fst journal

The Journal of the Foundation for Science and Technology

Volume 21, Number 2, October 2013

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

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fst journal

Volume 21, Number 2, October 2013

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www.foundation.org.uk carries reports on all Foundation meetings.

Clinical trials 'must be more transparent'

The Science and Technology Committee has described the current lack of transparency of many clinical trials as "unacceptable".

Committee Chair Andrew Miller MP said: "We consider that all trials conducted on NHS treatments—and all other trials receiving public funding—should be prospectively registered and their results published in a scientific journal. While the focus should be on implementing this change for future trials, the Government must also do what it can to ensure that historic trials are registered and published, particularly where they have been publicly funded."

The Committee also asked the Government to take steps to facilitate greater sharing of the raw data generated during a trial. In addition, the Report drew attention to the recent fall in the number of trials taking place in the UK, stating that the UK was a "particularly challenging" place in which to conduct a trial. It found that the need for multiple governance approvals from participating NHS organisations remained the biggest barrier to setting up a UK trial, but that lack of public awareness was also a key issue.

www.publications.parliament.uk/pa/cm201314/cmselect/cmsctech/104/104.pdf

Public investment and additional funding

Evidence to show how public investment in science and research leverages additional funding from industry, charities and overseas sources has been published by Research Councils UK (RCUK). The report *Leverage from public funding of science and research* examines the financial contributions made by each sector to the research base and their interdependencies. It illustrates examples of successful leveraging with case studies, provided by stakeholders, of the consequences of withdrawal of public funding from areas of research.

The report was written by Dr Sarah Main, now Director of the Campaign for Science and Engineering, while she was at the Department for Business, Innovation and Skills (BIS). Her team has been gathering evidence on the impact of public investment in science and research, looking specifically at leverage. It also looked at issues including efficiencies in higher education, the dual-funding model, and the impact of science and research on local economies.

www.rcuk.ac.uk/documents/documents/LeverageReport.pdf

Human influence on climate 'is clear'

Human influence on the climate system is clear and evident in most regions of the globe, the latest assessment by the Intergovernmental Panel on Climate Change (IPCC) concludes. The report says it is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century. It adds that the evidence for this has grown, thanks to more and better observations, an improved understanding of the climate system response and improved climate models.

Warming in the climate system is unequivocal and since 1950 many changes have been observed throughout the climate system that are unprecedented over decades to millennia. Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850, according to the *Summary for Policymakers* adopted by member governments of the IPCC, meeting in Stockholm, Sweden.

Thomas Stocker, Co-Chair of Working Group I which examined the physical science case for climate change said: "Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions."

Rajendra Pachauri, Chair of the IPCC, said: "This Summary for Policymakers provides important insights into the scientific basis of climate change. It provides a firm foundation for consideration of the impacts of climate change on human and natural systems and of ways to meet the challenge of climate change."

Over 250 scientists from 39 countries worked on the Working Group I report. According to the National Environment Research Council (NERC) more than 10 per cent of these scientists were from the UK.

www.climatechange2013.org/images/uploads/WGIAR5-SPM_Approved27Sep2013.pdf

Shale gas emissions assessed

The carbon footprint (emissions intensity) of shale gas extraction and use is comparable to gas extracted from conventional sources, lower than that of Liquefied Natural Gas and significantly lower than coal when used for electricity generation. That is one of the findings of a report by the Chief Scientific Adviser of the Department of Energy and Climate Change (DECC), Professor David MacKay FRS together with Dr Timothy Stone CBE.

The report, *Potential Greenhouse Emissions Associated with Shale Gas Extraction and Use* also concludes that, if adequately regulated, local GHG emissions from shale gas operations should represent only a small proportion of the total carbon footprint of shale gas, which is likely to be dominated by CO2 emissions associated with its combustion.

The study was welcomed by the Royal Academy of Engineering. It follows the Academy's joint report with the Royal Society in June 2012 on the risks associated with hydraulic fracturing. That study concluded that the health, safety and environmental risks could in principle be managed effectively in the UK providing that operational best practice is implemented and enforced through strong regulation.

Dr Martyn Thomas CBE FREng, Vice President of the Royal Academy of Engineering, said: "Shale gas is an opportunity that can't be ignored. Progress must be cautious but, if managed correctly, shale gas can contribute to lowering carbon emissions in the short to medium term and balancing increasing amounts of variable renewable electricity."

www.gov.uk/government/publications/potential-greenhouse-gas-emissions-associated-with-shale-gas-production-and-use

Adapting to low carbon transport

Given the chance to drive an electric vehicle, people get used to driving it very quickly. They find these cars simple to drive and even adapt to unfamiliar technologies like regenerative brakes within their first trip. These were among the conclusions from a major report published by the UK's innovation agency.

The report, *Assessing the viability of EVs in daily life*, analyses the experiences of 349 drivers who took part in this study funded jointly by the Technology Strategy Board and the Office of Low Emission Vehicles (OLEV). The vehicles were mainly pure electric vehicles with, in addition, some plug-in hybrids and fuel-cell electric vehicles. In all, total mileage during the course of the research was more than 1.5 million miles.

www.innovateuk.org/documents/1524978/2138994/ULCV%20Demonstrator%20final%20report

Putting science at the heart of the economy

Julian Huppert

Dr Julian Huppert is MP for Cambridge and co-Chair of the Liberal Democrat Parliamentary Party Committee on Transport. He hasa PhD in biological chemistry and has held research fellowships at a number of Cambridge institutions. He was elected as MP for Cambridge in 2010. He has campaigned in Parliament on many issues, including civil liberties, sustainable transport and the need for science- and evidence-based policies. He has reviewed science policy for the Liberal Democrats.

The decisions taken in the recent Spending Review will shape Britain's future and will have global consequences. Britain has been at the forefront of research for centuries, and while in other areas we may be seeing decline, in science we are going from strength to strength.

In my part of the country, Cambridge, there are now more than 1,500 companies, some 54,000 jobs and £12 billion in revenue from the high-tech, knowledge-based economy. As a result, unemployment has fallen to 2.3 per cent, with youth unemployment below 1.5 per cent. This is great for the region and for the rest of the country, now and in the future.

How could we earn our way in the world in 2020, 2030 or 2050 if not through the knowledge-based economy, building on insights that we are learning and developing now?

The UK continues to punch above its weight in scientific research. We may only have about one per cent of the world's population, but we have a huge research base, with 4 per cent of the world's researchers, an 11 per cent share of world citations and 14 per cent of highly-cited publications. This is a great foundation from which to grow.

In a policy paper *Developing a future: Policies for science and research*[1], I wrote about three key ingredients necessary to ensure the UK's scientific research flourishes: people, money and attitude. All are essential.

Drivers of change

In every industry, people are the drivers of change – they innovate, create and explore ideas. In science this is even more pronounced. The UK has to build a highly-skilled workforce that will attract industry and innovators to come here to do the best research.

There are two ways of doing this. One starts with students at school here in the UK. Schools must be able to provide a more solid curriculum in science, technology, engineering and mathematics (STEM) and employ teachers who are specialists in these fields. The Science Learning Centres do a great job, but they are not sufficient. The challenge is to be inclusive and encourage participation by all. Studies show that the vast majority of girls show an interest in STEM subjects but half think that these subjects are not typical career paths for them.

This view is, unsurprisingly, reflected in the number of graduates. Women make up approximately half of all science graduates (which is a very good thing) but these figures are highly skewed towards medicine and allied subjects, as well as veterinary and biological sciences. Looking at the physical sciences, engineering and maths, only 26.5 per cent of graduates are female.

We need to do more to support organisations such as STEMNET and other outreach activities. This will go some way to delivering, for example, 20,000 more engineers a year: we need these new graduates to cope with the retirement bubble as well as the growth in energy, automotive and aerospace. Of course, it does not just concern women: people from many different backgrounds do not get the opportunities they deserve.

We also need an immigration system that is fit for purpose, allowing us to attract students as well as skilled scientists and engineers. It must be made easy for people to come to this country to study, or to work in highly-skilled jobs. We want to promote the accessibility of this country to the world's leaders, just as we want our leaders to appreciate the standard of research carried out in other countries.

While talent is undoubtedly the most valuable commodity, it must be supported by the right infrastructure. This needs finance and a willingness to invest. The Chancellor announced a £600 million boost for scientific research in December and increased scientific capital spending in June's Spending Review. This will, I hope, serve as a base upon which to build a consensus for a new settlement – a 15-year ring-fenced science and research budget, with an annual increase of 3 per cent above inflation, to include both capital and revenue spends.

A change in attitudes

Attitudes in the corridors of Westminster and Whitehall also need to change. There must be better use of evidence-informed policy in decision making. Political interference in science should be kept to a minimum, but science must interfere in politics. We need to strengthen the role of Chief Scientific Advisers in making these decisions.

If we get this right, we will deliver jobs and growth, new knowledge and exciting technologies, as well as global competitiveness and inward investment. ☐

1. www.libdems.org.uk/siteFiles/resources/docs/policy/SciencePolicy.pdf

Making the results of the research base more widely available could have significant benefits for the UK economy. Yet what is the best mechanism to do this? The subject was discussed at a meeting of the Foundation for Science and Technology on 6 March 2013.

Accessing the results of research

Janet Finch

The term 'open access' can be very confusing. Often, it is used to express the general concept of expanded access to publications by various means. Sometimes, though, it used to denote one particular method of expanding access, the so-called 'Gold open access' system based on author payments.

The Working Group on Expanding Access to Published Research Findings was asked to investigate how to make the peer-reviewed, published outcomes of research more accessible, inside and – particularly – outside the research community. The challenge was to identify ways of increasing accessibility immediately upon publication, making it free at the point of use and ensuring the ability to reuse the material. Among the many potential pitfalls to be avoided were: damage to the high standards of the peer-review process, harm to the quality of UK research, or negative impacts on the publishing industry (in which we included both the commercial publishing community and Learned Societies in their role as publishers).

Internationally, UK research really punches above its weight on any criteria that you might wish to specify. It is an extremely important contributor, globally, to research and nobody would want to compromise that. However, this country is also a relatively small contributor: about 6 per cent of published research internationally has UK authors, so around 94 per cent does not! That fact had to be taken into account in any recommendations.

So just how is the publishing landscape developing? British Library research suggests that by 2020 almost all UK journals will be published digitally (either solely in digital format, or with parallel digital and print editions). In fact, we are quite close to that now. Currently, there are about two million research articles published globally every year and that figure is growing at about 4 per cent a year. There are about 25,000 journals worldwide. Many are already using the Gold open access framework. Of the rest, many are 'hybrids' where an open access route is permitted via a subscription-based journal.

Professor Dame Janet Finch DBE DL AcSS was Chair of the Working Group on Expanding Access to Published Research Findings. She joined the University of Manchester in summer 2010 as Honorary Professor of Sociology. Since 1995 she had been Vice-Chancellor of Keele University. Professor Finch was named as one of the Founder Academicians of Learned Societies for the Social Sciences in 1999. She was made Dame Commander of the British Empire in the 2008 Queen's Birthday Honours List, for services to Social Science and to Higher Education.

The remit for the Working Group specifically included a consideration of how to expand access beyond the research community in order to produce benefits to both the economy and quality of life. There are both practical and ethical dimensions. Morally, if taxpayers have funded research, they should have easy access to it.

In thinking about how to achieve a transformation, account had to be taken of the complex ecosystem of scholarly publishing, where parties inevitably have differing interests (Table 1).

Addressing the challenge

The working group was commissioned by the Department for Business, Innovation and Skills (BIS), but was to be independent of Government. It was composed of senior representatives from all the interested parties, nominated by representative bodies wherever these existed.

Right from the start, it was recognised that different parties would have divergent interests and these would not be easy to reconcile. So, essentially, the Group concentrated on searching for a solution that everybody could live with.

A formal set of success criteria was developed (Table 2). In broad terms this would entail more people getting quicker and better access to published outcomes of global (not just UK) research. This would have to be achieved in a way that was financially sustainable for the publishers and affordable for the funders. At the same time, any system would have to enable the UK to sustain the high quality of research publications as well as high quality services to researchers and to authors.

Recommendations

Achieving such an outcome does not mean an immediate switch to Gold open access. However, we did conclude that change is inevitable. Even if we were to do nothing, change will still happen fast. We thought it best to recognise this fact, embrace change and manage it.

No single route forward is likely to work on its own. For the foreseeable future there will be a 'mixed economy' in

Table 1. Different parties have differing interests
• Universities want to maximise research performance, while controlling costs
• Researchers want to publish in the best journals
• Funders seek maximum impact, but controlled costs
• Libraries aim to maximise services to readers, while controlling costs
• Publishers need revenues to secure profitability and maintain high quality services/products

Table 2. What does success look like?
• More people, getting quicker and better access to published outcomes of global research
• Financial sustainability for publishers, including Learned Societies
• Affordable for funders, universities and libraries
• Sustaining high quality research, and high quality services to researchers and authors

journal publishing: that should be accepted and managed. Policy direction, however, should be set towards a preference for so-called Gold open access.

Two very different business models will therefore co-exist: the traditional subscription model where the reader or a library buys the journal and the money flows back to the publisher at the end of the process. The Gold open access model reverses that process; costs are recovered at the beginning because they are paid by (or on behalf of) the author.

The open access model is the future. We expect to see a shift, gradually, as more and more publications follow that route. There will be quite a long transition period in which funders' requirements will be fulfilled either by Gold open access or by subscription journals with short embargoes.

As part of the package, there should be extended licences for subscription journals so that libraries have more journals available and we believe repositories should be used more extensively.

In the transition period, parties need to prepare. Funders have to accept that publication is a part of research costs and they must pay those costs in an appropriate way. Each university has to establish publication funds through which author payments are made (not via individual transactions between the author and the funder).

The model which we recommend does have increased costs during the transition, particularly if international change lags behind, as there will be a period when UK readers are paying subscriptions and also author payment charges. So change needs to be introduced gradually so as not to destabilise the system.

Developments

In response to the report, there have been a number of policy developments, with the Government accepting the recommendations. Academics have been very active and Parliament has also been looking at the issue. Internationally, the European Commission has introduced requirements in time for its next round of major funding (due in 2020) while also recommending member states to develop their own policies on open access.

In the USA, after a hiatus due to the presidential election, the White House and the Office for Science and Technology Policy have announced that federal agencies will need to develop policies on expanding access.

Although we recommended a route that does support and facilitate Gold open access based on author payments (and in that we are actually leading internationally), we did not see this as replacing the subscription route in the foreseeable future and, therefore, we produced a balanced package of recommendations designed to get the best out of the mixed economy for all parties.

Our recommendations acknowledge that a process of change is already underway. We think the parties should be actively engaged with that process and work together to create a stable environment for this change. □

Accessibility, sustainability, excellence: how to expand access to research publications. www.researchinfonet.org/wp-content/uploads/2012/06/Finch-Group-report-FINAL-VERSION.pdf

Achieving open access

Douglas Kell

Clearly, in terms of achieving accessibility to publicly-funded research, there has been a market failure with traditional subscription-funded publishing. Imagine a reverse process in which free, open access was the norm. Then it was proposed to put all these publicly-funded activities behind a paywall. The reaction would be one of outrage!

Studies show that there is an open-access citation advantage for researchers. This varies widely across disciplines and countries, but it can be substantial. The number of peer-reviewed biomedical papers published by PubMed is two per minute, one million per year. The whole of the peer-reviewed literature comes to five per minute. No individual can read this, but computers can. Let computers read them and individuals then access the science that is made available by this means. That is the key advantage of open access from my perspective.

There are many open access schemes around the world. Many countries have been doing it for quite some time. The National Institutes of Health in the USA are already spending about £100 million a year on open access publication and the National Science Foundation about £25 million.

A mixed economy

In the UK, 'Gold' open access is the only realistic model for a sustainable ecosystem, but nevertheless there are also benefits to the 'Green' approach in a mixed economy. If a publisher chooses not to offer a Gold option, then Green

Professor Douglas Kell FSB FLSW FAAAS was Chief Executive of the Biotechnology and Biological Sciences Research Council. Before joining BBSRC, he was Director of the Manchester Centre for Integrative Systems Biology. He has been a pioneer in a variety of areas of computational biology and experimental metabolomics, including in the use of evolutionary, closed-loop methods for optimisation. He also contributed to the discovery of the first bacterial cytokine which is presently on trial as part of a vaccine against tuberculosis.

DISCUSSION

The current system is not sustainable

Changes in technology (digitisation and the internet), changes in social attitudes and the Government's transparency agenda all make the present system for publishing research papers unsustainable. Moreover the nature of the system, with its current restrictions on access and usage, is denying the economy, researchers - and society more widely - the opportunity to derive the maximum benefits from the extensive high quality research carried out in this country.

open access (with an initial embargo for up to six months for STEM subjects and 12 months for arts and humanities) offers a workable alternative. In the event that money from the Research Councils and others for a Gold option were to run out, then a longer embargo period might be permissible. Anything much beyond two years of delayed access, though, is not within the spirit of open access.

Compliance with the new system will not be instantaneous and, indeed, a very rapid transition would likely destabilise the ecosystem. In reality, most journals of interest have already made the move and Gold open access is widespread. Interestingly, the Gold journals do not see Green as something antithetical; they find it complementary, with both systems assisting dissemination.

The Research Councils (RCUK) have produced a simple decision tree which allows one to work out the optimal way through these thickets (Figure 1). If the research has been publically-funded and there is a Gold open access option available, it should be taken. If not, then go Green with an embargo of six months. If the funds are available from research funders, then immediate Gold access is mandated, whereas if they are not then it is accepted there should be a delay, initially of 12-24 months, depending upon the subject.

Open access has already been around for a long time. The implementation process for RCUK is a journey, not an event. It is recognised, because the ecosystem is complex and uncertain, that a full evidence-based review should be done and this will be completed towards the end of 2014.

Part of the process

Funders recognise that the cost of dissemination is as much a part of the cost of the research process as is buying a pipette or a mass-spectrometer. About 1-1.5 per cent of the cost of carrying out the research is involved in dissemination. The Research Councils spent £11 billion between 2011 and 2014-15, so one per cent of that comes to around £100 million.

The Research Councils have collectively agreed to pay block grants to institutions (it would have been too messy to tie the funds too closely to individual grants). While allowing some flexibility about how the money is spent, RCUK does expect that a good fraction of it would be allocated to paying article-processing charges and assisting the immediate availability of the research.

To avoid unnecessary duplication and 're-inventing the wheel', the Research Councils are working with the Research Information Network (RIN) and Higher Education Institutes (HEIs) to develop the best and easiest way to set up various kinds of repositories and article processing activities within institutions.

If an article processing charge has been paid, then the material should become completely available in an unfettered manner, including for commercial re-use with attribution. This is referred to as 'CC BY' in the Creative Commons licensing system. The CC BY licence includes features that avoid plagiarism and misuse. It is, however, the simplest method of allowing re-use.

It should be borne in mind that the 'CC BY licence with attribution' does not affect third party rights; if something is published that included a licence for someone else's material, CC BY does not nullify the original licence: authors cannot waive any third party rights through this. In fact, in papers that acknowledge Research Council funding, a statement is required on how to access the underlying materials. This helps the transparency of the scientific process, which of course benefits science itself because it should be easy to reproduce the results.

Research benefits

What are the benefits to research from all this? A biologist can go to PubMed and read all of the abstracts there. But that is not good enough. Typically, only about 8 per cent of the scientific claims made in the body of a full paper actually appear in its abstract. So, through reading just the abstracts, a researcher could miss 92 per cent of the findings (I am a numerical biologist and I know that nobody ever puts numbers into the abstracts). The situation is clearly not at all satisfactory.

Open access facilitates modern, text-mining methods that allow computers to 'read' those two papers a minute being published in bio-medicine and the five papers a minute being published elsewhere.

There are three steps to text-mining: the first is retrieving the information and that, of course, requires open access. Second is to use computer methods in order to extract the facts from the material. Finally, the data mining phase employs genuine semantic techniques so that the computer actually 'understands', say, that glucose is not just a string

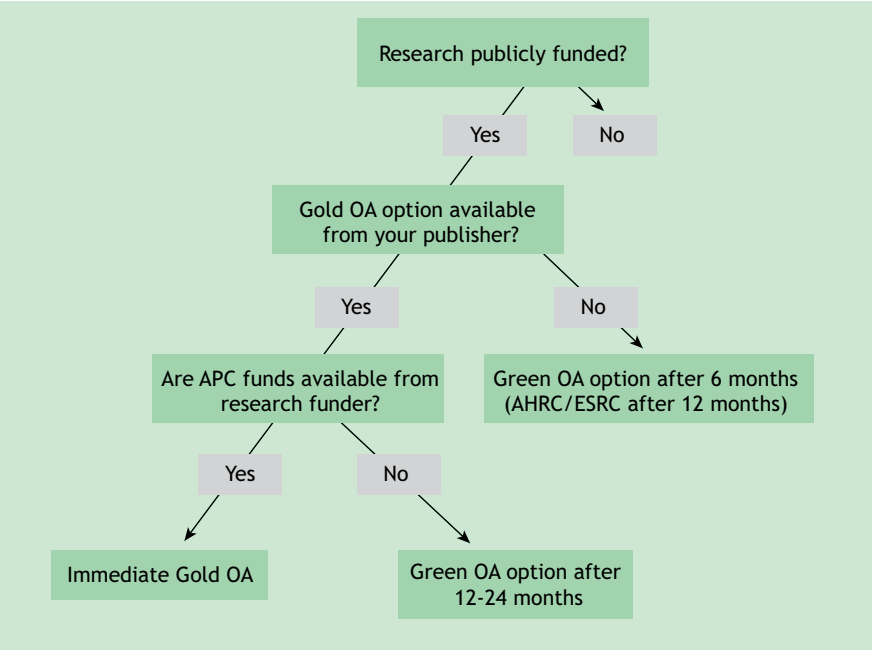


Figure 1. The RCUK Decision Tree

of seven letters but has a lot of other information attached: it is a sugar, it is a substrate for an enzyme and so forth. The National Centre for Text Mining in Manchester and many other similar bodies have tools that are starting to do this. Unfortunately, at the moment they can work only on the abstracts as they do not have access to most of the full papers.

There is another benefit. When I was researching the role of iron in human disease I accumulated many of the relevant papers. Even towards the end of this process I was finding reviews in major *Nature* family review journals that had not been cited by any of the others I was reading and which in turn did not cite them. The literature is often completely siloed for a number of identifiable reasons. Open access can tackle that problem too.

The Research Councils are putting resources and effort into implementing the Working Group's recommendations. We are keen on the CC BY licence and Gold open access because they allow better use of research results, which both funders and academics want. Crucially, these changes should not be seen as a threat, but as an opportunity. ☐

Making open access work for the benefit of all

Steven Hall

IOP Publishing (IOPP) was an open access publisher long before the term came into common use, launching the open-access journal *NJP* with the German Physical Society in 1998. Some 15 per cent of the papers published in our owned or co-owned journals in 2012 were open access and for a physics publisher, as opposed to a biomedical publisher, that is a significant proportion.

IOPP also offers a Gold open access on all its own subscription journals and a good number of those it publishes on behalf of partners. Under this 'hybrid' model, individual papers are published on an open access basis within subscription-based journals. Since last October, the Creative Commons CC BY licence has been our standard for open access publishing, so we are fully compliant with the Research Councils' Gold open access policy. We fully offset hybrid publication fees against subscription prices.

IOPP also permits authors to deposit their accepted manuscripts in an institutional or subject repository, usually after an embargo period of 12 months, thus supporting Green open access.

Benefits of Gold open access

There is a very powerful argument for Gold open access, in that it provides immediate universal access to the version of record with broad rights of re-use, although the benefits are perhaps sometimes overstated. There is already a very good level of access to the literature, particularly in higher education and in the corporate sector, and in those other sectors where access is less good, there are other ways to improve it rather than simply a wholesale move to the gold model.

Steven Hall is Managing Director of IOP Publishing. Having started out at Macmillan Press, Steven went on to Chadwyck-Healey as Sales and Marketing Director and then Managing Director. Following ProQuest's acquisition of Chadwyck-Healey, he was appointed Senior Vice-President, Publishing and Publisher Relations of ProQuest. He moved on in 2004 to become Journal Sales and Marketing Director for Blackwell Publishing and later Commercial Director for Wiley-Blackwell. Steven then ran his own scholarly publishing consultancy from 2008 to 2010, before joining IOP Publishing

Likewise, great benefits are claimed for the use of CC BY but these may also be overstated. It can certainly facilitate text- and data-mining but CC BY alone cannot solve the entire problem. That will require investments in infrastructure of the kind the cross-industry body CrossRef is working on, which will also enable easier text-mining of subscription and open access journals.

Some argue that research achieves more citations under an open access publishing model; frankly, there is as much evidence against as for it. It is also suggested that there are enormous opportunities for commercial re-use of open access content. There have not been many examples so far, despite the hundreds of thousands of papers available in PubMed Central.

Nonetheless, while recognising that expanding access will require a mix of solutions, the publishers that participated in the Finch Group – and I was one of them – took the view that if funders want open access publication and are willing to bear its costs, then we will wholeheartedly support that approach.

The recommendations

The first recommendation of the Finch Report is for a clear policy direction towards Gold open access. The second is that funders put in place more effective means of funding Gold. Government accepted the recommendations but provided no additional funding to support them. It has spoken of the massive economic benefits that will accrue to the UK from open access publication, but if it really believed that, why not spend the £50 million necessary to achieve those benefits? Instead, the costs are to be borne entirely by the current research budgets. That has caused some friction between the various stakeholders since the policy was published in July last year.

The recommendation that would have brought the largest single benefit to the UK in the short to medium term was that licences for access to journals in Higher Education and the health sector should be extended. For a total cost of about £10 million a year, the smallest or poorest university or hospital would have the same access to the global scholarly literature – not just the UK's share of it – that the largest or richest has. Government supported this in principle

DISCUSSION

Who is disadvantaged?

Two particular areas which may be especially disadvantaged by the new system are the Learned Societies and disciplines such as humanities and social sciences. There may also be unintended consequences during the transitional period as different stakeholders seek to safeguard their own positions in adjusting to the new policy environment. These may find they are either asked to pay APCs (which for bodies such as small medical charities might be more onerous than the present system) or to rely on funding which may prove to be inadequate.

but in the absence of additional funding the proposal has gone no further.

The report also supported the proposal from publishers to provide free on-site access to journals in every public library in the country. This was offered as an important component of the Finch 'balanced package': funding for Gold, and publisher support for it; no short embargoes in the absence of funding for Gold; and free access in public libraries.

The next recommendation was to find ways of extending access in sectors outside health and Higher Education, in particular for SMEs. Work continues on this.

The report noted that as long as the UK was ahead of the rest of the world in its adoption of gold open access, then costs to the UK would increase. While the principle of this is understood, the practice, in the absence of additional funding from Government, is more difficult. Universities in particular are concerned that they will have to divert funds from research to publication costs and are unwilling to do so. There have been some demands for publishers to offset their publication fee income from UK universities against the subscription and licence fees they receive from them, but publishers have argued that as the proportion of open-access articles in their journals grows, they will have to reduce subscription prices globally and not just locally. Creativity and compromise will be required to address this difficult issue.

Green embargo periods

The most contentious recommendation concerns the length of embargo periods for Green open access where there is no funding for Gold. The Finch report argued it would be unreasonable to require embargo periods of less than 12 months. Government policy, published a month later, fully reflected that position.

Since RCUK published its policy in July 2012, there have been difficult discussions over the exact meaning of that policy in relation to embargo periods. There is considerable ambiguity and the last thing we need as we go through the biggest transition in scholarly communications in the last 300 years is ambiguity; we need clarity.

In February 2013, Science Minister David Willetts was quoted as saying: "Green with a six-month embargo is not a sustainable option … someone has to pay for academic publishing."

Most publishers now offer a hybrid Gold open-access option on their subscription journals, along with the CC BY licence where it is required by funders.

RCUK has responded with the statement that "this is a journey and not an event". It is critical here that policy reflects the point we are at on that journey, rather than a destination that may not be reached for some considerable time. If and when there is full funding for Gold open access, then short embargoes where Gold open access is not offered by a journal may be acceptable; until then, the Finch recommendation and Government policy say that longer embargoes of at least 12 months apply.

The Higher Education Funding Council for England has also been consulting extensively with other stakeholders on a potential draft open-access policy. HEFCE expresses no preference in principle between Gold and Green, but essentially theirs is a Green policy. As it makes no additional funding available for Gold, and universities are unwilling to use QR funds to pay for article processing charges (APCs), the direction is essentially set towards Green.

Going forward

Publishers are ready to implement Government policy and any funder policies that are aligned with it. Most publishers now offer a hybrid Gold open-access option on their subscription journals, along with the CC BY licence where it is required by funders.

Most permit deposit in repositories of the accepted manuscript after a 12- or 24-month embargo, depending on the discipline. Authors have a very wide choice of journals in which they can publish in compliance with funders' open access policies. The two-year pilot to provide free onsite access in public libraries to a large number of scholarly journals is also on schedule to launch before the end of the year. In general, publishers are doing what they agreed to do under the Finch balanced package.

Assuming that outstanding issues around Green embargo lengths are resolved, the biggest remaining challenge to a successful implementation of Government open access policy may well lie with the research community itself. As a conference at the Royal Society in February showed, many researchers are unaware of, or are apathetic towards, the development of open-access policies, while some are hostile to any suggestion of being told where or how to publish. There is a strong need for both education and advocacy, and these need to be undertaken jointly by funders, universities and publishers. ☐

DISCUSSION

The wider context

It may not be in the national interest for the UK to move faster than its main international competitors towards full open access. UK published research is relatively small in terms of the quantity of papers published (but not in quality) with only 6 per cent of the global total. Therefore UK researchers will not be gaining benefits of access to international research material to the same degree as their foreign competitors. This wider access will be at the expense of the UK research effort with no new money being provided to research funders who will be required to support the new arrangements out of existing resources.

Should research and publicly-acquired data be made more accessible, and if so, how? The question was debated at a meeting of the Foundation for Science and Technology on 10 July 2013.

Ensuring access to the data behind the paper

Geoffrey Boulton

Henry Oldenburg was the first secretary of the Royal Society. A German theologian and inveterate correspondent with people now called 'scientists' in Britain, Europe and beyond, he persuaded the Royal Society to publish his correspondence. He required two things from his correspondents: that they write in the vernacular, not Latin, and – crucially – if they were to pose any concepts then these must be associated with the evidence (or data) upon which they were based.

This allowed others the opportunity to make similar observations, examine the evidence and explore the logic of the argument. It has been argued that this concurrent publication of both concept and evidence in open and accessible ways was one of the key building blocks enabling the scientific revolutions of the 18th and 19th centuries.

Openness is one of the most fundamental aspects of peer review. Pre-publication peer review is important, but what happens after publication is the absolutely crucial stage. Oldenburg underlined why this mattered.

Recently, a group of American researchers took the top 50 benchmark papers in pre-clinical oncology and attempted to replicate the results. They were only able to do so in 11 per cent of the cases, a conclusion they duly reported in *Nature*[1]. In the other 89 per cent, data were not provided or were inadequate, or else the metadata – data about data – were inadequate. Oldenburg's principle, that concept and data must be concurrently published, was not followed.

There is also a problem with the way we treat the data. In the traditional view of science, an hypothesis is created, then an experiment devised to explore whether that hypothesis works. Today, with a sufficiently complex database, there may be patterns which appear to replicate those generated by the hypothesis. But that is flawed logic. The fundamental question is 'What are the intrinsic patterns in the data?' rather than 'Is there something that will fit my theory?'

Professor Geoffrey Boulton OBE FRS FRSE chaired The Royal Society's inquiry into Science as an Open Enterprise. He is Former General Secretary of the Royal Society of Edinburgh, Regius Professor Emeritus and former Vice Principal of the University of Edinburgh. He was a member of the Prime Minister's Council for Science and Technology, the UK's top-level science and technology advisory body. Professor Boulton's research interests are in the fields of glaciology, Quaternary science and energy.

Informatics-trained, competent data scientists are needed in this new data-driven world. Many of us who pursue specific disciplinary objectives do not have the computational or statistical skills to treat the data in logically valid and appropriate ways.

Sharing data

If data is to be shared on a much bigger scale then scientists have to be convinced that it is in their interests to do so. In some areas of science this is happening. The bioinformatics community has begun to discover ways to collaborate which would be unfamiliar to most of us. In Europe, there are systems to exploit the vast data volumes that a large and complex community can create. One of the advantages of course is that bioinformatics is a relatively new science unburdened by the assumptions of more traditional disciplines.

Some of the benefits of doing things this way have been recently illustrated. Only two years ago there was an outbreak of a gastro-intestinal infection which had considerable capacity both to spread and infect. There was an extraordinary mobilisation of over 20 laboratories on four continents which shared data and were able to give public health authorities internationally the sort of knowledge they needed to create sensible strategies.

Sharing is facilitated by instantaneous access to the internet. Four years ago Tim Gowers, a Fields Medallist mathematician, put on his blog an idea for the solution of a long-standing mathematical problem. More than 25 people responded, suggesting different ways to approach the problem. These were either rapidly developed or quickly discarded and after about 30 days Tim concluded that they had solved not only the specific problem but also a much more difficult generalisation of it. His comment was that it was "like driving a car while normal researchers prefer pushing one".

Why not do this more frequently? Well, very simply, the criterion for credit and promotion is ideally a single-author paper which is referred to on the front page of *Nature*. That inhibits this sort of collaboration. So, we need to think fundamentally about better ways of giving credit to scientists and of stimulating science.

Of course there is a changing social context. There are now many citizens who are not prepared simply to listen to the opinions of scientists; they want the evidence that underpins conclusions which have implications for the lives of individuals and society.

Through the so-called 'citizen science' movement, the old division between the professional and the amateur can be over-ridden. There are interesting collaborations taking place in many areas of science and amateur scientists without a formal scientific education are

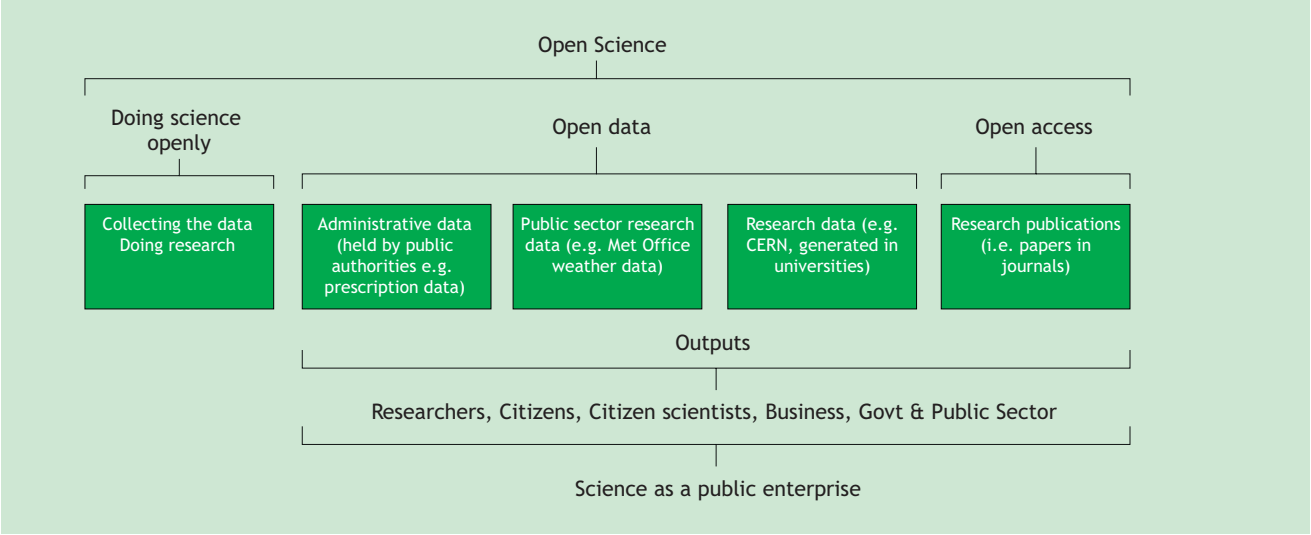


Figure 1. A taxonomy of openness.

becoming involved. Who knows what might happen in the longer term to the social dynamic of science?

The validity of data

One of the other important issues which relates to the release of data is reflected by a headline from a *Guardian* blog: 'Scientific fraud is rife. Science is broken'. There are far too many cases of data invented to support particular concepts. The crucial, default response should be to make data open so that it can be scrutinised. Hopefully, fraudulent data will be deterred on the one hand and more susceptible to discovery on the other. The non-publication of evidence for a published claim ought to be regarded as malpractice.

There will be cases where the researcher is not aware of cherry-picking the data, so all the data should be made public. Partial or biased reporting can be serious; it disrupts the connection between cause and effect. There are cogent arguments that the area of clinical trials needs reform in relation to biased reporting.

Openness *per se* has no value; what is required is 'intelligent openness'. The data and the methods have to be accessible. Data has to be intelligible, assessable (does the researcher have, for example, any financial interest in the particular outcome) and reusable. Only when those criteria are fulfilled are data properly open. These ought to be the criteria used by funding councils and others for evaluating openness.

Of course there are boundaries. There will be exceptions for commercial interests, but it is also important to recognise that there are great sectoral variations – the business models in some areas favour open data, in others not. Privacy is most important and the impossibility of the complete anonymisation of anything (other than relatively trivial datasets) implies that we must have an understanding of 'safe' data. This would cover the ways in which a dataset could be used by *bona fide* researchers without making it susceptible to misuse by those with malign intent.

Safety, security, dual-use – the boundaries between these concepts are fuzzy. Ask a lawyer to sit down and write a document which would define them and the result would probably be a 1000-page tome.

So where do the responsibilities lie? First of all, scientists have to accept that the data acquired as a consequence of public funding is not 'their' data, rather they are its custodians on behalf of the public. Funders of research need to mandate intelligent openness and, equally, publishers (who are the ultimate 'gatekeepers') need to move to a position where the publication of the data is a necessary prerequisite for publication of the concept.

There have been a number of recent important initiatives. Internationally, the G8 has published a statement outlining key principles for open data, and a new collaboration called the Research Data Alliance has been created by the UK, USA, Australia and a number of other research-intensive countries. If a new framework is to be realised, it has to be implemented through the involvement of those people that actually understand the necessary mechanisms. The European Horizon 2020 programme has accepted open data as a key principle for the work that it will fund and other European bodies are now engaged. In the UK, a number of bodies have been discussing these issues and the Minister for Science has created the Research Data Transparency Board. The Royal Society has decided to create a Science Data Forum involving those bodies that will be essential players in a UK open data regime, with the intention of identifying and circumventing barriers to its implementation.

'Open science'

Figure 1 attempts to describe the elements comprising the concept often referred to as 'open science'. On the left is 'scientific enterprise' – collecting the data, carrying out the research. In terms of open data there are really three categories: research data; administrative data which is held by

DISCUSSION

Informatics and statistics

There are costs associated with allowing access to any open dataset. If these need regular updating, that could increases the costs considerably. Having a great deal of data available also makes more demands on informatics and on statistics. There is a shortage of academic statisticians; many newly qualified statisticians go into business, especially the financial sector, and not research. A wider breadth of computer skills may also be needed to handle very large datasets. This is a challenge for those in newer branches of science such as informatics. Librarians too may need to improve their statistical skills.

Government; and public sector research data produced by bodies such as the Met Office. On the right hand side is the category of open access publication and access to the outputs of research.

The Royal Society's recent report was published as *Science as an Open Enterprise*[2], but the original working title was *Science as a Public Enterprise.* An example of a rapidly realisable aspiration that would enhance the work of science and its public interface would be to put all the scientific literature online, all the data openly online and for the two to interoperate. We should apply the appropriate pressures and mobilise the creativity of the scientific community and others in doing so. □

1. *Nature*, Vol 483, 29 March 2012.
2. http://royalsociety.org/policy/projects/science-public-enterprise/report

The power of 'open' - the fifth paradigm

Nigel Shadbolt

There was no accurate map of Port au Prince before the hurricane struck in 2010. The country was too poor to have a fully-mapped survey of the capital, but that makes it very difficult to run a crisis operation. The cry went out and a large number of people came together to address the problem. Using open-source software, open standards and open licences, satellites were re-focussed and a software system called 'open street maps' was used to crowd-source maps of a city. As they arrived in the city, people walked the devastated streets with GPS loggers, laptops, phones and they began to load, in real time, a common construct – a new and comprehensive map. When something like that happens, it really gives a sense of the power of the 'open' initiative.

The power of 'open' is not really new. There is remarkable parliamentary testimony from Florence Nightingale about her work on death in the Crimean War. Her dramatic 'infographic' of the principal causes of death changed the public understanding of what had to be done. She demonstrated that most people were dying of neglect and infection, not on the battlefield. Snow's work on the Cholera outbreak is well-known, but its power lay in making information available for people to scrutinise, use and interpret.

People do not always realise that the ability they have to move around and interact with the modern world, due to Berners-Lee's Protocol for the World Wide Web, is still fundamentally a distillation of the power of open standards.

Crucially, this dynamic is not just about data, but also licensing and the appropriate conditions under which material can be used. It concerns standards, the agreements between parties about representing their information and their processes in particular ways. It is about open participation and sometimes about open source software. Overall, it is something I refer to as the fifth paradigm: open innovation.

Professor Sir Nigel Shadbolt FREng is Chairman and Co-Founder of The Open Data Institute. Sir Nigel is also Professor of Artificial Intelligence and Head of the Web and Internet Science Group, Electronics and Computer Science, University of Southampton. He was one of the originators of the interdisciplinary field of Web Science. In April 2011 he became Chair of the UK Government's Midata programme - whose goal is to empower consumers by releasing their data back to them.

A key element of this is open data, which is information that is available for anyone to use for any purpose, at no cost. Open data really comes to life when it is intelligent open data, which is accessible, intelligible and useable.

The postcode

In 2009, Tim Berners-Lee and I were appointed by the then Prime Minister to open up non-personal and public sector data. *The Guardian* helped us produce a 'postcode paper' with all the useful information that the public sector held about each postcode: what the crime rates were, where the bus stops were, when the buses ran, where the recycling points were, how well the school was doing – all the things that we know are captured by the public sector.

Ironically, the postcodes themselves had to be paid for – they were not open either! We took the postcode paper to the Cabinet at the time who said: "This is excellent, what next?" We pointed out that 85 per cent of the data in the paper had been 'illegally' reproduced. This was the scale of the challenge to Government – to release that data as open data.

So the entire approach over the last four years has been to persuade increasing numbers of Government Departments and civil servants (and indeed governments around the world) that this is a worthwhile approach. In just 12 weeks we had a site hosting our first datasets – it was open source software and was running as a 'perpetual beta' (i.e. not finished software but continuously in development). In 24 months, we had about six thousand datasets and the point of entry was the postcode – a freely-available postcode by then!

A new Government committed itself to an open data agenda, meaning it was suddenly possible to find out how money was being spent in the name of the taxpayer, how the schools were doing, what the infection rate in local hospitals was: in fact a whole slew of information.

DISCUSSION

Explaining statistics

Statistical methods such as multiple regression can give very good answers overall, but may be rather unreliable at the edges where there are small numbers of cases. While a statistician can recognise that standard errors in some areas are much larger than in others, it can be difficult to explain such detail to the general public and in particular to journalists. But large data sets might be able to show that what had been taken as an apparently significant result based on a rather small sample, did not apply more generally.

Most recently we have witnessed the G8 Open Data Charter. There are concrete and specific commitments to build national and international information infrastructures. Essential infrastructure for countries (indeed, for the world) includes: mapping and addressing; transport; education; health; environment; and science. These are the key datasets which allow everyone in society – scientists, engineers, people going about their normal business, trying to conduct business – to effect more efficient transactions, creating and realising value.

Knowing where the bus stops are, the death rates in local hospitals or the weather (detailed forecasts for which can now be downloaded as actual data) – all this has made a material difference. The power of the results, I think, is the reason why people are talking about open data. There are benefits politically in transparency and accountability. There are also social benefits through a better understanding of poverty, diversity and inclusion/exclusion.

The data itself is being improved. The Government had a list of all the bus stops: it just happened that 17,000 of them were not where they were thought to be! In fact, that was only a 6 per cent error rate in the database – and there are many database engineers who would die for that level of precision!

By releasing data, it can be scrutinised – many eyes can offer a very fast form of debugging and error-finding. Interestingly, the argument which has seized attention recently is whether or not there is economic value to be extracted from these data releases.

A change in approach

One of the over-arching principles (and it may seem an abstract one) is that data-release results in a change in governance, because of increased accountability in the most general sense. This is one of the most striking features of science as an open enterprise, I think: instilling scrutiny and oversight into whatever one is doing.

At the Open Data Institute in London, work is taking place with a number of start-ups in an attempt to find the value in open data. One of these small businesses took the open data that GPs in NHS England now produce every month: all the prescriptions they write out – not to whom, but what the drug was. An analysis of a year's worth of prescriptions for statins (typically for blood pressure conditions) found that if the GPs had been prescribing the generic version they could have saved £200 million.

In a data-driven world there are challenges about collecting it, harvesting and maintaining it, depositing it, and so on. Science has to confront this, but so does the public sector and the National Archive – what slices of a nation's activity should be preserved, and for what reasons?

There are other challenges around quality: everyone knows data are often far from perfect. But if it needs improving, what does Open Data 2.0 look like? In open data we have only reached the equivalent of Web 1.

There was the example with the bus stop data where 17,000 locations were missing. A crowd source site was put together within a month with people actually putting in the accurate whereabouts; but the challenge for the Department of Transport is to validate that and internalise it as an actual useable public product.

Data literacy is another important issue. Understanding information and data is going to be so fundamental to everyone's decision-making and daily life. A balance must be found between security and privacy, though. There are many examples: work on whether avian flu could leap species barriers might be useful to terrorists as well as public health authorities. Then again, accurately reporting ships' positions in real-time is a boon for the shipping insurance business but also for Somali pirates. If the default position is to publish public data, then there has to be an understanding of the boundaries and where exceptions might lie.

Then there is the potential problem of incumbency. It is often a problem, when trying to obtain access to complex datasets, to persuade the people who have them that this is not a threat to their professional integrity but actually a huge opportunity to make everyone appreciate the challenges professional statisticians live with on a day-to-day basis.

There is a real challenge in helping parts of Government to understand there might be a wider external value to data than just the value of selling it.

Paradigms

Science often talks about the first paradigm as the embrace of the empirical and experimental method. The second paradigm is the attempt to formulate coherent, self-contained theories that embrace the data and information. The third, of course, was the arrival of large-scale algorithmic processing, or the ability to simulate *in silico* various aspects of science and engineering. That was a significant shift, not so many years ago.

The fourth paradigm, described by Jim Gray and Tony Hey, is the recognition that we are living in a deeply data-intensive world and that really very substantial data analytics are needed to make sense of it.

The real prize, I believe, is a fifth paradigm which takes the power of information and data released at scale and puts it in the hands of everyone. Open innovation happens when everybody can participate in this process.

I will end with the story of Jack Andraka, a 15 year old from Maryland, who has produced a paper-based sensor that can detect (within five minutes and at a cost of about 3 cents) pancreatic, lung and ovarian cancer. This is an extraordinary achievement. He did it by literally wading through thousands and thousands of papers, factoring out what the relevant proteins might be. He then went through a process of reconceptualising how you might use a technology of nanotubes, paper-based substrates, to find an antibody that binds the particular protein indicator. He then designed a realisable sensor.

He is rightly celebrated as an example of somebody who has produced genuinely disruptive innovation in a field by having access to the information. His invitation to all of us is to say: "Why can't we all do this?" □

1. ***The Pinch: How the Baby Boomers Took Their Children's Future – And Why They Should Give It Back*** **(2010) Atlantic Books**
2. **See: www.rcuk.ac.uk/media/news/2013news/Pages/130408.aspx**
3. **The Gateway to Research can be accessed at: http://gtr.rcuk.ac.uk/research**

DISCUSSION

Private and shared data

Private companies may have data which they are not prepared to share. While there may be good commercial reasons for such an attitude, there may also be public benefit in aggregated data being made more widely available. Although general insurance companies are very protective of their data, Lloyd's for example has organised the collection of data on catastrophes which may affect the whole market. Sometimes, then sharing of data may help the private sector work successfully towards a common goal.

Open access, open data and citizen science

David Willetts

There are several different aspects to the question of making best use of data. One concerns the sharing of research findings and the framework for open access to publically-funded research. Underlying that are issues surrounding the data upon which the research findings rest. Then too, there is the role of the public in helping to secure the data in the first place; 'citizen science' exemplified by Galaxy Zoo. The first two are areas of direct public policy and I want to focus on these.

With regard to research findings, the principle is very simple – the public has a right of access to publicly-funded and published research. One of the frustrations I had when writing my book[1], as a layman outside the academic community, lay in trying to track down information and finding out it was behind a paywall! Now my book is, in a sense, behind a paywall but the difference is that constraining access to research carried out by one of the Research Councils, which has been financed out of general taxation, is both unreasonable and unacceptable.

There is now an agreement between the research community and publishers on a way forward, captured in the famous 'decision tree', about circumstances in which researchers may opt for the use of either Gold or Green open access. This 'decision tree' was prepared by publishers in consultation with Government and funders and is now embedded in the Research Councils' published Guidelines[2].

Overall research costs could explicitly include the cost of communicating the findings – that results in the Gold form of open access and payment of an Article Publication Charge (APC) to the publisher to cover the cost of publication. Users then have nothing further to pay but enjoy full access and reuse of the published material.

Then there is Green, in which publishers are able to cover their publication costs through subscription charges that they collect for a set time or 'embargo period' by keeping the published work behind a paywall, but after that embargo time it is openly accessible. Additionally, negotiations are underway on a national licence for walk-in UK public library free-access to publishers' global material.

The Rt Hon David Willetts MP is Minister for Universities and Science at the Department for Business, Innovation and Skills (BIS) and MP for Havant. He has responsibility for all innovation, higher education, science and research policy. He leads on the Quality Research funding of universities, the Research Councils, the Technology Strategy Board, and other science and engineering bodies that report into BIS. He also has ministerial responsibility for space policy, the UK Space Agency and the Office for Life Sciences.

My concern is that some people – and potentially some institutions within the EU – believe that Green rules can be mandated with short embargo periods (six months for STEM and 12 months for Arts, Humanities and Social Sciences) even when there is no mechanism to pay for Gold open access. This is not a sustainable solution.

Publishing does, in general, add value to the research process and it is not clear how academic publishing can remain a viable enterprise with Green if at the same time we try to make embargo periods as short as possible.

Gold open access reduces embargo periods to zero. But if they are too short in Green, without any opportunity to pay APCs for Gold, then publishers and Learned Societies will fail to recover costs.

It is for this reason that the UK has a preference for Gold and has made funding available to pay APCs. Where that funding does not exist, or has run out, then our policy allows for longer embargo periods under Green (12 months STEM and 24 months AHSS).

Where publishers decline to make the Gold option available, then funders and researchers would be right to insist on the shorter (6/12 month) embargo periods. The exception to this general rule is that the UK maintains there is a need to access life sciences research at the earliest opportunity. Hence, an embargo period of only six months applies to life sciences under all circumstances. The UK believes it has got the balance of these various considerations right and will continue to convey these views in discussions with the EU as the Community refines its position on open access.

It is intriguing how internal tensions within universities are revealed by a policy like this. Some researchers tell me that they fear universities will not pay the processing charges incurred under Gold. This hardly seems to be a good way of motivating keen young researchers! The fact that some people have these anxieties suggests there may be a disconnect between the academic community and university management in some places. Some universities argue that the total cost of Gold to them could be excessive and so they are pointing their researchers to the Green route, contrary to what the 'decision tree' sets out. We expect these various tensions to be resolved as the merits of the policy become clear.

To improve further access to publicly-funded research and also, as importantly, the people behind it, work is underway in the Research Councils on the 'Gateway to Research': this is a single, unified web portal which will allow people to access information about all of the Research Councils' publicly-funded research projects. The portal is being developed with the needs of SMEs in mind, the objective being to enable SMEs to draw on the considerable research resources in the UK science base and to be able to contact the researchers themselves.

Networking in this way, as evidenced by the Silicon Valley and Massachusetts Route 128 phenomena, is a critical ingredient for the successful translation of knowledge. The Gateway to Research is expected to be fully functional by the end of 2013. We are committed to doing

more on knowledge exchange. Research can change the world – it has an impact on the wider environment.

Open data

The question of open data is trickier and there are greater technical issues, although some are shared by the open access challenge. After all, if material is going to be made open access, it is very important that it be fully searchable, that people are able to use and analyse it easily. Now, that requires a good deal of technical work. It is vitally important that the data behind published research should itself be accessible.

I remember a meeting hosted at the Wellcome Trust and attended by the main funders of life sciences research from the major western countries. Around the table were the people who had funded cancer research studies of perhaps a million patients. Behind every research paper published, there was an analysis of patients with cancer carried out in a whole host of different ways.

The hope must surely be that, at some point in the future, this incredible assemblage of data should be available for analysis, using all the capabilities that we are developing for taking very large data sets and identifying new patterns and meanings in them. That is what we should be aiming at: that all the data funded by the different agencies in advanced western countries should be publicly available (with proper privacy and confidentiality protections of course).

This is the vision, even if the world still has a long way to go in order to realise it. How to get there is a complicated process and it starts with a paradox. One of the anxieties of the research community concerned the application of the Freedom Of Information (FOI) Act to research work. Could researchers be made to disclose their data (and perhaps lab notes) before they were in a position to order their data and publish their conclusions? Well, the Government has made a commitment to apply what is called the 'Scottish exemption' to the rest of the UK. This provides an exemption for researchers, within a reasonable period, who have gathered data but have not yet published it. I pay tribute here to the campaigning of Baroness O'Neill: she shifted the Government's thinking on this issue.

There is, of course, the potential for text- and data-mining in all this and it is important to have a legal framework in place to permit this. Draft legislation has been published on the website of the Intellectual Property Office (IPO) for consultation. An infrastructure is also needed to handle these very large datasets and that is why the UK is making substantial investments in high performance computing: not just the hardware, but the software, the modelling, the simulations, etc. This will build the capacity to handle very large datasets.

In the 2012 Autumn statement, £189 million was made available for 'Big Data' which I have described as being one of the 'Eight Great Technologies'. This 'Big Data' programme is being coordinated across the Research Councils by the Economic and Social Research Council (ESRC). Developments within it, such as the Administrative Data Research Network, are already moving underway. These projects will underpin work on a future UK Data Capability Strategy.

Another project within the 'Big Data' programme relates to the involvement of the Science & Technology Facilities Council (STFC) in the square kilometre array of radio telescopes that will collect the data from 3,000 dishes spread across the deserts of South Africa and Australia. A massive investment in high-performance computing is required to handle such very large datasets. I am told that the computers will need to be 1,000 times more powerful than today in order to handle the data flows emerging from the square kilometre array. These flows alone will be greater than the whole of the internet achieves today. However, we are confident that by the time the dishes have been built, Moore's Law will have worked its magic and the computing power will be available!

Privacy

Getting the privacy régime right is another challenge. There is a particularly lively debate concerning health data. People are entitled to confidentiality and anonymity, but are they entitled to opt-out entirely from any use of their data, from any medical research? Are people living near power lines entitled to opt-out and prevent medical data about their health being used in the analysis of potential effects? It would be a rather peculiar project if every individual living near a power line had to be consulted before their data was put into the research.

There are, therefore, instances when scientists believe they are entitled to use large datasets without individual consent. But how can those instances be defined? A separate issue is confidentiality around so-called DURC – dual use research of concern. There is a body of opinion in the USA, for example, that believes the publication of some biological research, such as on the H5N1 virus, is as naïve as publishing material on creating a nuclear reaction would have been in the 1940s. The Americans will consider the potential military implications of this research and immediately say it should be kept private. They have a far more restrictive regime than we do in the UK and think we are too open in some of areas, particularly life sciences.

On the basis that, in the world of the internet, containing the communication of any research information is likely to be too great a challenge, assuming it is in the public domain and allowing the research community to address the risks it presents may, paradoxically, be a more robust security solution.

Then there are questions about skills and capabilities. Are we really confident of being able to analyse all this 'big data' and make it accessible? I am not convinced that we have that capability yet. We are trying to address these challenges in a group that I chair called the Research Sector Transparency Board which is digging deep into the open data agenda, not just the open access question.

After the 'open access to research findings' and the 'access to the data behind it' challenges, there remains the citizen science agenda. This is, I think, one of the most exciting developments in science communication. It allows people to participate directly in the scientific process. I am very interested in hearing about ways in which the Government can support and encourage that. □

1. ***The Pinch: How the Baby Boomers Took Their Children's Future – And Why They Should Give It Back*** **(2010) Atlantic Books**
2. **See: www.rcuk.ac.uk/media/news/2013news/Pages/130408.aspx**
3. **The Gateway to Research can be accessed at: http://gtr.rcuk.ac.uk/research**

Summaries, presentations and audio from all the events organised by the Foundation for Science and Technology can be found on the website at: www.foundation.org.uk

An increasing proportion of the world's population lives in cities. How can science and innovation help to make the cities of the future places where people want to live and work? The question was discussed at a meeting of the Foundation on 19 June 2013.

Growth, innovation and city planning

Steve Quartermain

Some 74 per cent of the UK's population live in cities and 78 per cent of all UK jobs are located there. Cities and their hinterlands are drivers of growth in the economy. The Harvard economist Ed Glaeser, argues that "cities are our greatest invention"; they lower transport costs, help us share knowledge and spark innovation. Cities are the building blocks of the global economy and it is because urban form and function are so vital that planning is so crucial to economic success.

It is not just a case that bigger is better. Our leading cities recognise that quality of life – whether excellent public transport, access to jobs, to culture, to visually stunning built environments – is vital to attracting people to live and thrive in cities.

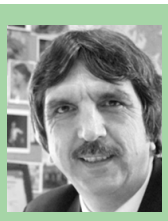
Driving economic growth

Governments can and must create the right conditions for growth and this challenge can be tackled strategically, striving for a sound economy with low interest rates with the right microeconomic conditions – competitive taxes, flexible labour laws and a skilled workforce.

Yet innovation and growth do not happen in the abstract: they happen in specific locations, so cities must be properly planned.

New enterprise and employment requires dynamic local leadership too, to drive economic growth on the ground. This means city leaders have to take decisive action to attract the private sector investment that is so critical to the future urban economy. They require the capacity and authority to articulate and drive forward an ambitious economic vision, building strong effective public-private partnerships and responding innovatively to challenges to growth.

The Government's ambition is to create powerful, innovative cities that are able to shape their own economic future, free from top-down controls. This is why it believes there needs to be a fundamental shift in the relationship between national Government and cities. It has endorsed an approach to effective planning which is set out for England in the National Planning Policy Framework (NPPF). Local councils should be working with businesses to deliver on a vision of growth and sustainable development in which the role of the city is crucial.



Steve Quartermain is Chief Planner at the Department for Communities and Local Government (CLG). He advises Ministers on planning policy and practice and is currently driving forward the planning reform and delivery agenda. He also advises Ministers on planning applications of major significance and political sensitivity. Steve acts as a champion of planning and, as Head of Profession, is the voice of planning in Government.

However, the importance of place can go beyond historic administrative boundaries. The Government has created Local Enterprise Partnerships (LEPs) to bring businesses and local authorities together, to give a stronger voice over practical economic areas: it is a strategy to give local partners a strong role in shaping and creating local environments. Our view is that this initiative is working well and showing signs of an effective local voice supporting and delivering growth.

As an example, take the Science Vale UK Enterprise Zone in Oxfordshire. It is one of the largest science clusters in the UK and ideally located to support growing industries in both London and Oxford. Split across two sites, Harwell South is just 20 minutes from Oxford and already has 150 organisations and 4,500 people in a vibrant community. Miller Park is home to 165 businesses employing 6,500 people and is strategically located next to the A34, close to Oxford, Newbury, Abingdon and Didcot, supporting development in all of them.

City Deals

The Minister for Cities, Greg Clark, works closely with individual cities and across Government Departments to agree a series of tailored City Deals. Each of these provides a chance for cities to negotiate agreements which give them the power and tools they need to deliver growth, to unlock projects and initiatives to boost the economy, as well as to strengthen their governance arrangements.

The first eight deals were concluded in July 2012 with the 'core' cities, that is Birmingham, Bristol, Leeds, Liverpool, Manchester, Newcastle, Nottingham and Sheffield. These and their surrounding areas are important hubs of economic activity. More than 6.5 million people work there, there are 37 universities and 680,000 students. The core city Local Enterprise Partnerships (LEPs) saw their populations rise by nearly one million people between 1999 and 2010 and 50 million people passed through their airports every year. There is a clear potential for further growth and the deals that have already been concluded will create 175,000 jobs over the next 20 years with 37,000 new apprenticeships. The Government is now taking forward a second wave of deals with other cities. The approach aligns strongly with the Heseltine Review which challenged the Whitehall-knows-best philosophy.

Many of the cities in the first two waves have made science and innovation a focus of their proposals. Sheffield focussed on the Nuclear Advanced Manufacturing Centre and the opportunities for developing a UK-based supply line for domestic and international nuclear power station investment.

Manchester has worked closely with Manchester University to establish the Graphene Institute. A joint project with UK Trade & Investment (UKTI) is identifying ways of attracting overseas investment to capitalise on the scientific discoveries of Nobel Prize winners at Manchester.

Finally, Cambridge is negotiating a city deal that recognises its networked and connected region. Cambridge

has over 1,500 technical companies, employing over 53,000 people with a combined turnover of over £11.8 billion. The spatial elements here are critical; a world class university draws talent from around the globe, fostering innovation and encouraging business spin-outs with strong hi-tech, biomedical and similar clusters.

The area's scale and connectivity allow overlapping networks to develop and facilitate a culture of cooperation and entrepreneurship. It is an attractive location which is a good place to live and a good place to do business.

Planning

The role of cities now and in the future has been recognised, as have the opportunities for them to create wealth, nurture innovation and act as technological drivers of growth. Planning has a critical role to play in unleashing this potential and managing its consequences.

The Government can see that its approach to the city needs to create the opportunities for local leaders to plan ahead, to plan for growth and recognise the role of the market in this ambition. It is determined to ensure that this happens. ☐

Closing the gap between concept and commercialisation

David King

There are currently 7 billion people on this planet and the figure is heading towards 9 billion. Just as important is the change in the proportion which is middle class. There were one billion in the year 2000, but in the 13 years since that figure has doubled. Take the projection forward and around five-eighths of the world's population could be middle class by 2030, spending between $10 and $100 per day.

In the year 2008, half of the world's population was in cities. It is expected to be 70 per cent by 2050, much of this, again, middle class. Most of the growth in the cities will be in the developing world. The projection forward indicates a three- to four-fold increase in GDP for cities in India, China and Africa in the period up to 2030. That has to be viewed as an opportunity for British private sector players in the field of urban development. The aim of the Catapult centres is to place our companies in a strong position to meet global demand and position Britain as a major player in that process.

Global challenges

Some 80 per cent of the world's population already lives in areas with a high threat to water security; 60 per cent of the world's ecosystems are already either degraded or used unsustainably. Then again, 95 per cent of food production is heavily dependent on oil which is a major issue in regard to resource scarcity. Finally, 11 per cent of the world's remaining natural areas could be lost by 2050 if societies do not look forward and plan for the future (much of this information comes from the *Future Proofing Cities* report[1]).

The Future Cities Catapult aims to ensure that we get advantages for the UK economy from these developments. I believe that quality of life, human wellbeing, has to be the first priority when developing our cities. Walk-ability, cycle-ability, live-ability have to be major factors along with protecting the environment. That is a very big challenge.

The Catapults were set up to close the gap between concept (the idea) and commercialisation.

So the programme of work for the Future Cities Catapult will involve the establishment of a laboratory which will be an open platform. It has been decided that we will place this in the capital. London is a global city – a globally-leading city – and it seems a highly appropriate location, therefore, for the new laboratory.

Figure 1 sums up the rationale for the Catapult. At the top are the aims: better quality of life, improved economy, reduced risk. Below are the essential components to build the cities of the future. They all have to be brought together to achieve the ultimate goals. And the laboratory in which the synergies can be developed and explored is the Catapult. It is a secure environment for people from different areas of the private sector to work together with us providing the cement, if you like, in that process. For the task is to create a means of establishing what future cities look like. The cities we create today will still have to be fit for purpose in 50 to 100 years' time, so we have to look at how we move towards sustainability and human wellbeing from today.

Looking back at the Foresight projects I initiated while Government Chief Scientific Adviser, a number of them impact on future cities. There are studies on: mental capital and wellbeing; sustainable energy management and the built environment; intelligent infrastructure systems; tackling obesity; flood and costal defences; brain science; addiction; drugs. These in-depth analyses provide a very useful set of starting points for what we hope to deliver in terms of the management of this complex process.

An holistic approach

Looking at the challenges of the 21st Century, there is a sense that a series of issues is hitting all at once and they will have to be managed holistically. Trying

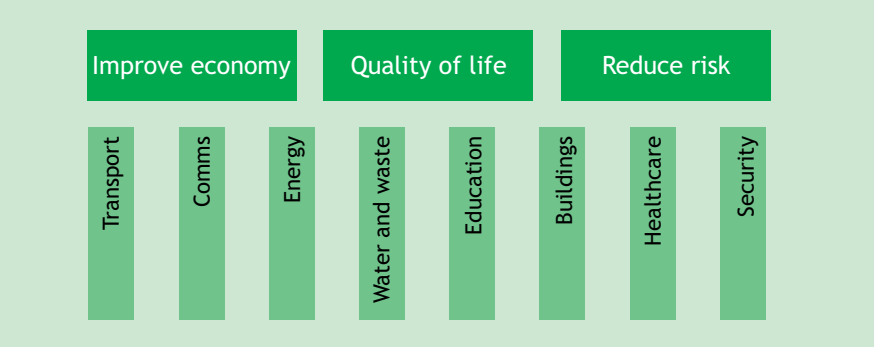


Figure 1. Elements and goals of the Catapult

to manage one in isolation from the others will make other bits of the puzzle more complicated. For example, it will not be possible to manage energy security without considering food production (especially given food's oil-dependence), so a systems approach will be needed to find the best answers.

Changing demographics are also producing resource scarcity and cities will have to be able to manage this. Take commodity prices: despite the downturn in Western economies, commodity prices have shot up recently around the world. This is a direct result of the rapid growth of middle class consumers. That has to be included in our thinking about the future.

When thinking about resource scarcity, it has to be recognised that our cities are a prime source of waste at the present time. Recently, though, the notion of a 'circular economy' has begun to gain traction. This supersedes the cradle-to-grave analysis with a cradle-to-cradle model because there is no such thing as waste in a truly circular economy. How to turn as much as possible of our waste into a resource is part of the discussion. I believe, for example, that our cities are a massive resource: human solid waste, nitrates and phosphates can be recovered and put back into the soil. So waste has to be part of the agenda when looking at future cities. Recycling is absolutely key, as is re-manufacturing.

The Future Proofing Cities report is a substantial piece of work, examining 129 cities around the planet in some detail. It is a report that focuses on the developing world. But there are lessons for developed-world cities there too. The report created an urban typology based on the challenges that developing world cities face as they grow rapidly (Figure 2). For example, Type 1 refers to energy-intensive, sprawled cities with a significant carbon footprint. Now, as a matter of fact, if we look at the typology of developed world cities, there are some, like London, which were developed in medieval times and are high-density cities – and there are cities developed in the post-automobile era which essentially became low-density. We also see, therefore, that we have cities with very different carbon footprints. Houston has, per person, the largest footprint and obesity is a big problem as well.

Sir David King KB ScD FRS HonFREng is Chair of the Future Cities Catapult. Previously he was the first Director at the Smith School for Enterprise and the Environment in Oxford. He returned to Cambridge at the start of 2013, where he had previously served as Head of the Department of Chemistry and Master of Downing College. From 2000 to 2007 Sir David was the UK Government's Chief Scientific Adviser and Head of the Government Office of Science. He is the Foreign Secretary's Representative on Climate Change.

It is possible to identify and bring together examples of best practice, something that I believe will be critically important. It is not only trying to develop 'next-practice', but looking at what is already happening around the world.

My favourite example of best practice is the city of Bogota. A new Mayor, Enrique Peñalosa, introduced a very simple policy to reduce the number of cars in the city. The policy was to transform the five-lane highways in and out of the city. The outer lane was re-designated for pedestrians only – they are now linear pathways. The next lane – cycles only. The third lane is for buses that make many stops through the city and the next is for express buses that make just a few stops. A final, single lane is for those that still insist on bringing their cars into the city. This is a transformational exercise that took an inspirational Mayor and almost no cost at all.

Lessons to learn

So there are quite dramatic lessons to learn, while at the same time it is clear that the world will not abandon individual transport vehicles entirely. Yet even here there are breakthroughs. In Seoul, South Korea, online electric vehicles are being introduced where the power for these vehicles is under the road; a primary coil under the road and a secondary in the car powering the electric drive.

The Future Cities Catapult will become a global hub, or laboratory, in London. It will carry out research but also provide a space in which to assemble policymakers, policy-influencers, private sector players, academics, financiers, and others. Its success will be determined by how successfully it becomes a magnet to attract the big players across the whole range of technologies that are vital for fully-functioning, sustainable cities that serve the needs of their inhabitants.

The Future Cities Catapult can also play a part in tackling the Department for International Development's (DFID's) challenges of eradicating poverty, combating natural resource depletion and protecting ecosystems. Then, finally, there is the complex matter of implementing the necessary financial mechanisms to achieve all this, and we will need to engage in that process as well. □

1. www.futureproofingcities.com

Figure 2. Urban typologies. It is possible to group cities into five types based on the most significant risks they face (129 cities assessed).

Building the future out of today's reality

Richard Bellingham

There is continuing growth in global population, particularly in the developing world, and in ageing populations across the planet. The desire for improved quality of life, the increase of the middle class, the rise of more consumerist lifestyles and the adoption of new technologies: these are global changes in social, cultural characteristics. Cities are the main concentrations of people and resources in the world; they are responsible for consuming most of the world's energy and producing 80 per cent of the world's greenhouse gas emissions. And they will continue to grow.

They have grown over thousands of years, through improvements in technology such as: food transportation and preservation; communication systems; economic systems that allow trading over a distance; energy production, storage and transmission, etc. Of course, it is not just the technologies, but also the social mechanisms that allow cities to work. We all expect to walk down the street without being robbed. We all use the sanitation systems, we choose to queue at the bus stop – all these things are essential to make cities work effectively.

Hundreds of millions more people will be moving into cities in the next 20 years, for different reasons. Cities provide huge opportunities to tackle poverty, improve health and education, as well as deliver economic growth. That is why China is moving 250 million people into cities over the next 20 years: it will lift inhabitants out of poverty. Approximately 60 million extra people are moving into cities every year worldwide.

There are many types of city across the world: disorganised cities in India; regulated cities in China; stable cities across most of the western world; shrinking cities such as Detroit where the decline of the motor industry resulted in almost half the population being lost; and newly-designed cities which, although popular in the media, are few on the ground.

The issues and opportunities in cities – and their continuing growth – create a huge global opportunity to develop (and sell) new urban technologies as well as new business models, financial mechanisms and systems of governance.

Richard Bellingham is Director of the Institute for Future Cities and Deputy Director at the Fraser of Allander Institute at the University of Strathclyde. He is European coordinator for the new STEP UP sustainable city planning programme – a partnership between Glasgow, Gothenburg, Riga and Ghent focused on creating innovative, integrated, low-carbon energy projects. As programme manager for Sustainable Glasgow, Richard wrote the Sustainable Glasgow strategy – working with the city government and commercial organisations.

Glasgow

Three years ago the Sustainable Glasgow report was published[1]. It set out a series of strategic solutions to make Glasgow a more sustainable city. Some of those solutions are now being realised. For example, Glasgow can decrease its carbon emissions by over 30 per cent within 10 years while drawing in around £1.5 billion worth of investment.

Glasgow was, only 50 years ago, one of the world's largest centres of manufacturing – shipbuilding, sewing machines, steam engines. Today that has all gone – primarily as a result of unpredictable changes in the patterns of global trade. It is worth remembering that sometimes wider events just happen and that planners at a city level cannot always control them. So, cities need to be resilient to a range of possible futures – not just an ideal future envisaged by city planners.

Glasgow today has some significant problems; over 30 per cent of homes in the city are in fuel poverty. It has some of the most deprived areas of Scotland, so that means some of the most deprived areas in Western Europe. A World Health Organisation (WHO) report looked at two different parts of Glasgow, a rich area in the North and one five miles away in the East[2]. Average male lifespan was 28 years shorter in the East. This highlights the effect of poverty and the impact it has on health. Recently, there has been huge public investment in the city and in 2014 the Commonwealth Games are coming to Glasgow.

The city has now adopted a target to become one of Europe's most sustainable cities within 10 years, achieving it in a way that is technically and financially deliverable. A very strong partnership is being built in Glasgow, bringing together the major public sector players, the providers of infrastructure, energy, transport, the health service with major private sector players. Given the issues and opportunities in the city, when we use the word 'sustainable' in Glasgow we do not mean just addressing environmental targets – our projects, our solutions must also address the social and economic issues in the city.

So how can this be done? One of the insights from this process is the need to look at the bigger picture. Too often designers treat their schemes as islands, looking at how to optimise individual projects and buildings rather than understanding them as a part of a wider city, linking to the wider systems, as well

DISCUSSION

Dangers of expediency

For democratic societies, where political power changes at frequent intervals through popular elections, there will always be the temptation for politicians to court public approval through short term measures, avoiding long term commitments which might disadvantage them at the next election. Unfortunately most large-scale infrastructure problems take many years before benefits appear. There are examples of long term infrastructure or management successes (the London Thames Barrier, Bogotá traffic management, etc), but there have been many failures too. And these initiatives must take into account the scale of the problem and the location - what works in the Pearl Delta in China may not be relevant for the River Thames.

DISCUSSION

Communicating with the wider community

Communication with the public about future dangers needs to be authoritative, resting on good scientific evidence, and must not be needlessly alarmist. Advice to policymakers must include possible alternatives, taking into account always, in times of economic scarcity, unwillingness to spend money. Contingent risks and the concept of resilience are not easy for many to grasp, and experts are not often the best people to communicate them to the public. Communication should not be couched in terms which would lead one set of politicians automatically to oppose action.

as the wider social and political context. This lack of joined-up thinking often leads to significant opportunities being missed. By looking at multiple layers of data – such as carbon emissions, land-use, poverty, patterns of investment – a whole set of new opportunities were found for the city to balance environmental, economic, and social outcomes.

Generating solutions that are more likely to meet a range of needs helps gain community and political support. By mapping carbon emissions geographically, for example, it is possible to identify the areas of the city where carbon reduction measures will have most impact. As carbon emissions are a reflection of economic activity, this also means that proposed abatement investments follow the money, making it more likely the proposed solutions will actually be built and generate jobs for the city. These novel opportunities had not been found before due to the tendency to look at the city as fragmented individual systems rather than understanding the city, its needs and its prospects as a whole.

The Future Cities Demonstrator

When Glasgow bid for a share in the Technology Strategy Board's Future Cities Demonstrator programme, our proposals were designed to be relevant to the city's needs, while also tackling issues that were relevant to global markets. The problems that Glasgow has – and their potential solutions – are relevant worldwide.

A number of programmes were already underway: the Commonwealth Games preparation: a £90 million innovation and technology centre that is bringing together academic and commercial research; new health facilities; new transport facilities; the UK's largest urban regeneration project, the Clyde Gateway Project. The Future Cities Demonstrator is designed to build on, and enhance, these opportunities.

Then we have the big issues like urban regeneration, fuel poverty and health. These are global issues where solutions developed and tested in Glasgow could become a showcase for the rest of the world. The Demonstrator is allowing different city systems to be joined together for the first time – improving monitoring and control of critical city systems. The Demonstrator will also gather hundreds of different datasets into a City Observatory that will allow the city to be understood in new ways by policy makers, by service deliverers, as well as by citizens.

The Demonstrator will deliver a range of facilities and services based on joined-up traffic management, joined-up emergency management, improved street lighting, etc. From the University of Strathclyde's point of view, this is not just about Glasgow; we want to draw in data from hundreds of cities around the world so that we can carry out analyses and comparisons across them – ensuring that our solutions have global relevance and the ability to be implemented in a wide range of urban contexts.

The Institute for Future Cities

The University of Strathclyde has established a new Institute for Future Cities[3]. Our vision is simple: to improve the quality of human life across the world. We will do this through innovative research that enables cities to be understood in new ways, and through innovative approaches to the way we live, work, learn and invest in cities.

The new Institute will create a focus and strategy to coordinate academic research on urban themes, as well as build partnerships with cities, business and government across the world.

Cities create a huge opportunity for international multi-disciplinary working – and for academics to work in partnership with business and government. Multiple disciplines need to work together to develop effective solutions, and to capitalise on the very significant opportunities offered by cities to deliver economic growth, reduce environmental impacts, and tackle major social issues (e.g. in crime, health, and education).

The Institute will therefore work in partnership – integrating and catalysing expertise and research from multiple disciplines within Strathclyde and other research institutes internationally. The opportunity is enhanced by the large and increasing amounts of funding for this agenda and the range of existing research and infrastructure projects that we can link with and build upon – including the new City Observatory. □

1. www.sustainableglasgow.org.uk
2. www.who.int/social_determinants/publications/en
3. www.strath.ac.uk/business/cities

How will policy shape the cities of the future?

Mark Walport

While in New York recently, I chanced upon *The Death and the Life of Great American Cities*[1], a book by Jane Jacobs, published originally in 1961. She was a social scientist and an extraordinarily acute observer of cities. She wrote: "To understand cities we have to deal, outright, with combinations or mixtures of uses, not separate uses, as the central phenomenon. The diversity, of whatever kind, that is generated by

cities, rests on the fact that in the cities so many people are close together and among them contain so many different tastes, skills, needs, supplies and bees-in-their-bonnets." It is a beautifully written book and her prescription is really quite detailed.

She continues: "To generate diversity, the district must serve more than one primary function, preferably more than two. These must ensure the presence of people who go outdoors on different schedules and are in the place for different purposes but who are able to use many facilities in common."

She comments on density, too. "There must be a sufficiently dense concentration of people for whatever purposes they may be there. This includes dense concentration in cases of people who are there because of residence."

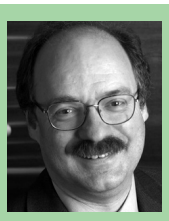
She makes a further important point that one should not equate high density of population with overcrowding. Her prescription is really to mix work and play – to mix housing and services. This book was a strong criticism of the city planners of the time and she argued: "One must not yield to a temptation to neatly and tidily zone cities into different functional units."

There is an immense amount of work on cities being carried out at the moment: this has, indeed, been the case for a very long time. The Government is going to contribute further to that work because the Government Office of Science is launching a new major Foresight project on the future of cities[2]. It will look at the trends that might be expected over the period to 2050.

What is a city?

Working from the UNICEF 2012 Urban Population Map, and projecting forward, an extraordinary proportion of the world's population will be living in urbanised environments. To focus on Europe, nearly all of it will be urbanised by 2050, including the UK.

Yet what is a city? It is tempting to say that we know one when we see one. Cities are often characterised by a strong sense of identity – 'Maybe it's because I'm a Londoner', 'Ich bin ein Berliner'. But increase the commuting distance from any city and they can draw in nearly all of the surrounding population in terms of work. That then leads to some interesting questions. What, for example, would the high speed rail line HS2 do in terms of city footprints as people move around between home and city, or between one city and another?



Sir Mark Walport FRS FMedSci is Government Chief Scientific Adviser and Head of the Government Office for Science. Previously, Sir Mark was Director of the Wellcome Trust, a global charitable foundation dedicated to achieving extraordinary improvements in human and animal health by supporting the brightest minds. He has been a member of the Prime Minister's Council for Science and Technology since 2004 and has chaired a number of inquiries for the Government.

The physical boundaries may be constrained by geographical features – a river, a coast – but often the boundaries are rather more amorphous. Cities may be defined in terms of population size, which may include the hinterland. Cities within a country and beyond are linked by transport systems which also have to be included in our understanding of them.

Issues to consider

In thinking about cities (both of today and tomorrow), issues of poverty and wealth, of culture and diversity need to be considered. Crime, demographics, questions of identity and belonging are important elements in how people think about cities. Governance and legal designations of cities are also relevant.

Take London, a very substantial component of the UK. London is out-performing the rest of the UK economically and one of the big challenges for this country is that our large cities lag behind London in their performance but, more importantly, lag behind their European rivals in terms of level of GDP per capita achieved.

The relationship between cities and their surrounding environments can be a mixed blessing too. Rousseau wrote, in *Emile* in 1762, "It is the cities which exhaust the state and are the cause of its weakness. The wealth which they produce is a sham wealth. There is much money and few goods.

"They say the city of Paris is worth a whole province to the King of France. For my own part I believe it costs him more than several provinces. I believe that Paris is fed by the provinces in more senses than one and that the greater part of their revenues is poured into that town and stays there without ever returning to the people or to the King."

Foresight

The Foresight programme currently includes a study on the changing demography of the UK. This involves input from across Government but particularly Jil Matheson, the National Statistician. The study underpins much of the wider Foresight work, for example, on how to cope with aging populations, but also with youth.

The programme is dealing with important questions about economic competitiveness and growth, about governance, about the impacts of climate change and our built and natural infrastructure.

But the tasks for the Foresight project on cities are to identify the key enablers of success for different cities and determine the most important decisions to be taken in preparing for the future.

Foresight projects look forward, they are intended to have policy impact and, as so much of public policy is delivered via cities (they are the centres of innovation and growth), it will take a cross-Government, interdisciplinary approach and will, of course, build on existing work. The aim is to provide a broad understanding of the challenges and the opportunities that UK cities will face in the future.

It will also seek to learn from and integrate the findings of other countries. As British urban planners, architects, designers, are hugely in demand around the world, cities represent an important export opportunity for the British economy. Yet to take maximum advantage of this potential it is important to ensure that that we learn as much as we can from others.

In the words of Theodore Roosevelt: "We cannot afford merely to sit down and deplore the evils of city life as inevitable when cities are constantly growing, both absolutely and relatively. We must set ourselves vigorously about the task of improving them and this task is now well begun." That was true in 1895 when he wrote it and it is certainly true now. The Foresight Project will be a very important piece of work. □

1. **Jacobs J (1961) The Death and the Life of Great American Cities. Random House, New York**
2. **www.bis.gov.uk/foresight/our-work/projects/current-projects/future-of-cities**

Can a new institutional structure be established that facilitates long-term decision-making in strategic infrastructure planning? The question was debated at a meeting of the Foundation for Science and Technology on 16 April 2013.

Taking a long term approach to infrastructure

John Armitt

I accepted the opportunity to chair a review of infrastructure delivery[1] in part because of the Olympics. One of the immediate reasons for their success was the degree of political consensus on the need for the Games to be successful. The country passed from one Government to another, from one Mayor to another and in both cases the process was seamless and had no impact on strategy or budgets.

The challenge I was asked to address by the Labour Party last year concerned the institutional framework that would enable the UK to make better long-term decisions about our infrastructure. How could the country avoid flipping backwards and forwards on policy between one Government and another, or indeed within a single Government?

Sir Howard Davies's Commission had been set up to review airport capacity in the South East, so the need for such reviews was recognised. I had the privilege of being on that Commission. Somebody at the beginning said: "Why do we need three years to understand what we should do about airport capacity?" I now see how we needed that time to debate all the options and listen to an enormous amount of evidence.

To take the new project forward, I brought some individuals together:

- Sir David Rowlands, former Permanent Secretary at the Department for Transport;
- Rachel Lomax, who also held that role but was also Deputy Governor of the Bank of England;
- Chris Elliott from Barclays, who has been financing infrastructure around the world for 25 years;
- Dr Paul Golby, until recently Chief Executive of Eon UK and now Chairman of EPSRC;
- Lord Andrew Adonis, former Labour Transport Minister;
- Alan Buckle, a Senior Partner at KPMG.

Sir John Armitt CBE FREng is Chair of the Olympic Delivery Authority. He has been Chief Executive of Network Rail, Railtrack, Costain and Union Railways, the company responsible for development of the high-speed Channel Tunnel Rail Link. Sir John is also Chairman of National Express Group and of City and Guilds, Deputy Chairman of the Berkeley Group and a member of the Board of Transport for London. He was formerly Chairman of the Engineering and Physical Sciences Research Council (EPSRC).

Helping to pull all this together as our Executive was Ed Thomas from KPMG.

The panel compiled a list of 15 questions about the way infrastructure development has been taken forward in this country: what had been learnt from the past; what the obstacles had been in the past; and the political issues in the past. This was sent to about 180 individuals and organisations and around 80 responses were received.

There were quite a few common views. The most obvious was that the country could not afford "to continue to muddle along as it has done for at least the last 50 years".

All previous reviews of airport capacity had bitten the dust when faced with the need for political action, for example. A key theme that emerged was the challenge of turning evidence into policy and then achieving political action. The Labour administration's approach to airport policy in 2003 was to sit on the recommendations of that year's review because it was politically too difficult. That opened the door for the Conservative Party to use the HS2 rail proposal to delay a decision on Heathrow expansion. It was a lovely piece of political opportunism that had nothing to do with the long-term requirements of either rail or civil aviation.

Perhaps surprisingly, Network Rail's response to our enquiry was to say that they did not believe there was a problem. Why? Well today, there is a reasonable degree of planned strategy in the rail sector. A high-level output requirement has to be given to the railway by Government and also a statement of funds available. Then Network Rail works out what is needed to meet that. The regulator asks for efficiency savings and at the end a five-year budget emerges. This is one sector which has, currently, a reasonable degree of strategic direction (though it may be the only one).

The other group that was reasonably content was the communications sector. That may be because much of their infrastructure is satellites, etc, and therefore does not affect us here on the ground. Their other infrastructure tends to lie underground and is installed without too much difficulty – and nobody notices. This sector is able to operate without much need for political consensus.

Independence

Those that responded were strongly in favour of an independent commission on the subject. This reinforced a report from the London School of Economics (LSE) about growth in the UK; the Engineering Employers Federation (EEF) had also made a similar suggestion. An independent commission would assess what was necessary for the continued economic growth of the UK in the major sectors of infrastructure and then come forward with its views of the current need and how that could be met. We settled on a 25 year horizon although some wanted longer and others shorter.

The basis for the commission's recommendations would be

fundamentally economic in most people's view: what would aid economic competitiveness and growth? However, there was a recognition that economics alone would not be sufficient: sustainability and wider socio-economic factors would need to be taken into account as well.

Which sectors should be included in the terms of reference? Those under the civil engineering umbrella in the main – so transport, waste and water, energy (most important of all), flood defences and telecommunications. Housing is not so clear cut. Some respondents believed housing should be a central part of any such assessment, others argued on the contrary that this is fundamentally a local issue that should be left to local government.

We took evidence from NGOs, but where would they sit in relation to any such commission – would they be full members or sit on expert panels supporting it? Would their role be to prevent the commission becoming too business-dominated?

Some thought the commission should be allocated capital. In Australia, the National Commission for Infrastructure allocates funds to projects that meet part of a wider overall need for infrastructure in the country.

The commission would need to have a major review at least every 10 years, but could give an update to Parliament every five years on any particular sector.

Some people contended that the commission should have the power to deliver while others felt just as strongly that delivery should be undertaken through existing means, be these Government agencies or the private sector. In Singapore, once a high-level view of requirements in a particular sector has been formed, the government department (for roads, say) is then required, within a year, to produce a policy for meeting that requirement inside 10 years. That policy becomes enshrined in statute. The UK already has National Policy Statements which could play a similar role.

This independent commission would report to Parliament on a regular basis as to whether these National Policy Statements were being delivered. It would have to be an independent voice commenting on progress and suggesting what political action might be necessary to maintain momentum.

Membership

There were divergent views on membership; some thought politicians should be on it, others that politicians should not be allowed near it. A number of respondents considered that it should be located within a Government Department; the obvious one for many people was the Treasury, although others thought that would be a bad idea. Most considered that, even if it were sited in a Department, the Commission should not be accountable to it. For example, the Office for Budget Responsibility does not take its instructions from the Chancellor, even though it sits within Treasury and has access to information.

Both the Committee for Climate Change and the Office for Budget Responsibility make useful examples of this type of approach. Those two recently-created bodies have a degree of independence and some cross-party understanding and support. The difficult part in all this is establishing political consensus – is it possible, in fact, to achieve this within the UK system?

People in Singapore told us that their system was modelled on Britain and how similar it was to Britain's. However, when asked about the details of decision-making, they explained it was done through consensus – not really the current model in the UK! We spoke to the Chief Executive of Schiphol about the development of the airport. He explained that this was done through constant discussion and debate, listening to everybody's point of view. All parties accepted that, at the end of the day, they were not going to get everything they wanted. To get the best overall solution for the Netherlands, everybody had to give way a little. So that is how they reached a consensus and were able to create Schiphol airport with six runways – while we are still arguing about a third at Heathrow.

Political consensus

Political consensus is critical. So at the start of this project, I suggested to Ed Balls that representation from the Conservative Party would be beneficial. He agreed and I contacted one or two members of the Party who were no longer politically active but knew something of the subject. Initial reactions were positive but the Party machine was unenthusiastic. Officials in the Treasury have also been told not to talk to us about this subject.

This goes to show the measure of the task. Both political parties, I am sure, acknowledge the need for the country to take a long term approach to infrastructure development. Yet they find it very difficult not to use infrastructure to gain political advantage with the electorate. That is, I feel, the real dilemma that we face.

I hope something positive can come of this. Must we continue to muddle along? Frankly, if we do the lights will go out because we still do not have an energy policy, for example. We are certainly not going to succeed as a nation if we do not address this issue and other infrastructure challenges. □

1. www.armittreview.org

Creating an effective framework for delivering infrastructure

Brian Collins

The 'top-down versus bottom-up' issue has not been adequately addressed in the last 50 years. There has not been a top-down national plan for national infrastructure since the end of the Second World War. At that time, what is referred to as 'infrastructure' was in the public sector and controlled by one Department.

So at what point did this country dispense with that model? There is a seminal paper, written by Nicholas Ridley in 1977, reporting on the work of the Nationalised Industries Policy Group. In it, he says quite plainly that after privatisation there will be no national energy or transport policy. This policy was in the party election manifesto two years later and was the basis of what took place over the next 25 years.

Today, there are partial plans for

motorways, the National Grid, and Gas. Yet most of those national plans were in place prior to privatisation. The plans are now being updated, but in isolation from each other. Importantly, the regulatory structures that were put in place in those earlier days did not have a requirement for master planning or coordination between regulators post-privatisation. So, in terms of 'top-down v bottom-up', it appears that the pendulum has swung too far in the direction of market efficiency, i.e. bottom-up.

The National Infrastructure Plan

The National Infrastructure Plan is a bottom-up policy but one driven by a pipeline of disconnected projects. Yet these projects all depend on one another, a fact which becomes all too obvious when something fails. Nevertheless, it is the plan used by Infrastructure UK in the development of infrastructure policy, and within the Treasury, the City and Government Departments.

The Institution of Civil Engineers has been leading a study examining that interdependence. This will certainly highlight the risks of infrastructure failing, but also indicate the opportunities if individual elements – such as land, airspace or major construction projects – are considered holistically from design stage. With 'joined-up doing' as well as 'joined up thinking', money can actually be saved.

But such an approach will not deliver a National Strategy or (in some ways a more important objective) a sense of national purpose. The UK has had master plans in the past. Abercrombie devised a master plan for London in 1943. That was just after the Blitz. London needed to be reconstructed and this could be done using a top-down view. The plan was not implemented though. The literature, in fact, shows that there has been a master plan for London about every four years until 2012. None of them has ever been fully implemented. The planning is there, but not the execution.

So instead there is the family of projects that Infrastructure UK has on its list for the next 40 years, including high speed rail (HS2), nuclear power stations, etc. Is the country going to continue to muddle through without any common purpose or consensus?

Consensus

Market instruments are not designed to achieve consensus. They involve competition and financial efficiency. I discovered as a Chief Scientific Adviser that some Secretaries of State thought they were not accountable if a programme was 'out in the market'. Of course, the media and the public did hold them accountable. One of the Management 101 guidelines is 'never get responsibility, authority and accountability in different places'. Yet we have done precisely that, which is not very helpful in terms of delivering consensus.

There is a very simplistic silo treatment of infrastructure in this country and we have a relatively simplistic regulatory structure as well. That results in less importance being given to other elements – environmental aspects, adaptability (particularly to extreme conditions), resilience and, importantly, liveability. We are sleepwalking into a situation where things are gradually getting worse. My concern is that it will take a major catastrophe before we do something. Politicians of all parties have avoided putting all these issues together and considering them in the round. They have been happy to muddle through with the silo treatment which is becoming quite unacceptable.

Mrs Thatcher, in her time as Prime Minister, espoused the value of 'the Three Es'. The first was Economy, the second was Efficiency and the third was Effectiveness. But the Conservative administration was voted out of office before effectiveness could be enhanced. However, on a day-to-day basis, we experience effectiveness much more than the other two.

How could the effectiveness of consensus be assessed? What are the metrics for a good infrastructure? Who should evaluate it? That brings us back to the Armitt Review. It is designed to consider the stewardship of the consensus-making process. It will of course need to engage with a wide range of stakeholders, all of whom have their own views on how effective the overall planning is. And then, who would be responsible for allocating resources? Should this body be given that role, as the Australian equivalent has, or would resources remain within the Departments and their agencies? Singapore has authorities, not agencies. These enjoy delegated authority to spend money; agencies have to keep referring back to their parent departments. What is the role of the regulators in all of this?

Then, if something does go wrong, who has responsibility for fixing it? There is almost never a single body or political unit or market institution that has overall responsibility. That means no single point of responsibility, authority and accountability. So effectiveness is a difficult subject to pin down.

Meeting stakeholder needs

I would argue that no Government solution is going to be optimal but could one work 'sufficiently well' to protect the vital interests of stakeholders, including the public, financiers, operators and regulators?

For example, the public wants a solution that works and delivers the services required. Government, on the other hand, wants affordability (of its own investment, some of the cost is in the market) and an acceptable level of political risk. A crucial factor is the timescale for that risk. If it is just five years (one Parliament), then one set of actions comes within scope. If the risk is spread over decades, then a different set come into play. At the moment, though, there is no mechanism for politicians to address these decadal processes, although as public servants they should be worried about *our* long-term needs as well as *their* electability.

Financiers clearly need to manage the financial risk and achieve a return on investment.

The operators want reliability, resilience and profit while regulators wish to make sure the infrastructure is safe, fair and environmentally acceptable (depending on their remit).

That all provides a framework that the commission would need to consider. How those factors are enshrined in its terms of reference so that it can take an holistic enough view of the factors is yet another question.

If consensus is essential, what process should be used to arbitrate between disparate vital interests? The

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Commission's remit could stipulate a mechanism for arbitration. Of course, parties might not like the results, just as some people do not get the desired result from arbitration over wage deals.

Cities

Cities can be pathfinders in delivering new infrastructure. The majority of people in the UK live in cities and city leadership is becoming more powerful and more motivated to deliver a local agenda. This trend is not confined to this country, it is happening across the planet. Statistically, some 70 per cent of the human race will be living in cities and producing about 70 per cent of global wealth in 40 or 50 years time. The infrastructure in cities, therefore, is crucial.

To what extent, though, is competition in the political ecosystem a distorting factor when it comes to delivering the infrastructure we need? In a democracy we need to preserve that competitive framework but it has to be diluted a little in this space in order to deliver some national good. This is a constitutional and a structural issue that has to be debated.

There should be an independent research base to underpin all of this planning and to provide analysis and assessment, not just nationally but internationally. That would help us to arrive at an informed view on the right things to do about infrastructure development.

If we do not address these issues voluntarily, then we will wait for some major catastrophe. The last one that made the country act was the Second World War. The next time it could be a natural disaster. But our infrastructure is currently very poorly-governed for its role in supporting and maintaining our developed society. ☐

Planning for a secure future

Tim Yeo

For first time in history of the world, every modern prosperous economy now faces genuine global competition. Jobs and investment are becoming more mobile than ever before. Neither of those trends is likely to go into reverse any time soon.

To remain competitive in the 21st century countries will require three things. First, a top class education system which enables the talented élite to shine while at the same time preparing students for working lives in which change will be more rapid than in previous generations and new skills will have to be learned several times over a single career. Second, a tax and regulatory framework that attracts and encourages investment and high value-added jobs, at a time when other countries are competing for the same funds.

Third, a modern 21st century infrastructure whose key components are a modern transport system; an up-to-date, reliable and cost effective energy industry; and a state-of-the-art IT network.

Some 40 years ago, when I started work in the investment business, I told friends they should travel to America at least once a year to understand where the world was heading. Today, I tell them they must go to Asia every year. The world's centre of gravity is shifting rapidly eastwards. This is, in fact, happening so rapidly that western Europe must get its skates on in this decade if it is not to be relegated to third-world backwater status by the middle of the century.

Short of natural resources, geographically out on a limb, burdened by historic high tax rates and heavy debts, Europe needs to act fast to avoid a long-term decline in its living standards compared with the rapidly growing East. Nowhere is this relative decline more apparent than in the painful contrast between the transport infrastructure of many Asian countries and our own. Anyone returning to London from Hong Kong, Beijing or Singapore must bemoan our failure to update our railways, airports and roads.

Tim Yeo MP is Chair of the House of Commons Select Committee on Energy and Climate Change and MP for South Suffolk. He was a member of the Thatcher and Major Governments. As Minister of State for the Countryside and Environment, he reformed planning law, helped to develop climate change policy and established the now thriving Energy Saving Trust. He was a member of the Shadow Cabinet from 1998 until 2005, when he resigned to speak freely about issues such as the environment.

Energy

As another example, take energy. Today, both business and domestic life depend on a continuous supply of electricity. I do not believe that the public, here or elsewhere, would now tolerate the power cuts which were an unhappy aspect of Britain in the early 1970s. They are not acceptable in any modern economy. Yet as growth continues, populations increase and both transport and heating systems are electrified, so too does the demand for energy inevitably grow.

It is estimated that the UK needs £110 billion of investment in new generating and transmission capacity. About £75 billion of this will be for generation and the rest for transmission systems. The Government's aim is to have 30 per cent of electricity generated from renewable sources by 2020, much of it from wind. This is a formidable target which can only be achieved by the construction of huge numbers of new wind turbines, solar panels and so on.

Finding the money is the first challenge. There is no automatic reason why investment, which on this scale involves international investors and companies whose marketplace is global, will flow into Britain. If investors see better returns in jurisdictions whose policy framework is more stable they will go there.

The current delays in the passage of the Energy Bill (born after a gestation of elephantine length) through Parliament; the confusion about how far the Government intends to rely on gas; doubts about the extent of its commitment to reducing the carbon intensity of the electricity generation industry – all are contributing to a hiatus in investment decisions.

The construction of nuclear power stations is stalled amid disagreement between the Treasury and EDF about the price EDF can charge. Urgently needed investment in new gas-fired capacity is not taking place because the details of the so-called capacity market have not been made clear.

Planning

Yet in Britain we have a further obstacle to overcome. Even when investors want to support energy projects here, our planning system represents a challenge, capable of causing lengthy delays in the commencement and completion of these developments. Such delays significantly raise costs. In extreme cases some projects may be blocked completely.

When time is of the essence for new energy investment, a more streamlined decision-making process is essential if Britain is to remain competitive. A step in the right direction has been taken by the transfer of responsibility for considering nationally-significant infrastructure projects away from individual local authorities to the Planning Inspectorate and the Minister. But further changes are needed.

Years ago, when the mobile phone industry was in its infancy, the urgent need to roll out a nationwide network of mobile phone masts was recognised in planning guidance. Masts of less than fifteen metres in height were exempted from the need to obtain planning approval. This meant that local objections could be ignored. Although this was a draconian approach, its effect was to facilitate the rapid growth of the mobile phone industry for the benefit of millions of consumers.

I believe that such interventions in the planning process should only occur rarely, where there is a clear national interest at stake. There can be little doubt that in relation to energy infrastructure such a national interest exists.

Shale gas

Let me illustrate this by reference to different types of energy. Firstly, shale gas: many people believe that the presence of abundant shale gas reserves in Britain will be the saviour of our energy needs. Envious eyes have been cast across the Atlantic at the game-changing impact of the discovery and exploitation of huge shale gas reserves in the USA. Two years ago my Committee recommended that the Government should give the go-ahead for the development of shale gas in Britain.

We reached this conclusion after a careful examination of the environmental and other risks which shale gas poses. We believe that it is possible to establish a regulatory regime which ensures that shale gas can be safely exploited. We regret that two years later, the Department for Energy and Climate Change (DECC) still seems to be hesitating. There are signs, though, that approval will be forthcoming, at least for some exploration without which the scale of the recoverable reserves cannot be accurately assessed.

Even if this approval is given, individual shale gas projects will still face formidable difficulties in securing planning consent. Some of the more promising areas for shale gas are in Hampshire, Berkshire and Sussex. Groups of protesters are already being formed, years before any planning applications are likely to be submitted, with the aim of preventing shale gas drilling in cherished communities. The exploitation of a valuable national resource is likely therefore at best to be severely delayed and at worst prevented.

I do not think the Treasury, the strongest advocate in Whitehall of shale gas development and its benefits, has factored into its thinking the planning difficulties the industry will face.

Low-carbon electricity

Second, in terms of low carbon electricity, onshore wind turbines are one of the more cost-effective technologies available. The subsidy required by onshore wind is substantially lower than offshore, on which the Government seems keen to place a disproportionately large bet.

At present the Renewables Obligation Certificates, through which consumer-funded subsidies are paid to various low carbon electricity generators, are so opaque that few consumers have any idea about the relative costs of offshore wind compared with solar PV, anaerobic digestion or onshore wind. This obscurity will end this summer with the publication, for consultation, of the proposed strike prices for the new system of contracts for difference which the Energy Bill is introducing to support low carbon generators.

But even if it becomes clear that onshore wind offers far better value for money, the intense local opposition to many wind turbine applications means that the expansion of the industry is likely to be tortuously slow. At least it can be said that the planning system is technology-blind – equally difficult for both fossil fuel and non-fossil fuel generators!

What concerns me is that the projects likely to be obstructed in these two important industries are relatively small scale. Major wind farm developments, for example, will enjoy the status of being nationally significant infrastructure projects. This enables them to by-pass some of the local objections.

Improving the process

A curiosity of the planning system is that objections from people not directly affected by applications submitted for approval must be considered. Very few communities which have hosted a nuclear power station in the last 40 years have serious reservations about the construction of replacements. However local support for a project is no guarantee of swift approval. So I have three recommendations for improving the planning process in relation to infrastructure projects and in particular for the improvement of our energy infrastructure to meet the needs of the first half of the 21st century.

The first is the introduction of a strong presumption in favour of infrastructure development which meets the needs of national energy objectives. These objectives can be defined as greater energy security, a reduction in carbon emissions and value for money for consumers.

Projects which clearly contribute to the achievement of these objectives should have a strong presumption in favour of approval (even in the face of local objections) when they are submitted to local councils for determination.

The second is to facilitate the sharing of the benefits of specific individual energy projects with local communities. At present those benefits too often accrue to people and organisations who suffer none of the environmental impact. This is an inherently unfair approach. Costs and benefits need to be more equally shared.

More imagination should be used. For example, why not freeze the cost of electricity for consumers living close to new energy developments? That prospect might make a couple of wind turbines a great deal more acceptable in some places. Or else allow local communities to share some of the revenue created by a new shale gas development?

The third is the introduction of a fast-track approval process for projects promoting energy efficiency. Too often the enormous benefits of greater efficiency in the use of energy are overlooked. The technology available today could cut the cost of energy significantly for domestic consumers. But much of it is ignored. Belatedly the Government has woken up to the need to stimulate energy efficiency investment.

The biggest contribution can come in the built environment, both through new build and retrofit. If developers saw the chance of a fast track through the planning process by incorporating state-of-the-art elements in the plans they bring to local councils for approval, then Britain's buildings would be both more economic to run and more environmentally friendly. ☐

To mark the centenary of the Medical Research Council, a meeting of the Foundation on 22 May 2013 considered what the priorities of medical research should be over the coming 25 years.

Medical research – from simple organisms to the human genome

Sydney Brenner

I first became involved with the Medical Research Council 60 years ago. I had driven to Cambridge from Oxford, where I was a research student, to see the model of DNA. That journey opened the door for me. No sooner had I returned to Oxford than I started to work on the coding problem – theoretically of course – and that early interest in genetics has stayed with me throughout my career.

In the 1950s, the medical research establishment consisted of biochemists, none of whom had an appreciation of the nature of their discovery, nor any sense of what it might bring. Molecular biology did not exist as a discipline at that time. But as it became established, the work proved to have profound ramifications for the whole of biology.

Major discoveries

In almost every decade since, there have been major discoveries that have advanced our understanding of organisms, first the simple organisms such as bacterium phages and then later more complex, multi-cellular organisms.

Although sequencing the human genome in the 1980s was seen as an amazingly difficult task, in fact once sequencing had been invented we could determine the complete genetic composition of any organism. We will probably have schoolchildren sequencing their genomes in the near future: the technology has improved to that extent.

In 1956, Francis Crick arranged for me to join the MRC Unit in the Cavendish Laboratory. This was a small unit headed by Max Perutz working mainly on determining the structure of proteins by X-ray crystallography. The unit was a long-term gamble by the MRC but it had had its first success in 1953 with the DNA structure. Later we were joined by Fred Sanger and his group to found the MRC Laboratory of Molecular Biology and in 1962 moved into a new building on the hospital site.

I ended up spending almost 35 years working for the MRC. At that time we did not belong to any Government department, but instead reported to the Privy Council. The annual report of the MRC was submitted directly to Parliament, which provided our budget. That all changed in the 1960s.

Dr Sydney Brenner CH FRS HonFMedSci is a Nobel Prize winner and a Senior Distinguished Fellow at the Crick-Jacobs Center, Salk Institute for Biological Studies. He founded the Molecular Sciences Institute in Berkeley California in 1996, serving as its President and Director of Science. He is also Founding President of the Okinawa Institute of Science and Technology.

The laboratory that was created in Cambridge and which began its expansion in 1962 spearheaded this type of work throughout the world. The laboratory had a culture that made it easy to move around and to progress – it was a very 'open' and non-hierarchical organisation. We all had a rather contemptuous view of administration that would not be possible now!

Biology in the 21st century

The question now, for those of us who are still concerned with the problem of how genes affect the phenotype of the organism, is what organism to work on? To me the answer is unequivocal and clear: we should work on humans. Why? Because in the past 50 years we have been given all the tools we need to bring these investigations to bear on ourselves – and because we are a unique species on this planet. We are the species that invented science and the only species that can think about the future. I believe we deserve priority.

It is reasonable to ask how we can do human biology when human experimentation is illegal. I would answer that everybody is doing it. Nature is doing it. The Government is doing it. Fast-food chains are doing it. You are doing it to your children. Your children are doing it to you. All of these experiments have been going on for a very long time, but now we have the tools we need to see the results. Human biology is where the exciting discoveries will be made in the future. It is linked not only to medicine but to all human activity. This is the challenge for the next generation of scientists.

Side-effect

There has been a rather unfortunate side effect arising from the focus on big projects such as the Human Genome Project. We now have a scientific community that resembles a corporation – not a laboratory but a corporation in which there is a lot of top-down planning. It is mainly concerned with the three 'M's: money, machines and management. The preoccupation with those has led to us losing much of our freedom to create innovations.

Everybody now wants absolutely risk-free futures, so that means we have to know the results before we are given the money to do the research: there is much I could say about that! I hope that the MRC

DISCUSSION

Animal experimentation and human biology

There was a strong consensus at the meeting that human biology should be the focus of future research. However, work on humans is not the only priority. The transfer of disease from other animals to humans remains a crucial area of study. A focus on human biology does not mean that experimentation on animals will cease or reduce significantly: the study of simpler models continues to be vital.

will find some corner of its activities where it can allow flexibility in proposals for new research. When I was with the MRC I chaired a committee that gave fellowships to young scientists to enable them to pursue their careers, among them Paul Nurse, now President of the Royal Society, and Kay Davies, Director of the MRC Functional Genomics Unit. People such as Paul and Kay would have been lost to science without funding to enable them to do independent work. I hope the MRC will continue to recognise and support talented young scientists in the future. ☐

Priorities for medical research

Paul Nurse

When the MRC was founded in 1913, biomedical science was in its infancy. Genetics and biochemistry were barely invented, and there was no conception of molecular biology, structural biology or genomics, all of which today contribute greatly to our understanding of biomedicine. Despite these limited beginnings, the advances of the past century have resulted in extraordinary improvements in lifespan and healthcare. One can only imagine what is likely to be achieved over the next 100 years, given our present knowledge and the potential we now have to dramatically improve that knowledge.

One of the reasons the MRC has been so successful is that it has always recognised the importance of discovery science and the central fact that better understanding of how living organisms work is fundamental to controlling disease and improving human health. Here, I want to focus on science, giving my own view of some of the scientific problems where significant progress can be expected over the coming decades.

The behaviour of cells

One major research objective will be better understanding of the cell. The cell is the basic unit of life, and as the nineteenth century founder of pathology Rudolf Virchow argued, it is the pathological behaviours of cells that form the basis of many diseases. There are now real opportunities to advance our knowledge of how cells work, using a combination of techniques and approaches, including advanced microscopic visualisation of living cells, biochemistry and genetics.

Because the cell is the simplest entity exhibiting the characteristics of life, many of the principles underlying how life works are likely to be found through study of the cell. A primary objective will be to combine the descriptions of molecular phenomena underlying cellular behaviour into a complete description of the cell and its operations. This will require an approach whereby the cell is considered as a complex system made up of molecular components that generate higher-level biological functions.

Sir Paul Nurse PRS FMedSci HonFREng is a Nobel Prize winner and President of the Royal Society. He is a geneticist and cell biologist whose major work has been in how cell reproduction is controlled. Sir Paul is also Director of the Francis Crick Institute and has served as Chief Executive of Cancer Research UK and President of Rockefeller University.

However, it is important that we are not satisfied solely with descriptions of molecular phenomena. Our real objective is to build on these descriptions to increase our knowledge and understanding. What will be essential here is the approach that was dominant during the early years of molecular biology, one emphasised at the time by Sydney Brenner: that is the importance of information and the management of information in living systems. This means understanding how information is gathered, stored and used to generate purposeful teleonomic outcomes.

The lessons learnt about information management in living systems obtained from the study of cells will apply to tissues, organs and organisms as well. In my view, this approach will be informed by applying concepts developed by evolutionary and ecological scientists who have long experience of studying complex living systems.

One major problem with the systems approach to cells is the issue of identifying the values of molecular parameters that should be fed into subsequent analyses and models. For example, present approaches generally try to estimate the rate constants and concentrations that operate within the cell, but these are difficult to determine accurately for all the parameters that will be necessary. A solution might be to reduce the complexity of descriptions to 'black boxes', focussing on inputs and outputs that can be measured, rather than trying to describe all the quantitative details of what goes on within those boxes.

Understanding cells will require work in a range of organisms, including single-celled organisms such as bacteria and yeasts, because the problems will be easier to solve with these simpler organisms than more complex multi-cellular organisms. Yet ultimately we need to understand human cells if we are to work out the basis of human disease. A good example is cancer. Cancer occurs as a consequence of genetic damage in cells that leads to uncontrolled cell division, and to cell shape and motility changes that result in the spread of cells throughout the body. Such disease pathologies can only be understood and better managed through improved knowledge of how human cells work.

Human biology

The poet Alexander Pope is sometimes misunderstood when his line "The proper study of mankind is man" is quoted in support of the importance of researching human beings rather than the rest of the living kingdom. In fact, Pope was attempting to redirect human endeavour away from God, as is clear in the preceding line, "Know then thyself, presume not God to scan".

Nevertheless, it is right to focus biomedical research on the study of humans. In the coming decades there will be a continuing need for the study of model living organisms, especially mice, but increasingly we will need to take all opportunities to investigate human beings. I am not speaking here only of translational work (that is research aimed at achieving a particular diagnostic or therapeutic outcome) but also of research into human biology.

There are a number of promising possibilities for human biology in the future. The first is human genomics, which exploits knowledge of the sequence

of the genome and its variation within human populations. Having the human genome sequence is like having the list of characters in a play; it is essential for the play to be written but it is not sufficient. The task now is to use the cast list, the genome sequence, to write the text of the play, that is, to understand how humans work.

Identifying the genomic variations within populations and correlating them with phenotypic variations, including predisposition to disease, informs our understanding of the genetic contribution to disease. Sometimes this will be relatively simple, but more often it will be complex, because many genetic differences are likely to contribute to disease onset. Yet as more data are gathered over the coming decades, these complexities will be gradually unravelled.

Nature and nurture

What will be especially powerful is to combine this deep knowledge of genetics with investigations of the effects of the environment on human health and disease. This is essentially the nature–nurture debate, which should not be seen as a conflict as it sometimes is, because it is obvious that both are important. They should be combined in major epidemiological studies to improve our power of prediction beyond what is possible if only genetics or environmental differences are examined.

This is a big data issue, which the UK is well poised to tackle, both with its strengths in genomics and with the NHS, a unitary health care system that, if effectively used, has great potential to drive this type of research. Because the NHS is seen to be a service for the people rather than as a for-profit organisation, I believe many of the public will be happy to contribute their own personal data for this project which is ultimately for the public good.

This approach will contribute to a more precise personalised medicine, tailoring treatment to the individual, based not only on their genome sequences, but on other physiological and pathological markers as well. Genome sequencing will also be illuminating about the pathways that may be implicated in disease predisposition, opening up new approaches to diagnosis and therapy. Because the cost of sequencing is decreasing, it is not far-fetched to expect that soon everyone will have their genome sequenced at birth, although the ethical implications of this must be handled with care.

Imaging human physiology

A second opportunity in human biology is to promote new approaches to human physiology using sophisticated imaging modalities. Imaging used in clinical care can also be employed in studies of human physiology. It needs to be combined with chemistry and radiochemistry to provide new markers that can monitor physiological states throughout the body.

A more fanciful development might be to generate miniature micro-robots that can travel freely around the body, equipped with microsensors to assay their local environments. Perhaps they could also be equipped with microscopic worms that burrow into solid tissue to monitor more remote regions of the body in a relatively non-invasive manner.

Given that these micro-robots would be controlled from outside the body, they might be further developed for use in microsurgery. More multidisciplinary and interdisciplinary approaches will be needed to tackle such initiatives.

Creating human organs

Another opportunity will be to use human stem cells combined with three-dimensional tissue scaffolds to create prototypic human organs in the laboratory, not just for organ replacement but also for physiological studies. Studies of such 'human organs' would complement animal models, helping us to better understand normal human physiology and providing possibilities for the treatment of degenerative disease.

Genetic manipulation of the cells used to generate these organs will allow disease states to be more readily modelled, as well as allowing sensing systems to be built into cells to more precisely monitor cellular and tissue behaviours. These types of human studies will provide novel approaches to major diseases.

Studying the brain

Understanding the brain is difficult. I think two contrasting approaches will be important in the coming decades. The first, given the complexity of the problem, is the use of simple model systems to study nervous systems, brains and behaviour, particularly invertebrate models such as the worm and the fly. The simple organisms can be studied while they perform behavioural acts in virtual environments, monitoring their brains and nervous systems in real time, correlating neuron activity at a fine level with sensory inputs and behavioural outputs. Another opportunity is the study of neural development using the transparent zebra fish embryo.

Work on these simpler systems should help develop more general principles to underpin neuroscience and its application to mammalian systems, including human beings.

The second approach is to try and combine neuroscience studies of the human brain with studies of the mind. There is real promise here too but it is difficult and requires overcoming the cultural barriers between the often quite different scientists who are working on neuroscience and the mind.

Tackling infectious diseases

Infectious disease continues to be a major problem, both in the developing world and in the UK. New ways of combating infectious agents are required, especially to deal with antibiotic resistance in bacteria. One promising approach is the use of environmental DNA, or e-DNA.

Only a rather small fraction of micro-organisms can be cultured easily in the laboratory, but their DNA can be extracted from natural sources such as soil and then cloned and expressed in cultivatable micro-organisms. These can then be subsequently screened in the laboratory for antibiotic activity. The use of e-DNA should significantly widen the classes of antibiotics available.

What next for the MRC?

Is there anything new the MRC should be doing? In my view it should consider using more public-private partnerships in clinical trials, working better with both the NHS and industry. Clinical trials could be expanded beyond the objective of a commercial company, which generally has a specific translational application in mind, to include monitoring many more markers of human physiology. This information can be used to determine if the drugs or other interventions being tested may be relevant to other physiological systems or disease states.

This is a cultural change that emphasises major clinical trials as not simply proofs of principle, but as research tools. Such a change will require new practices and shifts in regulatory frameworks.

Without question, the MRC will continue to make important scientific discoveries that will lead to great improvements in the human condition over the next century. Yet we need to recognise that the MRC and biomedical research in the UK face great competition from the rest of the world. This comes not only from scientifically-developed nations such as the USA and Germany, who spend

significantly more on science than we do in the UK, but also from nations such as China and India who are rapidly increasing their budgets and improving the quality of their research. This is something our political leaders need to take account of, not only over the next century, but right now. □

The MRC: an historical perspective

Keith Peters

I would like to recall some of the individuals and a few of the achievements that were instrumental in forming the unique character of the MRC. They are both an inspiration for the future and a reminder of how much the MRC has achieved during its first 100 years.

Sir Austin Bradford Hill (1887-1991)

Sir Austin Bradford Hill was a pilot in the First World War who was invalided out after developing tuberculosis. In a way, his illness was a stroke of luck because the life expectancy of a pilot was considerably shorter than that of a person with tuberculosis. As a result of his illness, he was not able to attend medical school, so he took a degree in economics by correspondence instead.

What he went on to do after that was a great advance for medicine – he invented the randomised control trial. It was first used in studies of the treatment of tuberculosis and later, with Sir Richard Doll, in the famous study that established the relationship between smoking and lung cancer. Note that this was an experiment and not simply observational epidemiology. The study population consisted of doctors who smoked. Those who gave up fared better than the heavy smokers, who had a 20-fold higher risk of dying from lung cancer.

Jerry Morris (1910-2009)

Jerry Morris was a Scottish epidemiologist who carried out a survey showing that conductors on London's double-decker buses had lower rates of heart disease than sedentary drivers. He extended his study to postal workers and found that postmen who delivered mail by bicycle or on foot had fewer heart attacks than their colleagues who worked behind counters or in offices. Using these simple epidemiological comparisons, he established the importance of exercise in reducing morbidity and mortality from cardiovascular disease. He received a gold medal at the 1996 Olympic Games for excellence in the science of sport and exercise as well as his pioneering studies into how exercise reduces the rate of heart disease.

Sir Keith Peters FRS FMedSci FRCP FRCPE FRCPath FLSW is Emeritus Regius Professor of Physic, University of Cambridge. His research interests centre on the immunology of renal and vascular disease. His major contributions to British medicine have been through the promotion of clinical research. He is currently a Senior Consultant in Research and Development for GlaxoSmithKline.

Archie Cochrane (1909-1988)

Archie Cochrane was a Scottish doctor who joined the MRC's Pneumoconiosis Unit at Cardiff in 1948, carrying out studies of Welsh coal miners. With the demise of pneumoconiosis, the unit became the MRC Epidemiology Unit.

Between 1960 and 1969, he was the Davis Professor of Tuberculosis and Chest Diseases at the Welsh National School of Medicine, now Cardiff University School of Medicine. Archie's experiences during the Spanish Civil War, when he served as a member of a British Ambulance Unit, and later as a Medical Officer during World War II, convinced him that many medical treatments were ineffective and indeed some were harmful.

He became a passionate proponent of the scientific method in medicine. Archie was messianic in his belief in the value of the randomised controlled trial and he laid the foundations of what we now know as 'evidence-based medicine'. He went on to establish the Cochrane Library of Systematic Reviews and the International Cochrane Collaboration.

Sir Brian Greenwood

Sir Brian Greenwood is an expert in tropical medicine and is currently Manson Professor of Clinical Tropical Medicine at the London School of Hygiene and Tropical Medicine. In 2012, he received a knighthood for his work tackling malaria in Africa. He demonstrated the efficacy of bednets impregnated with insecticide in preventing malaria. By this expedient, the lives of millions of people have been saved.

The LMB

The Laboratory of Molecular Biology (LMB) opened in Cambridge in 1962 and is today one of the world's leading research institutes. The work carried out there has resulted in nine Nobel prizes so far (shared among 13 researchers), awarded to some remarkable scientists, from Crick and Watson, through Kendrew and Perutz, Sanger, Klug, Milstein and Köhler, Walker, Brenner, Horwitz and Sulston to Ramakrishnan. Their work is just a fraction of the output of this facility whose research has led to many of the techniques and disciplines we routinely employ in biomedical science today.

The Human Genome Project

My involvement with this project included a presentation I had to make to Margaret Thatcher in 1988. I told her that we were

DISCUSSION

The use of patient data

It is vital that public confidence in the use of patient data is maintained. The potential advantages of the NHS as a research resource are obvious. When the public is effectively engaged they are overwhelmingly positive about the use of their data to support the public. It is essential to provide reassurance that patient data will be handled safely. This will depend on effective systems and clear, positive communications.

DISCUSSION

Breaking down institutional barriers

More emphasis should be placed on multidisciplinary, cross-organisational working. There should be more movement between academia and industry, as well as more co-funding of posts. A positive example has been set by the Office for Strategic Coordination of Health Research, which coordinates the work of the MRC and the National Institute for Health Research. Yet there is still undoubtedly more progress to make in breaking down institutional barriers.

ready to proceed with the identification and mapping of human genes. I added that this would not cost very much and that the resulting database would become the central tool for basic and applied research in the medical sciences. The first part of that statement may not have been borne out in practice, but the second certainly was.

Cancer

A good example of the achievements of the MRC is the diagnosis and treatment of cancers. Cancer, being a genomic disease, is very amenable to genomic investigation. We can now produce a 'genomic signature' that provides a prognosis for the patient. However, it is not as simple as it may seem. Applying genomic technology to what appears to be a simple condition such as breast cancer reveals that it is actually made up of multiple cancers. This is a great challenge in terms of treatment.

There have been significant successes in treating cancer, however, such as the discovery of the BRAF mutation inhibitor in malignant melanoma and the subsequent therapeutic use of BRAF inhibitors in the treatment of melanoma. BRAF inhibitors are among the great recent advances in cancer therapy.

We know that cancer is heterogenous. One cancer can have seven mutations in it. The mutations may be different in the metastases and it is not practical to biopsy the cancer tumour in several places, nor is it practical to biopsy (in most cases) the metastases.

Recent work in Cambridge has led to the development of a non-invasive method that measures DNA in the plasma of cancer patients. This is a low-cost, high-throughput method of personalised cancer genomics that is essentially a liquid biopsy. I mention this to illustrate the point that medicine is, and always has been, dependent upon technological advances.

Age-related macular degeneration

Another good example of the use of genomics in medicine is age-related macular degeneration, which is the commonest cause of blindness in older people. Until recently there was no treatment for it. Through genomics we discovered something very surprising, namely that there was polymorphism of a factor in the blood of the complement system. This had not been linked with eye disease, but the discovery ignited a frenzy of activity by the biotechnology industry in a search for anti-complementary drugs. This is an excellent example of the unlikely way that medicine advances.

Genomic signatures

Finally, another example of the fruits of genomics. We were all brought up to believe that disease was a mixture of genetic susceptibility and environmental influences. However, work in Cambridge has led to the discovery that your genome is a determinant of your prognosis in particular diseases. It was found, extraordinarily, that in four quite disparate diseases – vasculitis, ulcerative colitis, systemic lumpus erythematosus and Crohn's disease – if you have one genomic signature you do well, and if you have another genomic signature you do badly. This discovery has important implications for the planning and conduct of clinical trials.

Experimental medicine in the future

It is clear that the future depends on extending our knowledge of human biology through experimental medicine – by which I mean the intensive study of small numbers of patients with all the technology at our disposal.

To achieve this we need to strengthen the links between our academic and industrial institutions – both sides need it. The drug discovery pipeline is not as healthy as one might expect, considering the investment in underpinning biomedical science.

I will close with a quote from Sir Harold Himsworth KCB MD FRCP FRS, late Secretary and Deputy Chairman of the Medical Research Council: "The idea that it is in the best interests of a country that research (as distinct from development) should be established independently of political interest or administrative commitment is not one that would normally occur to those concerned with machinery of government, even though it is but the translation into the scientific sphere of the time-honoured caution that no man should be judge of his own case." ❐

Intellectual curiosity and discovery

Speaking after dinner, **Sir John Savill,** the MRC's Chief Executive, thanked the speakers for their contributions and thanked the Foundation for marking the centenary of the MRC in such a way. He welcomed the speakers' emphasis on the need to study human biology. What they had demonstrated, he said, individually and collectively, working with the MRC, was the enduring importance of intellectual curiosity and flexibility, alongside a long term commitment to medical science. Sir John also paid tribute to the present Government's commitment to support the direction set by its predecessors, not least in respect of ring-fencing the science budget.

Science Minister **David Willetts** recalled that Henry VIII had established the system of regius professorships at Oxford and Cambridge; Charles II had given the Royal Society its charter; and Lloyd George had passed the legislation which led to the creation of the MRC. The achievements of these three statesman were reflected in the continued contributions of the universities, the Learned Societies and the Research Councils to the rich, diverse and open culture of intellectual inquiry and discovery from which this country still benefited.

This was something to be celebrated and gave us precious advantages in science and research, which we can still exploit internationally, particularly if we could maximise the use of large scale, accessible datasets. This will require international collaboration which the Government is actively pursuing.

The Earl of Shannon

23 October 1924 — 9 May 2013

Richard Bentinck Boyle, Ninth Earl of Shannon, was the first Chairman of the Foundation for Science and Technology. He was asked to become Chairman of the Science Centre Project Committee on the death of its original Chairman, Professor Bob Payne, in 1977. At that time, Richard ran the Committee of Directors of Research Associations, and it seemed appropriate that he should have an involvement in establishing a science centre in London. This would be a place where smaller and newer learned societies could find accommodation and share office facilities.

Lord Shackleton provided him with contacts to visit the well-established Clunies Ross Centre in Melbourne, Australia, and the Science Centre in Sydney.

On 31 August 1977, the Committee established the Foundation for Science and Technology, a registered charity, with the Science Centre as its 'working arm'. Richard became the first Chairman and the Foundation arranged a short-term lease on a 10-room house attached to the Royal Society of Arts.

Richard was enormously helpful and supportive to me, the first Director, in the appeal for funds. However, the Centre itself was loss-making and had to rely on support from industry as well as from generous grants from the Commonwealth Foundation, the Royal Society and other institutions. The appeal failed to raise the required sums and the Foundation adapted its role to its current one, while at the same time continuing to act in support of Learned Societies. Richard's six year chairmanship came to an end in 1983 when the Lord Lloyd of Kilgerran succeeded him. He remained a Vice President of the Foundation until his death.

Though his original vision of a London Science Centre could not be realised, the Earl of Shannon nonetheless set the ball rolling for what has become a highly successful organisation. □

David Hall

Recent dinner/discussions organised by the Foundation for Science and Technology are listed below. Summaries of these and other events – as well as the presentations and recordings of the speakers – can be found on the Foundation website at: www.foundation.org.uk

Raising the bar - can learned societies and professional institutions particularly the engineering institutions do more to contribute to economic growth?

24 September 2013

Professor Tim Broyd FREng FICE, Vice-President, Institution of Civil Engineers
Professor Jeremy Watson CBE FREng FIET, Vice-President and Trustee, The Institution of Engineering and Technology (The IET)
Patrick Kniveton FIMechE FIET, President, Institution of Mechanical Engineers
Professor John Uff CBE QC FREng FICE, Barrister, Keating Chambers [panellist]

Maximising the use of public data - should research and publically acquired data be made more accessible?

10 July 2013

Professor Geoffrey Boulton OBE FRS FRSE, Chair, Royal Society Inquiry into Science as an Open Enterprise
Professor Sir Nigel Shadbolt FREng, Chairman and Co-Founder, The Open Data Institute
The Rt Hon David Willetts MP, Minister of State for Universities and Science, Department for Business, Innovation and Skills
Professor Sheila M Bird OBE FRSE, Programme Leader, MRC Biostatistics Unit, Institute for Public Health, Cambridge [Panellist]

Can university-business collaboration be used to maximise short-term economic growth and reduce unemployment levels in Wales?

3 July 2013

Professor Colin Riordan FLSW, President and Vice-Chancellor, Cardiff University
Sir Leszek Borysiewicz FRS FRCP FMedSci FLSW, Vice-Chancellor, University of Cambridge
Sir Terry Matthews OBE FREng, Chairman, Wesley Clover
Edwina Hart MBE CStJ AM, Minister for Economy, Science and Transport, Welsh Government

Cities of the future — science, innovation and city management

19 June 2013

Steve Quartermain, Chief Planner, Department for Communities and Local Government
Sir David King KB ScD FRS HonFREng, Chair, Future Cities Catapult
Richard Bellingham, Director, Institute for Future Cities, Strathclyde Business School, University of Strathclyde
Sir Mark Walport FRS FMedSci, Government Chief Scientific Adviser, Government Office for Science

Celebrating the centenary of the establishment of the Medical Research Council - What should be the research priorities for medical research over the next twenty-five years?

22 May 2013

Dr Sydney Brenner CH FRS, Senior Distinguished Fellow, Crick-Jacobs Center, Salk Institute for Biological Studies
Sir Paul Nurse PRS FMedSci HonFREng, President, The Royal Society and Director, Francis Crick Institute
Sir Keith Peters FRS FMedSci FRCP FRCPE FRCPath FLSW, Emeritus Regius Professor of Physic, University of Cambridge
Dame Kay Davies DBE FRS FMedSci, Director, MRC Functional Genomics Unit and Associate Head of Division of Medical Sciences, Department of Physiology, Anatomy and Genetics, University of Oxford (*panellist*)
Sir John Savill FRS FMedSci FRSE FRCP, Chief Executive, Medical Research Council
Rt Hon David Willetts MP, Minister of State for Universities and Science, Department of Business, Innovation and Skills

The Armitt Review of the UK long-term infrastructure project pipeline

16 April 2013

Sir John Armitt CBE FREng, Chair, The Armitt Review of the UK Long-Term Infrastructure Project Pipeline
Professor Brian Collins CB FREng, Head, Department of Science, Engineering, Technology and Public Policy, University College London
Tim Yeo MP, Chair, House of Commons Select Committee on Energy and Climate Change

Open Access - the Finch Working Group report on expanding access to published research findings

6 March 2013

Dame Janet Finch DBE DL AcSS, Chair, Working Group on Expanding Access to Published Research Findings
Professor Douglas Kell, Chief Executive, Biotechnology and Biological Sciences Research Council (BBSRC)
Steven Hall, Managing Director, IOP Publishing

Threats and opportunities - scientific challenges of the 21st Century

6 February 2013

Professor Sir John Beddington CMG FRS FRSE HonFREng, Government Chief Scientific Adviser, Government Office for Science
Dame Sally Davies DBE FMedSci, Chief Medical Officer and Director General of Research and Development, Department of Health
Sir Mark Walport FRS FMedSci, Government Chief Scientific Adviser Designate and Director, The Wellcome Trust

Science, Innovation and International Development

5 December 2012

Professor Chris Whitty FMedSci FRCP FFPH, Chief Scientific Adviser, Department for International Development
Mme Geneviève Fioraso, Secretary of State for Higher Education and Research, Government of France (Professor Cyrille van Effenterre from the French Embassy spoke on behalf of the Minister)

The contribution of mid-sized companies to the growth of the economy

26 November 2012

Dame Nancy Rothwell DBE FRS FMedSci, President and Vice-Chancellor, University of Manchester
Tera Allas, Director General for Economics, Strategy and Better Regulation, Department for Business, Innovation and Skills
Professor Luke Georghiou, Vice-President for Research and Innovation, University of Manchester
Richard Burslem, Site Director, Wallwork Heat Treatment Ltd

Delivering the industrial strategy - how can government promote growth?

14 November 2012

Sir John Parker GBE FREng, President, The Royal Academy of Engineering
Professor Alan Hughes, Director, Centre for Business Research, Judge Business School, University of Cambridge
The Rt Hon David Willetts MP, Minister of State for Universities and Science, Department for Business, Innovation and Skills

Energy policy: selecting the right options for future electricity supply

7 November 2012

John Hayes, MP for South Holland and The Deepings, Minister of State for Energy, Department of Energy and Climate Change
Dr Andrew Spurr, Managing Director, Nuclear Generation, EDF Energy
Dr John Loughhead OBE FREng, Executive Director, UK Energy Research Centre
Dr Paul Golby CBE FREng, Former Chairman and Chief Executive, E.ON UK (*panellist*)

What are the best ways to promote a culture of enterprise and innovation in Scotland?

25 October 2012

Ian Ritchie CBE FREng FRSE FBCS, Vice President, Business, Royal Society of Edinburgh
Professor Peter Downes OBE FRSE, Principal and Vice-Chancellor, University of Dundee
Phil Smith, Chairman, Technology Strategy Board, and Chief Executive Officer, UK & Ireland, Cisco

An ageing population: meeting the challenge of caring for the rising number of dementia patients

3 October 2012

Dame Sally Davies DBE FMedSci, Chief Medical Officer, Director General Research and Development, and Chief Scientific Adviser, Department of Health
Professor Julienne Meyer, Professor of Nursing: Care for Older People and Director of the My Home Life Programme, City University
Professor James Goodwin, Head of Research, Age UK
Jan Hall, Founder Member, The Evington Initiative

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