Meggs**, Chief Executive, Infrastructure and Projects Authority, Cabinet Office

**The Rt Hon The Lord Adonis**, Chair, National Infrastructure Commission

**Sir Terry Morgan** CBE, Chairman, Crossrail

**Darren James**, Managing Director, Infrastructure, Costain [Panellist]

### **Using science to authenticate, verify or assure the identity of people and things**

**2 March 2016**

**Sir Mark Walport** FRS FMedSci, Government Chief Scientific Adviser

**Dr Derek Craston**, Government Chemist and Managing Director of Science and Innovation at LGC

**Professor Dame Sue Black** DBE FRSE, Professor of Anatomy and Forensic Anthropology at the University of Dundee

### **Bringing science to the heart of government: the Nurse Review of the Research Councils**

**12 January 2016**

**Sir Paul Nurse** FRS FMedSci, Chair, the Nurse Review of the Research Councils, and Director, The Francis Crick Institute

**Professor Phil Nelson** FREng, Chair, RCUK Executive Group and Chief Executive, Engineering and Physical Sciences Research Council

**Gareth Davies**, Director General, Business and Science, Department for Business, Innovation and Skills

**Professor Dame Jocelyn Bell Burnell** DBE FRS FRAS PRSE, President, The Royal Society of Edinburgh [Panellist]

### **Closing the US/UK productivity gap: connecting innovation and research to economic output**

**2 December 2015**

**Dr Ruth McKernan** CBE, Chief Executive, Innovate UK

**Professor Jonathan Haskel**, Professor of Economics, Imperial College Business School

**Tony Harper**, Head of Research and Advanced Systems Engineering, Jaguar Land Rover

### **Responding to a changing Arctic: The House of Lords Arctic Select Committee Report**

**4 November 2015**

**The Lord Teverson**, Chair, House of Lords Select Committee on the Arctic, House of Lords

**Jane Rumble**, Head, Polar Regions Department, Foreign and Commonwealth Office

**Professor Dame Julia Slingo** DBE FRS, Chief Scientist, Met Office

### **The Accelerated Access Review for the Department of Health (the Taylor Review)**

**26 October 2015**

**Sir Hugh Taylor** KCB, Chair, Accelerated Access Review, Department of Health

**Sir Leszek Borysiewicz** FRS FRCP FMedSci FLSW, Vice-Chancellor, University of Cambridge

### **The Future of the Energy Sector in Scotland**

**22 October 2015**

**Phil Boswell** MP, MP for Coatbridge, Chryston & Bellshill, House of Commons

**Iain Conn** FREng FRSE, Chief Executive, Centrica plc

**Gary Haywood**, Chief Executive Officer, INEOS Shale

**Professor Rebecca Lunn** FRSE FREng, Head of Department, Civil and Environmental Engineering, Professor of Engineering Geosciences, University of Strathclyde

**Ben Ritchie**, Senior Investment Manager, Pan-European Equities, Aberdeen Asset Management [Panellist]

### **The Dowling Review of Business-University Research Collaborations**

**7 October 2015**

**Professor Dame Ann Dowling** DBE FRS FREng, President, Royal Academy of Engineering

**Sir Peter Gregson** FREng, Vice-Chancellor and Chief Executive, Cranfield University

**Eric Hawthorn**, Managing Director, Radio Design Ltd

**Professor Jeremy Watson** CBE FREng FIET, Professor of Engineering Systems, University College London [Panellist]

### **How can international research be mobilised to drive down the cost of renewables, storage and smart grids to achieve parity with coal fired electricity generation?**

**8 July 2015**

**Sir David King** ScD, FRS, HonFREng, The Foreign Secretary's Special Representative for Climate Change, Foreign and Commonwealth Office

**Dr Bernie Bulkin**, Director, Ludgate Investments Ltd

**Ed Heartney**, Environment, Science, Technology and Health Counsellor, Embassy of the United States of America in London

**Sir Colin Humphreys** FRS FREng, Department of Materials Science, University of Cambridge [Panellist]

### **The business of the environment: can the tension be resolved between resource extraction and environmental protection?**

**24 June 2015**

**Professor Duncan Wingham**, Chief Executive, Natural Environment Research Council

**Professor Simon Pollard**, Pro-Vice-Chancellor, School of Energy, Environment and Agrifood, Cranfield University

**The Lord Oxburgh**, House of Lords

**Professor Jane E Francis**, Director, British Antarctic Survey [Panellist]

### **Is the Haldane Principle fit for purpose in the 21st Century?**

**3 June 2015**

**The Lord Hennessy of Nympsfield** FBA, Member, House of Lords Select Committee on Science and Technology, House of Lords

**The Lord Rees of Ludlow** OM Kt FRS,

Former President, The Royal Society

**The Rt Hon David Willetts**, Former Minister of Universities and Science

**Professor Jane Elliott**, Chief Executive, Economic and Social Research Council [Panellist]

Presentations and audio from all Foundation events are available at [www.foundation.org.uk](http://www.foundation.org.uk)

## A

Aberdeen Asset Management  
AIRTO  
Arts and Humanities Research Council  
AstraZeneca  
Atkins Limited

## B

BAE Systems  
Babcock International Group  
BCS, The Chartered Institute for IT  
Biotechnology and Biological Sciences Research Council  
BP  
BPE Innovation  
BRE Group  
British Academy  
British Geological Survey  
Brunel University  
BSI Group

## C

Canterbury Christ Church University  
Caparo Group  
Cardiff University  
Chartered Institute of Plumbing and Heating Engineering  
City & Guilds of London Institute  
City University London  
Comino Foundation  
Cranfield University

## D

Department for Business, Innovation and Skills  
Department for Environment, Food and Rural Affairs  
Department of Health  
DWF

## E

Economic and Social Research Council  
Energy Institute  
Engineering Employers' Federation  
Engineering and Physical Sciences Research Council  
Environment Agency  
ERA Foundation

## G

Genomics England  
GlaxoSmithKline (GSK)

## H

Haskel Family Foundation  
Heads of University Centres of Biomedical Science (HUCBMS)  
Health and Safety Executive

High Value Manufacturing Catapult  
Higher Education Academy  
Higher Education Funding Council for England

## I

Imperial College London  
Innovate UK (formerly Technology Strategy Board)  
Institute of Mathematics and its Applications  
Institution of Chemical Engineers  
Institution of Mechanical Engineers

## J

Japan Society for the Promotion of Science  
Jisc  
John Browne Charitable Trust  
Johnson Matthey

## K

King's College London

## L

Landscape Institute  
Lloyd's of London  
Lloyd's Register Group  
London School of Hygiene & Tropical Medicine

## M

McLaren Racing  
Medical Research Council  
Met Office

## N

National Oceanography Centre  
National Physical Laboratory  
Natural Environment Research Council  
Natural History Museum  
Network Rail  
Nottingham Trent University

## P

Parliamentary and Scientific Committee  
Premmit Associates  
Public Health England

## Q

Queen Mary, University of London  
Queen's University Belfast

## R

Risk Solutions  
Rolls-Royce  
Royal Society of Biology  
Royal Society of Chemistry  
RPS Energy

## S

Science & Technology Facilities Council

Smith Institute for Industrial Mathematics and System Engineering  
Society for General Microbiology  
Society of Maritime Industries  
Sovcomflot (UK)  
Stemnet

## T

The Academy of Medical Sciences  
The British Standards Institution  
The Institution of Engineering and Technology  
The Kohn Foundation  
The Lloyd's Register Foundation  
The Medical Schools Council  
The Michael John Trust  
The Nautical Institute  
The Royal Academy of Engineering  
The Royal Commission for the Exhibition of 1851

The Royal Society

The Wellcome Trust

Transport Systems Catapult

TWI

## U

University College London  
University of Aberdeen  
University of Birmingham  
University of Bristol  
University of Cambridge  
University of Chichester  
University of Dundee  
University of East Anglia  
University of Edinburgh  
University of Glasgow  
University of Kent  
University of Leeds  
University of Leicester  
University of Reading  
University of Sheffield  
University of Southampton  
University of Strathclyde  
University of Warwick  
University of Wolverhampton

## W

Wheatsheaf Group  
Wiley-Blackwell, John Wiley & Sons  
Willis Towers Watson

## X

XL Catlin

# The Journal of The Foundation for Science and Technology

The Foundation for Science and Technology  
10 Carlton House Terrace  
London SW1Y 5AH

**Telephone:** 020 7321 2220

**Fax:** 020 7321 2221

**Email:** [fstjournal@foundation.org.uk](mailto:fstjournal@foundation.org.uk)

[www.foundation.org.uk](http://www.foundation.org.uk)



THE FOUNDATION  
FOR SCIENCE AND  
TECHNOLOGY