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THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

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New resource for life sciences

The Wellcome Trust is creating a new business that will invest in emerging businesses and technologies in the healthcare and life sciences sectors. The business's initial capital will be £200 million, drawn from the Wellcome Trust's endowment. The business is currently operating under the working title Project Sigma, and a name and brand identity will be announced shortly.

Sigma will be a directly owned and managed business that will seek to deliver attractive returns on the capital it invests. Sigma will give the Wellcome Trust an additional opportunity to identify and invest in promising healthcare businesses, which will typically be at an early stage in their development with significant potential to grow.

Sir Mark Walport, Director of the Wellcome Trust, said: "The Wellcome Trust is known as an investor that takes a long-term view. Sigma will extend this successful approach to direct investments in emerging healthcare technologies, to give small and medium-sized companies the support they require to fulfil their potential."

www.wellcome.ac.uk

Tackling consumption and population

The most developed and the emerging economies must stabilise consumption levels, then reduce them, to help the poorest 1.3 billion people to escape absolute poverty through increased consumption according to a new report from The Royal Society. Alongside this, education and voluntary family planning programmes must be supported internationally to stabilise global population. The report, *People and the Planet*, is the result of a 21 month study.

Sir John Sulston, Fellow of the Royal Society and Chair of the report working group, said: "The world now has a very clear choice. We can choose to address the twin issues of population and consumption. We can choose to rebalance the use of resources to a more egalitarian pattern of consumption, to reframe our economic values to truly reflect what our consumption means for our planet and to help individuals around the world to make informed and free reproductive choices.

"Or we can choose to do nothing and to drift into a downward vortex of economic, socio-political and environmental ills, leading to a more unequal and inhospitable future."

http://royalsociety.org/policy/projects/people-planet/report

Managing the risks of hydraulic fracturing

The Government has published an independent expert report recommending measures to mitigate the risks of seismic tremors from hydraulic fracturing - and is inviting public comment on its recommendations. See also page 23 of this issue.

An effective monitoring system and a traffic light control regime are among measures recommended. The report, from the Department for Energy and Climate Change (DECC), confirms that minor earthquakes detected in the area of the company's Preese Hall operations near Blackpool in April and May last year were caused by fracking carried out by energy company Cuadrilla.

DECC's Chief Scientific Advisor David MacKay said: "This comprehensive independent expert review of Cuadrilla's evidence suggests a set of robust measures to make sure future seismic risks are minimised - not just at this location but at any other potential sites across the UK."

The study recommends:

- the hydraulic fracturing procedure should include a smaller pre-injection and monitoring stage;
- an effective monitoring system to provide near real-time locations and magnitudes of any seismic events should be part of any future hydraulic fracturing operations;
- future hydraulic fracturing operations for shale gas should be subject to a 'traffic light' control regime, similar to that recommended by Cuadrilla's consultants. A red light at activity levels of magnitude of 0.5 or above means fracking should be stopped and remedial action taken (this is lower than the magnitude 1.7 proposed by Cuadrilla's report). Unusual seismic activity, even at lower levels, should be carefully assessed before operations proceed.

The Royal Society is also undertaking a review, jointly with the Royal Academy of Engineering.

http://og.decc.gov.uk/en/olgs/cms/explorationpro/onshore/cuadrilla_decc/cuadrilla_decc.aspx
http://royalsociety.org/news/shale-gas-review-launch

Investment at the Hadley Centre

£60 million of investment in the Met Office Hadley Centre's Climate Programme has been announced, aimed at maintaining the UK's place as a global leader in climate research and modelling.

Nearly £50 million of funding is being committed to a programme of research and modelling until 2015. This investment will significantly enhance the evidence available to Government, supporting both mitigation and adaptation actions and will build upon the Met Office Hadley Centre's strong collaborations with UK academic science.

Over £11 million of new High Performance Computing (supercomputing capacity and associated hardware) will be provided to underpin this programme of research. This significantly enhances the Met Office Hadley Centre's capability until 2015 and is a response to the recommendation of the Government Chief Scientific Adviser.

New centre for Carbon Capture and Storage

The Engineering and Physical Sciences Research Council (EPSRC) and the Department of Energy and Climate Change (DECC) are jointly undertaking a £13 million investment to establish a UK Carbon Capture and Storage (CCS) Research Centre. This forms part of the Research Councils UK (RCUK) Energy Programme which is led by EPSRC.

EPSRC will invest £10 million over a five-year period, with funding of £3 million from DECC, to establish new capital facilities that will support innovative research. DECC has also launched its CCS Commercialisation Programme and Roadmap which sets out the Government's vision for achieving commercial deployment of CCS in the UK in the 2020s, including investing £125 million in CCS research and development between 2011-2015.

The new Centre, which will have its coordination base at the University of Edinburgh, will bring together over 100 of the UK's world-class CCS academics and provides a national focal point for CCS research and development. The Centre will be a virtual network where academics, industry, regulators and others in the sector can collaborate on analysing problems and undertaking world-leading research. A key priority will be to support the UK economy by driving an integrated research programme that is focused on maximising the contribution of CCS to a low-carbon energy system for the UK.

www.epsrc.ac.uk
www.decc.gov.uk/en/content/cms/emissions/ccs/demo_prog/demo_prog.aspx

Arts, Humanities and Social Sciences

John Enderby

Professor Sir John Enderby CBE FRS is the Editor of *FST Journal*. He was Professor of Physics at Bristol University from 1976 to 1996. He was elected a Fellow of the Royal Society in 1985 for his pioneering studies into the structure and properties of liquids and amorphous materials. He served as a Vice-President of the Royal Society from 1999-2004. One of his responsibilities was the Society's publishing activities. Sir John was President of the Institute of Physics in 2004. He was the Chief Scientist at IOP Publishing.

Readers might think it odd that the Editor (a physicist) of a journal primarily concerned with Science and Technology should stray into territory more properly covered by the British Academy and the relevant Research Councils. I hope to convince you that the success of Science and Technology depends crucially on the Arts, the Humanities and the Social Sciences (AH&SoSc).

The starting point of my thinking on this was an article by Ben Macintyre in *The Times* some months ago. He described the impact of a fringe group, the Kilburn Tricycle Theatre, in performing *The Great Game*, a series of plays depicting Afghanistan's turbulent past.

Nothing unusual there, you might say. What caught my eye, though, was the effect the series had on General Sir David Richards, who is Chief of the Defence Staff. He is quoted as saying, "If I had seen this series of plays before I had deployed myself in 2005, it would have made me a better commander".

This is a truly remarkable statement. Here is a most distinguished soldier who has achieved the highest possible position in the British Army. He has had vast operational experience and was both a student and an instructor at the Staff College, Camberley. As preparation for high office, he undertook the rigorous Higher Command and Staff course. Nevertheless, it was a *theatrical* experience and not further courses on strategy, tactics and logistics that, in his own words, had the potential to make him a better commander. Not a better person but, in the strictest military sense, a better commander.

Now that statement is highly relevant to the theme of this Editorial. I have long believed that First World War poets like Siegfried Sassoon and Wilfred Owen influenced senior military men – through their poetry – as the military strategists rethought their tactics in order to eliminate the horrors of trench warfare. Sir David's remarks substantiate my belief.

Great works of art, novels, poetry and plays are not only of value in their own right but, by illuminating the human condition, they impact in a direct way on other disciplines. Sir David's example is but one where this synergy is manifested. Another example of the power of the performing arts was Jeremy Sandford's 1966 TV play *Cathy Come Home*. This did more than any other activity to raise awareness of homelessness and even provoked discussions in Parliament. The subsequent success of the charity Shelter owes much to this broadcast.

Marrying art and science

The death of Steve Jobs reminded us that he was, to quote a headline from *The Times* (7 October, 2011), "a genius who married art and science to place the world at your fingertips". Fred Anderson, a former CFO of the Apple Corporation said that: "Jobs understood the importance of combining Art and Science in the creation of truly innovative products."

Interestingly, it was a British engineer, Sir Monty Finniston, who, in a 1980 report, wrote of the 'Engineering Dimension'. Finniston argued that to translate science, via good engineering, into economic benefit required an appreciation of the market environment and this would include design, appearance and a deep understanding of the customer base. In short, as most practising industrial engineers have long recognised, the very skills which those trained in the arts, humanities and social sciences bring to the table are essential components of successful innovation.

There is increasing concern that the necessary skill base in design might be squeezed out as an unintended consequence of changes in FE and HE funding and the school curriculum. To address these issues, the Associate Parliamentary Design and Innovation Group has asked Vicky Pryce and Baroness Whitaker to co-chair an enquiry into the role of design education in promoting innovation.

I suspect that we are still too influenced by C P Snow's 'two cultures' analysis of contemporary society, yet it is surely time to embrace the idea that the Arts and the Sciences are cousins. The early Fellows of the Royal Society, for example, would not have recognised Snow's analysis. Their world view was informed by classical philosophy which held, for example, that natural phenomena, music and number theory are intimately related. A graduate in the History of Art need not know the precise formulation of the Second Law of Thermodynamics (the example always quoted by followers of Snow). What really matters is that he or she should understand why scientists worry about it.

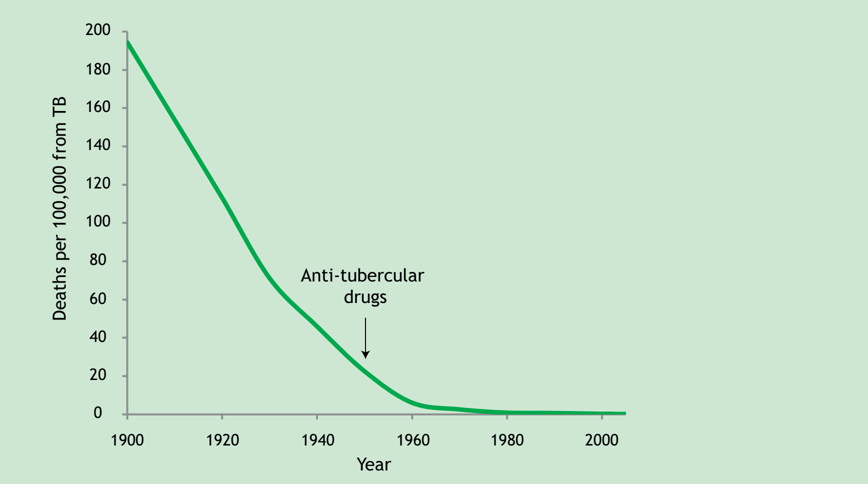


Figure 1. Deaths per 100,000 from TB (US figures).

Likewise a Physics major might not fully understand the significance of the Punic Wars but should respect those scholars who draw conclusions from the wars in terms of the nature of power and human behaviour. In a recent speech, the President of the British Academy, Sir Adam Roberts, challenged "the sterile and outdated notion of a society of two cultures" and drew attention to the increasing mutual dependencies of the natural sciences with the humanities and social sciences in responding to the major social challenges of our age.

What are these major challenges to which Sir Adam refers? Let me give two examples as illustrations of the necessary synergy between Science and Technology on the one hand and the Arts and Humanities on the other.

New and old diseases

The first 'new' disease which hit the headlines in the early 1980s was Aids, the cause of which was soon established to be the Human Immunodeficiency Virus (HIV). 'New' is in fact a misnomer as HIV is now known to have existed for decades in sub-Saharan Africa, but changes in social and sexual behaviour, combined with relatively low cost travel, led to its emergence in the West. Other examples include swine flu (H1N1) and the new strains of TB which have proved to be highly resistant to anti-tubercular drugs.

To deal effectively with these diseases clearly needs the intervention of medical science in the form of anti-viral drugs and other therapies. Yet these will fail if social, economic and cultural contexts are ignored. While the worldwide pandemic of Type 2 diabetes will certainly make demands on medical science, we will be missing a trick if we fail to spot that the Arts could play a role in raising public awareness of the danger of obesity. With diabetes costing the NHS £286 every *second* and a predicted case load of four million in the UK alone by 2025, it is surely a 'no-brainer' to ask the AH&SoSc community how their particular expertise could best contribute to solving a growing problem.

Without in any way wishing to downgrade the role of new therapies and drug developments, it is interesting to look at the historic changes in mortality rates for TB (Figure 1). These are figures from the USA but essentially the same trend has occurred in the UK.

Changes in social awareness, better diet and housing led to the dramatic fall between 1900 and 1950. Much of the thinking behind these came from social scientists. The new drugs were undoubtedly of huge benefit in essentially eliminating the disease in the UK, but nature has a knack of finding ways round our best efforts and new strains of *mycobacterium tuberculosis* are sadly becoming a serious problem, particularly in developing countries.

Public acceptance of new technologies

This huge field includes the application of biotechnology to food production (GM for short), therapies based on stem cells, genetically informed medicine and nuclear power. Most scientists believe that if we are to address the acute problems facing the world such as food and water security, the challenges of population growth and the effective use of resources, major interventions at the scientific and technological are necessary and, moreover, all of the above have a role to play.

Yet such technologies are viewed with suspicion by a significant fraction of the world's population. This is particularly true for GM so far as Western Europe is concerned. The European Parliamentary Technology Assessment Group concluded that "for the time being, there is little indication of an increase in overall acceptance. While it is possible that public perception will change as new consumer-oriented GM products become available, this cannot be taken for granted." Advocates for GM are largely drawn from the scientific and commercial sectors, thereby opening themselves to the totally unfair criticism "Well they would say that, wouldn't they?"

Clearly more work needs to be done: there is the danger that, for example, stem cell therapies might suffer from a similar lack of public support. Again, it is surely a no-brainer to encourage colleagues from the AH&SoSc community to become involved and indeed to campaign for adequate funding. An illustration of what can be achieved can be seen in the work of artist Gina Czarnecki, which is currently being exhibited at the Bluecoat Artistic Hub in Liverpool. Gina makes films, installations, public art works and sculpture which emphasise human relationships to disease, evolution and genetic research.

Wasted is a series of sculptures that explore the use of human tissue in art, the life-giving potential of 'discarded' body parts and their relationship to myths and history. The works draw attention to timely concerns such as stem cell research and issues surrounding the process of informed consent.

Palaces is a resin sculpture with participatory artwork made from thousands of milk teeth donated by children around the UK and was jointly commissioned by Bluecoat and Imperial College.

A crucial role

It is evident that subjects outside the natural sciences are highly relevant to scientific and technological innovation. Products must be well-designed, user-friendly and reflect the cultural norms of the customer base. Likewise, changes in patterns of behaviour which are necessary to gain full benefit from new technologies and medical interventions need to be encouraged. Above all, technologies must command wide acceptance of the benefit they bring to society generally. This requires a deep understanding of the historical, cultural, economic and geographical context of the relevant societies.

Our friends and colleagues from the AH&SoSc community could, if properly resourced, play a crucial role as the challenges facing mankind become ever more acute. It is of direct importance to STEM subjects that this is fully recognised. ☐

How should the Government, the Research Councils and Technology Strategy Board focus their resources to maximise economic growth? The question was debated in the light of the recent publication of the Government's innovation and research strategy at a meeting of the Foundation for Science and Technology on 1 February 2012.

The intrinsic connection between research, innovation and growth

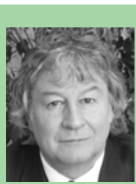
Adrian Smith

Since the last spending review, the Government has put nearly half a billion pounds of new capital into science and technology, into initiatives such as: the Institute of Animal Health; high-powered computing and e-infrastructure; and the commercialisation of graphene. It has been hugely supportive of science and research but, of course, against the background of a very difficult economic and fiscal position.

How has that investment been justified? Well, the UK has to take account of what is happening in the rest of the world. There is a great deal in the news about the economies of China and India, but less of Russia, Mexico, Indonesia and others which are also expanding. There has been an acceptance on the part of Treasury that even in the current economic circumstances it is vitally important to invest in science and technology.

We are not alone: in the USA President Obama has singled out research and innovation as key areas in which to invest. On the other side of the world, China is making huge investments in this area. Underlying these decisions is a substantial evidence base relating economic growth to investment in R&D and innovation.

R&D is an important part of the wider story. Looking at global investment, this is increasing at a rapid rate in China and the USA but not so fast in the UK (Figure 1). So, is this a disaster? Well, even if in recent years this country has not kept pace with others, one proxy for output (citations or the most cited citations) per pound invested, shows that the UK has been remarkably productive. A priority now is to sustain that in the face of the financial investment being made elsewhere.



Professor Sir Adrian Smith FRS is Director General, Knowledge and Innovation, Department for Business, Innovation and Skills (BIS), where he leads on all aspects of policy relating to research, innovation and higher education, including funding, science in society and women in science. Previously he was Principal of Queen Mary, University of London. Prior to this he was Professor of Statistics, Head of the Department of Mathematics, Member of the Management and Planning Group and a Company Director of ICON (the Imperial College Consultancy).

Innovation

Now while science and research are concerned with a great deal more than short term, economic growth, for Government the economy – including growth and jobs – is a primary focus. Innovation is a key driver of our policies. When enterprises are engaged in any one of the following they are described as 'innovation active':

- introducing a new or significantly improved product (good or service) or process;
- investing or engaging in:
  - internal R&D, training, design
  - acquisition of capital goods for the purpose of making new products or improving processes
  - acquisition of external knowledge;
- engaging in development projects that have neither been completed nor abandoned.

Innovation does not always occur in high-tech areas – there is a great deal in engineering-based manufacturing, but also in retail and distribution as well as construction (Figure 2). Engagement is not purely concerned with research: there is a whole host of ways in which business engages with academia and it may be through meetings, joint research or consultancy. Indeed, there is a whole 'ecosystem' of inter-relationships between universities, businesses and those who fund research (the Research Councils, Technology Strategy Board, etc).

A strategy

The recent *Innovation and Research Strategy for Growth*[1] published by BIS had five strands: discovery and development, innovative businesses, knowledge and innovation, global collaboration, and challenges. Under 'discovery and development' come what were originally called Technology and Innovation Centres, now re-branded as 'Catapults': centres to support technology commercialisation, bridging the gap between academia and business. The Catapults have been announced in the following seven technology areas: High Value Manufacturing (operational Oct 2011); Cell Therapy (operational in 2012); Offshore Renewables (operational in 2012); Satellite Applications; the Connected Digital Economy; Future Cities; and Transport Systems. The network will be fully operational in 2013.

The Strategy also identified emerging technologies where it is believed there is an opportunity for the UK to become the global leader in their development. There will always be debates about picking

DISCUSSION

The international dimension

UK universities are very internationally minded, with large numbers of students and staff from overseas on UK campuses. There are also some successful campus ventures in a number of overseas countries. However, the Government's inward investment initiatives may have underplayed the importance of the UK's knowledge and research base as well as the strengths of the UK university sector. Action is now in hand through Trade and Investment to address that.

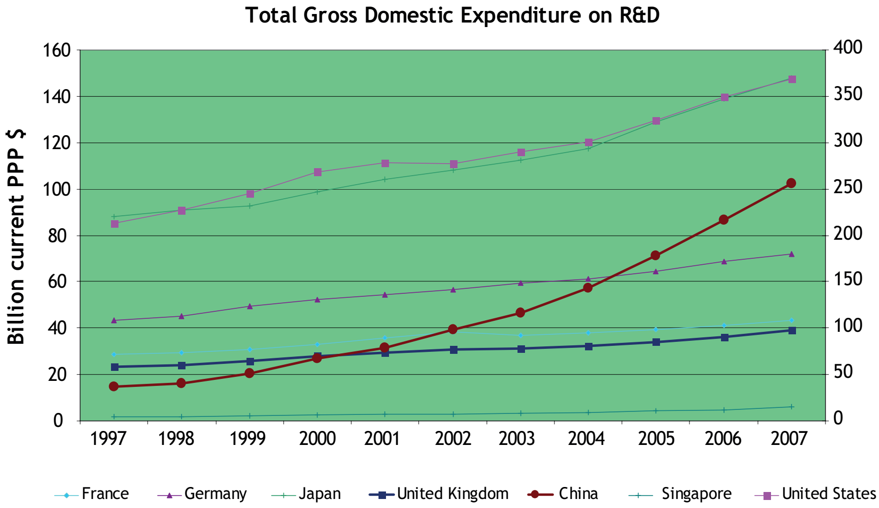


Figure 1. Total gross domestic expenditure on R&D (USA on right axis)

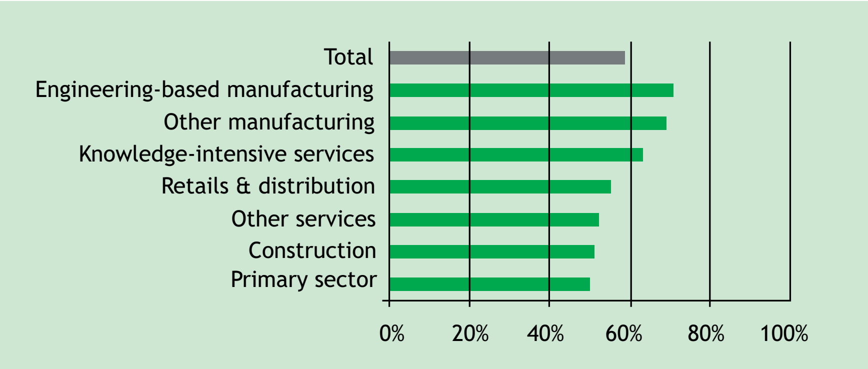


Figure 2. Highly innovative firms are found in all industries and regions. Proportion of innovation-active enterprises in the UK by sector 2006-2008.

winners; it has become a pejorative phrase which is odd because with limited resources choices have to be made. The aim of the current initiative is to underpin growing technologies – synthetic biology, energy efficient computing, energy harvesting, nano-technology – those that are going to be important in the future.

Further investment

The Autumn Statement announced further investment for innovative businesses: £75 million is going into various programmes for small companies, there is an expansion of the R&D Tax Credit scheme, as well as funding for a Future Cities demonstrator. The Small Business Research Initiative (SBRI) has historically produced excellent returns, so there will be continued investment here as well.

More generally, the Government recognises that geographical clusters with critical mass – where new companies can grow near, and interact with, great university departments and scientific facilities – are highly desirable. One barrier to working together has been the way that joint companies were liable for 20 per cent VAT: efficiency savings would have to be at least 21 per cent for the project to work. At last the Treasury has been persuaded to exempt universities and charities from this.

There is a saying that 'he who out-computes, out-competes'. So, in terms of the 'knowledge and innovation' agenda, the Government will continue to invest heavily in high-powered computing and the e-infrastructure that goes with it.

Global collaboration

On global collaboration, the UK must ensure that it fully exploits its links with partners who are making massive investments. This is not just with countries like India, for example, but also within the EU, where the Horizon 2020 programme will succeed the current framework programmes. There is a great deal activity on this agenda, such as that between the Research Councils and China to take just one example.

Open access, open data, open publication, getting data and ideas freely out there – addressing all these challenges will encourage innovative business, so the Government will be focussing on these areas. This will include the largely untapped potential of public procurement as a driver of innovation.

Universities

The universities are fundamental in all of this. They are, after all, where most of the research funding goes. They are where bright people work, where they come from and where the interaction with industry happens. There have been a number of recent initiatives that bring together innovative areas of the economy with universities: the Maritime Centre at Southampton; the links between Strathclyde and renewable energies; and the very strong links built up over a number of years between the automotive industry and Warwick Manufacturing Group.

An ecosystem

There is an ecosystem of funders, universities and business. Commitments of £500 million since the Spending Review demonstrate Government's support for this approach. David Willetts, the Minister of State for Universities and Science, restated that the Government wants to do everything possible to make the UK the best place in the world to do research.

So let us get more universities into the world's top 100. Let us also encourage more thinking between private providers, industry and other existing institutions in order to see if there are any alternative models that might give even better results. ☐

1. www.bis.gov.uk/assets/biscore/innovation/docs/i/11-1387-innovation-and-research-strategy-for-growth.pdf
www.bis.gov.uk/assets/biscore/innovation/docs/e/11-1386-economics-innovation-and-research-strategy-for-growth.pdf

DISCUSSION

Learning from other cultures

The apparently greater success of other countries, such as Germany and Japan, in translating innovation into commercial success was raised. Yet surely it is unrealistic to think that systems and structures which reflect cultural characteristics specific to other countries can simply be imported and emulated in the UK. It is more sensible to ensure that the UK learns from other countries and uses that knowledge to make the UK's own system work even more effectively.

Business and universities in partnership

Tim Wilson

One of the initial problems in conducting my review of business-university collaboration[1] lay in defining its scope: the interactions between universities and business are very diverse. Universities do a great deal of work with the public sector and other sectors within our economy, but it is the interface with wealth-creating business which was the focus of my review.

Although the definition of a university is fairly straightforward, there are many more institutions accredited to award degrees in this country than just universities: private sector education providers and some FE colleges. The review therefore covered all of these institutions.

Landscape and domain

Many research academics – and equally many research people within business – work in their own domains, developing new technologies, innovating and creating wealth. This work is well recognised. Yet there are many other domains within the overall university/business landscape: supporting undergraduates forming their first new business, encouraging entrepreneurship, developing enterprise and employability skills. Upskilling our workforce through work-based learning is a further example of university/business collaboration, as is the provision of internships and placements.

Diversity is a fundamental strength of the sector. No one university can cover all domains within that landscape – it is simply impossible and, indeed, not desirable. But, for an excellent system of collaboration, all domains within the entire landscape need to be excellent.

To achieve that excellence, collaboration between universities is vital. When a business approaches a university and asks for a service, a simple answer of 'no we don't do that' is simply not good enough. There are far too many examples of 'unresponsive' universities; not because they actually do not respond, but because when asked they neither offer what the business requires, nor refer the business somewhere else. Without inter-university collaboration, we cannot achieve excellence.

Professor Sir Tim Wilson DL was Chair of the Wilson Inquiry into University-Business Collaboration. He held the post of Vice-Chancellor of the University of Hertfordshire from September 2003 to December 2010. A strong advocate of the role of universities in economic development, he is acknowledged as one of the leading thinkers and practitioners in university-business collaboration.

Supply chains and people development

A university is an integral, strong part of the supply chain to UK business. It supplies high-level skills, it supplies innovation, it supplies research, and it supplies enterprise as well as entrepreneurial graduates and postgraduates. The supply chain model is well-understood by most people but it is not a linear model: strong supply chains have feedback loops, involving empathy between supplier and user.

This type of supply chain is all about people and people development. There are, however, blockages that need to be removed. The situation regarding the employment of undergraduates is well publicised: the need for work-integrated learning is well-acknowledged and yet each year we see the number of students going out on placement declining. There are many reasons given but I do not accept them. The universities that are really active in sandwich courses, and which make sure their students get full year placement experience – places like Loughborough, Brunel, Bournemouth and Ulster – have student work experience in their educational genes.

This phenomenon of placement decline is far more about university culture and mission than about student motivation. The evidence is strong and compelling that undergraduates who go on a placement year are better equipped to contribute to their future employer. Additionally, more and more companies are taking interns, not just because they want the intern inside the organisation, but almost as an extended interview for future employment. Internships offer a new way of work-integrated learning.

Industry-sponsored degree programmes, although well-advertised today, are not new. Southampton Solent University and the Merchant Navy have been doing this for years. We will certainly see more company-sponsored, undergraduate degree programmes, but in the postgraduate research market too. Rolls Royce and Cranfield have their Masters portfolios, GlaxoSmithKline and Strathclyde their PhDs; these are jointly sponsored programmes and will certainly increase in number as companies become more engaged in ensuring a supply chain of high-level skills for their future workforce. They need to be encouraged and promoted.

Internships and placements need not apply just to undergraduate programmes. I have recommended there should be internship opportunities for PhD students – work outside the university should be an integral part of their programme. That also applies to post-docs – surely they should have similar opportunities?

Knowledge exchange is all about people, too. The growth of Knowledge Transfer Partnerships (KTPs) and mini-KTPs are among the successes of the last 30 years. These are excellent ways of promoting innovation and research especially in the context of SME growth.

Facilitating economic growth

The facilitation of economic growth has to be considered in the wider sense. In the knowledge-based economy of the 21st century, universities are the engines of economic growth. They are the suppliers of high-level skills, they are the suppliers of innovation, they are the suppliers of research. Frederick Terman, Dean of Engineering at Stanford, persuaded the university in 1951 to establish a 700 acre industry park on part of the campus – that is now the Stanford Research Campus. Those 700 acres, next to a university which was receiving so much investment in research, was a key reason why the 'tech industry' grew up there as Steve Jobs acknowledged in his autobiography.

DISCUSSION

Innovation in social sciences

The emphasis on science and technology could result in too little attention being given to innovation in the social sciences which could themselves produce enormous benefits for society as a whole. The BIS Strategy paper does define innovation as applying much more widely than just science and technology. There is a great deal of value to be gained by the nation from innovation stemming from social science research; this does not just benefit society in general but also businesses, for example in the field of business ethics and governance.

Now, here in the UK there is an under-utilised resource in our research universities. The facts are compelling – the UK universities have one of the best research profiles in the world. There is enormous research power in this country. Do we use it sufficiently in the context of economic growth? Do we work hard at obtaining further research from international companies into our universities? While we welcome new investment in R&D, where is the investment that is going to create jobs outside the university? Are we doing enough to build on this excellence to create more economic wealth in this country? Universities are engines for economic growth; they need to be recognised and promoted as such.

Local Enterprise Partnerships are fairly new; it has taken time to get them together. Some are doing extremely well. Look at Warwickshire and Coventry, for example, where Warwick University and Coventry University are working in partnership. Here are two excellent universities working in partnership and collaborating; not competing but complementing each other. The LEP is making a difference, working with excellent universities, working for local economic growth. It is a good exemplar for others to follow.

As LEPs are the only game in town, they must be made to work and to succeed. So my review recommends that these organisations take a significant role in the promotion of future university/business collaboration. That includes the promotion of innovation vouchers with the Technology Strategy Board. It includes a role in developing high-level skills training. It includes helping SMEs with apprenticeships and internships. The Local Enterprise Partnership is critical to the future economic health of our country; it cannot all be achieved centrally. ☐

1. www.wilsonreview.co.uk

The creative power of disruption

Andy Hopper

The enterprise culture within UK universities has seen a substantial change over the past 30 years. Today it is as good as anywhere around the world. In general, universities have three functions: teaching (which some people forget but it is important); supporting current industries; and then a 'disruptive' effect where they help to create new industries.

Professor Andy Hopper CBE FRS FREng who is Head of the Computer Laboratory at the University of Cambridge. He is an elected member of the University Council. His research interests include computer networking, pervasive and sentient computing, and using computers to ensure the sustainability of the planet. He has co-founded a dozen spin-outs and start-ups, three of which floated on stock markets.

While it is good that the Government has maintained the research budget this year in cash terms, our competitors have actually increased Higher Education R&D. Yet the UK does appear to have a large share of R&D undertaken by subsidiaries of foreign companies. A study by Hughes & Menner on the UK R&D landscape found that the country has the lowest share of government support for independent SMEs among a range of leading economies. Taking out the small companies which are subsidiaries of multinationals, only 3.5 per cent goes to SMEs – and that is a worry.

University culture has become very institutional; more like the multinationals than entrepreneurial bodies. The system of governance appears to be very conservative and constrained; at all levels it appears you have to show the outcome of what you are proposing before you get going. That is not good.

Industry is changing: there is technological change, the invasion of digital into everything and new materials as well. In the more established industries, disruption occurs in the structure of the business, through fragmentation, consolidation and so on. Importantly, there has been a loss of corporate research laboratories. I personally think this is a huge problem and a huge gamble.

The issue of Intellectual Property Rights (IPR) is very complex but oversold. Business is about selling something to somebody and that is how to make profit, not by negotiating IPR. There is, however, too much money involved in IPT; just try paying a patent for a lifetime as an SME – it is almost impossible.

Capital is expensive but it is interesting to compare venture capital (VC) and Angel funding. Angel funding for SMEs, in particular in the UK, has done rather well. The amounts of money are smaller – £1-2 million in general, but this tool has been making money and recycling it. Fiscal schemes, like R&D tax credits, are great from an SME point of view. Yet the financial landscape within which SMEs operate is complex and, perhaps even more important, it keeps changing. Stability is crucial.

The interface

Collaboration between universities and business tends to work in one of two ways: high barrier-high cost; and low barrier-low cost. In the first, the university is encouraged to produce patents, which it then sells to companies or start-ups for as much as possible. Research prices are high, with full economic costing. It could be termed the 'turnstile' model and there is almost nothing in it for an SME. Yet it continues to operate.

In the low barrier-low cost model, the university is concerned with generating knowhow. If patents are created, these are given away – alternatively, the research is deliberately patent-free. The research is priced low. One might call that the 'revolving door' model and there is great deal of potential for SMEs in that situation. The norm at present seems to be the high barrier-high cost model but I would encourage a move to low barrier-low cost wherever possible.

The SME disruptive sector seems to work in the following way. A start-up or an entrepreneurial arm of a large company comes up with a business idea. They liaise with a university to get the very best people. Then, to generate knowhow and to understand what is happening in the academic sector, they need that research group to be as brilliant as possible. It can then be used as a 'radar mechanism' to scan the worldwide academic world and identify any disruption that might affect their business.

I was involved with the original ARM technology. Back in 1981-2, the university was designing chips and CAD. The 'radar' focussed on the idea of reduced instruction set architectures being developed in California. There were no IP rights and the business model in ARM's case was ultimately a corporate spin-out. This was very much a case of low cost innovation.

Policy

It is very important to encourage hybrid institutions which lie between industry and academia; like the Institute for Electronics, Communications and Information Technologies (ECIT) in Queen's University Belfast, for example, which is a research centre in the university with a number of development engineers.

It is worrying that the Research Councils are neither focussing on quality, nor on specific directions – this is the worst of both worlds. It is not really possible to predict what will happen in the next five or 10 years, but it is possible to make decisions based on track records. The Research Councils should employ some experts in different domains and let them make decisions about who or what to back. And be careful about how you measure this activity. Inappropriate metrics airbrush out some of these good things: for example, if you only count companies as spin-outs if the university retains a shareholding, that is going to distort the picture.

The fact that only 3.5 per cent of Government support goes to SMEs is a real problem and I would encourage tax benefits for independent SMEs. In the Netherlands, there is a scheme which allows them to delay paying tax on dividends. I would encourage investment in money-making funds, in Super Angel Funds, the Royal Society Enterprise Fund, for example.

In conclusion, stability and simplicity are crucial. I would incentivise the revolving door model rather than the turnstile model, I would be very much more cautious about measurement, I would measure less but much more wisely. I would also be very careful of innovation lists: Whitehall seems to have ideas which are not completely joined-up with the real world. ❑

A strategy for growth — a response

Ric Parker

In terms of the traditional metrics of research excellence, the UK is superb. While research excellence is a necessary precursor for innovation, though, it is not a sufficient condition. Traditional measures are dominated by citation indices and publications, not patents and products brought to market in the UK. The new strategy outlines initiatives that may start to enable true innovation.

Yet look at the challenges facing the UK. The strategy includes investment of £158 million in e-infrastructure: that is a large sum and yet is unlikely on its own to get the UK into the world's top 20 nations in this area. The issue is not just having big computers, but in UK industry having access to them. It is sad to say that today, Rolls-Royce can get greater access (and at a considerably cheaper rate) to the University of Illinois super computer than to any in the UK.

The BIS strategy is a bit light on the importance of universities to the innovation process. However, as Tim Wilson pointed out, UK universities do a superb job in bridging that 'valley of death' between research and successful commercialisation. We do not have Helmholtz Institutes or Max Plank Institutes, we have dismantled many of our corporate research centres and national research centres; so universities have to fill that gap, and many are very good at doing so.

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The strategy also propagates the myth that all innovation is carried out by SMEs and that they are without exception full of wonderfully innovative people. In reality the linkages between SMEs and large companies are also vital to innovation. The strength of the Small Business Innovation Research (SBIR) programme in the USA is that it allows large companies and small companies to join together in order to bring innovation to the market. The grant is not withdrawn if the recipient is bought by a large company, which unfortunately tends to happen in the UK.

Research investment is, of itself, a good economic stimulus. It creates jobs, it provides investment in capital and equipment. Much of this is sourced in the UK and, unlike many job-creation schemes, it has a lasting legacy in terms of intellectual property (IP), which contains the seeds of future growth. ❑

How can the research carried out in Higher Education be used to create economic growth? This was the issue debated at a meeting of the Foundation for Science and Technology on 23 November 2011.

The state of Higher Education

Richard Lambert

A flourishing Higher Education sector is vital if we are to achieve sustained economic growth. The universities' biggest single contribution to a dynamic economy is the flow of well-educated graduates that they produce each year to join the workforce. The HE sector itself is an important contributor to the economy, and at regional level universities are a magnet for talent and inward investment.

The universities are the partners of choice for business R&D. In many cities the local economy has been transformed by the relations built between the academic and business sectors. Indeed, it is hard to think of a really successful city anywhere in the world that does not have a successful university or two at its heart.

Yet today, the English Higher Education sector is suffering. It thrives on confidence and stability, but both qualities are in short supply.

The fiscal crisis meant that changes were inevitable whoever was in power. Prior to the big spending decisions in the autumn of 2010, the Department for Business, Innovation and Skills (BIS) faced a big problem. It was the largest spending Department not ring-fenced against the cuts and the universities loomed large in its budget. That presented some tough political choices: sharp cuts in student numbers, salami-slicing of funding or tuition fee increases — probably all three.

The Browne review

Lord Browne's review, which suggested putting most of the funding for teaching in the hands of the students rather than the universities, appealed to the Conservative side of the Coalition. Placing power in the hands of the student could be presented as a shift towards competition and market forces. For the Liberal Democrats, though, who had campaigned on the abolition of tuition fees, it would spell trouble.

The Coalition says it has accepted roughly 85 per cent of Browne's proposals, but it is the missing 15 per cent that is the problem. Lord Browne favoured removing the fee cap altogether,

Sir Richard Lambert has been Chancellor of Warwick University since August 2008. He was previously Editor of the *Financial Times*, Director General of the CBI and a member of the Bank of England Monetary Policy Committee. In 2002 he undertook an independent review of higher education and business collaboration for the then Government.

but that was politically unacceptable. It was also important that the system could be presented as progressive, with an emphasis on widening access. The Coalition ignored another of Browne's ideas, that universities should pay a levy on income from fees above £6,000 to cover the extra costs to the taxpayer of providing students with up-front finance.

The decision to set a standard figure for fees at £6,000 a year, with an upper limit of £9,000 in exceptional circumstances, seems not to have been based on research. In practice, most universities announced fees close to the £9,000 ceiling. Demand for places exceeded supply; a university charging lower prices might be saying something unflattering about how it saw itself; inflation was rising; and this might be the last chance to increase income for some time.

When it became clear how universities would play the game, the system was adjusted to reserve places at the top end for candidates with A-level grades of AAB or better [the Government has since announced this will be ABB from 2013 – Ed], and a university could take as many of these as it wants. Another 20,000 places would go into a separate pool, to be competed for by institutions whose average fee did not exceed £7,500.

The consequences

What are the likely consequences of all this? Top universities will benefit as the best-qualified students focus on the best-ranked institutions – and these will be allowed to accept more of them than they do today. The outlook for many other institutions is uncertain. Students from middle-income families may be relatively price-insensitive, but how students from poorer backgrounds will react is unclear.

Some of the post-1992 universities, offering low-cost courses and with a good record of getting their graduates into employment, will do well. Others will find themselves locked in competition for candidates with the Further Education colleges.

Some middle rankers, including members of the Russell Group, will find their high fees hard to justify in a more competitive world. Newcomers will cherry-pick their most profitable courses. There will be increasing competition from continental Europe, where universities from Madrid to Maastricht offer competitive courses taught in English. Revenues will become more volatile as student preferences shift.

There will be a growing number of for-profit entrants at the bottom end of the scale, offering courses like business which cost less to put on, and which do not have to cross-subsidise more expensive courses such as engineering.

Moreover, it is hard to find anyone who thinks the new model is sustainable

DISCUSSION

The situation outside the UK

Not enough attention is being given to what is happening in the rest of the world: to the role of inward investment in contributing to the UK's research and innovation; to the opportunities in the rest of the world - and especially in the EU - for UK researchers; and the scope for the UK to exploit research output from outside the UK. There is also much which we can learn from the experience of other countries.

over anything more than the next few years. Furthermore, it is unclear how much it will cost the taxpayer. Some believe that Government estimates of the proportion of student loans that will get paid back are too optimistic, and that the new system could cost the taxpayer more than the old.

There are other uncertainties. Perhaps of most interest to employers is what the changes will mean for the teaching of science, technology, engineering and maths (the STEM subjects). Since many more students do well at A-levels in the humanities than in STEM subjects, will STEM students find it harder to find places in the best universities under the new quota system? Will the subsidy paid to support expensive-to-teach STEM subjects be big enough?

The White Paper does not consider the funding of postgraduate work. This is especially relevant to STEM, where the falling proportion of home students on postgraduate courses is already of concern.

The Higher Education Funding Council for England (HEFCE) proposes to offer protection for expensive STEM places by creating the price-based margin of 20,000 places, but how will that work?

Other policy changes will also affect the universities' role as magnets for talent. There are worrying reports about the drop in student applications from outside the European Union — especially India — as a result of the stricter approach to visas.

The Government's decision to maintain the research budget, at a time when everything else was being cut back heavily, is to be applauded. However, research can take years to translate into economic activity.

Taking action

The Government should, I suggest, now do three things. It should work to give prospective students and their families the information they need to make informed choices about the costs and benefits of going to university, and about what different institutions have to offer. The piecemeal way in which the policies have been launched, with the initial focus on fees, means there is a lot of catching up to do. In response, the Government has set up an Independent Taskforce on Student Finance Information.

Second, it should follow the advice of the recent Business, Innovation and Skills Select Committee report and allow the changes that have already been announced sufficient time to settle down. We need more stability.

Finally, and most important, it should be bolder in its aspirations for our university system. Universities are a powerful engine for innovation and economic growth and they need to turn out high-achieving graduates for the workforce, but they are about much more than that. Perhaps the British Academy is being harsh in its criticism of the reforms, saying that they imply that "study at university is only successful if it leads to a higher salary in employment". Yet we must never forget that Higher Education is a public as well as a private good, bringing benefits to the nation as a whole. ☐

Browne report:
http://webarchive.nationalarchives.gov.uk/+/http://hereview.independent.gov.uk/hereview/report
BIS Select Committee report on Government reform of Higher Education:
www.publications.parliament.uk/pa/cm201012/cmselect/cmbis/885/88502.htm

Innovation and economic growth

Graham Spittle

The United Kingdom has a tremendous university sector. The country is widely acknowledged as being excellent at research — but not always the best at exploiting it.

Dr Graham Spittle CBE is former Chairman of the Technology Strategy Board as well as the Chief Technology Officer and Vice President for IBM's Software Group Europe. Previously he was Vice President, Integration Development, and Director of the IBM Hursley Laboratory. He has lectured and published on software contracting and intellectual property.

At IBM I work with companies globally as they seek to transform their businesses and now the same process of modernisation is taking place in governments. Suddenly the Western model looks outdated, and while here we talk about a global recession, in some countries they talk about a North Atlantic recession.

We are still struggling for growth. We need to reform the economy, understanding that we are in a race for skills and renovation. At the Technology Strategy Board (TSB), the emphasis is on the importance of research and development in achieving those goals.

The support that businesses get from universities is vital, and of clear benefit. Two-thirds of the projects supported by the TSB are direct collaborations between business and universities, and two-fifths of its funds are spent in universities. A recent survey of SMEs working with universities recorded an 80 per cent satisfaction rating. Research is the bedrock, but if we are to benefit from that research it must feed into products that reach the market.

Since being spun out of the old Department of Trade and Industry (DTI), the TSB has come a long way, with a much-increased budget and with new approaches. It is an organisation driven by business and run by business people. In the four years since re-forming the TSB, we have invested £2 billion. Nearly 4,000 businesses have participated in various initiatives and the focus has shifted from the pure subjects and technologies to multidisciplinary areas such as healthcare, energy, food sustainability, transport and buildings.

Priorities

Priority is given to work on energy supply, security, climate and the ageing population, because these are the areas that will shape the national economies of the future and drive innovation. While the old DTI looked at big technology projects in the traditional large industries, the TSB works with companies big and small in healthcare, creative industries, financial services and satellite engineering: it aims to cover a broad spectrum.

The Small Business Research Initiative (SBRI) helps SMEs win Government business through pre-commercial R&D contracts and helps Government deliver more effectively and save money.

The TSB investigates how whole systems could work, rather than individual projects. Also it has established more networks with the Knowledge Transfer Networks (KTNs) and _Connect.

DISCUSSION

Manufacturing in the UK and abroad

The decline in the UK's manufacturing base is a cause for concern as is the short-termism of UK investors as compared with those in the USA and Japan. One consequence of this is the low level in the UK, relative to the public sector, of private sector research and development. However, the importance of manufacturing in the UK is comparable to that of many other advanced economies, although Germany is an exception with its manufacturing sector being exceptionally large when compared to the rest of the economy.

One of the complaints heard from people who are 'head down' in business is that they do not know where to go to get support. I have been amazed how much support is available, but it is still too difficult for businesses to know where to find it. We need to address the question of how we can better join up the UK Government/innovation infrastructure and make it easier for people to navigate.

TSB's thematic priorities include advanced materials, information and communications technology, electronics, photonics and biosciences: all areas where the UK has deep strength, intellectually, in our universities. Then there are the more 'societal' areas of energy, the built environment, food, transport and healthcare. High value manufacturing crosses many of these areas.

In order to support SMEs, we have launched feasibility study grants, 'launch pad' grants for R&D, the Small Business Research Initiative (SBRI) — which has proved very popular — and the Euro Stars programme, to ensure continuous evolution. If programmes work, they will be continued: if not, better ways of using the money will be found.

In 2011, the TSB launched a £200 million programme for six technology innovation centres (TICs) now renamed Catapults. The Government acknowledges that innovation is important and confirmed that it would provide funding for this new network.

Business needs

Two things are important for businesses worldwide — a continuity of policy and a visibility of continued funding. We are lucky that politically the UK is viewed as stable 'free traders', always (irrespective of our political colour) ready for innovation and growth based upon the technologies that we have. That is what will transform our economy.

The link between innovation and economic recovery can be seen the world over. China has invested in education and research, and is now enjoying commercial success. The UK must grasp that message, invest and take risks. The economic urgency for faster innovation could not be stronger.

All governments can do more; we cannot use deficit reduction as an excuse not to invest properly in economic growth. Based upon recent output evaluations, we calculate that our current programmes in the TSB deliver a return of between 10 and 50 times on the original investment. But we spend only £300 million a year on this. That is not enough to change the macro-economic state of a country. It must be many times that to make a difference.

We want to make the UK irresistible to major global corporations seeking to invest in knowledge-based industries. We are a perfect dropping-off place for Europe, and we have the English language on our side, as well as our free trade and heritage. That is working in the automotive sector, where we are producing more cars than ever.

Procurement

Now we must put procurement to work. I am encouraged that the Government are saying all the right things and I believe we have an opportunity here. We can ensure that the money we spend on health and defence is spent in a more intelligent way to stimulate innovation and manufacturing in the UK.

I was heartened by the investment in graphene — I personally do not know whether it is a brilliant thing to do, but I think it is a good bet. Practically every other country in the world supports its industries, and we need to follow suit.

We must maintain pressure on Government to deliver ever-stronger support for research, skills and innovation. It means taking an economy-wide view of the growth and innovation policy. We will have succeeded in 10 years' time if we no longer need a TSB because we are doing all these things automatically. That is the way the world is rapidly moving. Fortunately, we have the gold standard of intellectual capital. We can build on that if we focus on the total ecosystem, while keeping the faith with innovation and the exploitation of our best ideas. ❐

How the Research Councils contribute to growth

Catherine Coates

The core business of the Research Councils and the main way in which they contribute to the economy is through the huge amount of research that is commissioned each year and through the support given to thousands of postgraduate students, many of whom ultimately leave academia taking a wealth of knowhow with them.

Research Councils are encouraging researchers in every discipline to give some thought when planning research proposals to how their work might be of interest to someone else — perhaps in another discipline, or to organisations in the private or public sectors. We recognise that will involve a culture change over time. While clearly not every branch of every discipline will contribute directly to economic impact, it should be as natural to researchers to consider who might be interested in their research as it is to teach and research in the first place. It should then be automatic to take steps to make the right connections.

The Research Councils have campuses where new and established companies work alongside technological and intellectual research as it is happening — in campuses like Babraham and Harwell, and in the university sector through organisations such as the Innovation Knowledge Centres that we co-fund with the TSB. This arrangement brings people together from inside and outside academia, enabling them freely to

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exchange knowledge about what they are doing. There are some 2,400 businesses and other organisations collaborating on our research portfolios, as well as a suite of strategic partnerships with a number of companies and sectors. So we are actively connecting companies and researchers.

Why do companies want to deal with the Research Councils, rather than exclusively dealing direct with universities? What we offer is national knowledge of excellence. Everything we fund is the result of highly competitive peer review, so we know where the best research is going on. If businesses are interested in structured collaboration with the university sector, they need this knowledge and we can give then a more tailored, strategic view of their options.

It helps us greatly when companies come together in sectors. We are particularly pleased to be working with industry bodies like the UK Automotive Council and the National Aerospace Technology Strategy Programme. These groups provide roadmaps that help us to direct funding to their long-term future needs in potentially disruptive and pre-competitive areas. We are also brokering cross-business partnerships, for generic technologies, for example in autonomous systems.

Our relationship with the Technology Strategy Board has matured over the years. When the TSB was formed, Research Councils had financial targets ('you will do this amount of business with the TSB') and that was the metric. It was crude but helpful as everybody was new at this. Now, we are looking at a much tighter and smarter relationship for innovation. This means that the TSB can reach further back into our funded research base to consider where potential new technologies are coming from and the Research Councils can plan transition to TSB's more strategic business–led support. To that end, the Research Councils are working closely with, and are very supportive of, the TSB. ❐

The role of Government

David Willetts

Three drivers of growth — research, innovation policy and Higher Education — must all be functioning well if we are to achieve economic growth in the coming years. Sir Richard Lambert has expressed his concerns about the uncertainties facing the higher education sector, but I would like to put these into perspective.

The Rt Hon David Willetts MP is Minister for Universities and Science at the Department for Business, Innovation and Skills, and MP for Havant. He is also responsible for the Technology Strategy Board, the UK Space Agency as well as a range of other bodies and also has ministerial responsibility for space policy. He has written widely on economic and social policy including his latest book *The Pinch: How the baby boomers took their children's future — and why they should give it back.*

The Coalition Government urgently had to reduce public spending across the board. John Browne's report into Higher Education — set up by the previous Government in consultation with opposition parties — identified radical changes that would reduce costs while maintaining standards. It called for a big reduction in teaching grants, with more finance delivered to universities via fees and loans. The alternative would have been an unacceptably large reduction either in student numbers or in grant, with no offsetting increase in income from fees and loans.

The biggest single difference between our policy plans and the Browne report relates to the levy — we chose not to impose a levy on universities setting fees above £6,000 and instead went for a £9,000 fee cap. The conceptual argument for a levy is that it compensates Government for the cost to it of subsidising the loans, measured as the Resource Accounting and Budgeting (RAB) charge. However, the levy was set as a general rate across all universities and the draconian rate of sliding-scale levy that was likely to result would be no improvement on the fee cap.

Areas of competition

On the issue of the fee cap, it is important to remember that price is only one area in which universities compete. Course content, university location and many other factors are important — and a student's payments are limited to 9 per cent of their earnings above £21,000, so a difference in fees of several hundred pounds might translate into the difference between completing graduate repayments at the aged of 43 or 45, which will not be a big factor for a young person taking a decision.

In setting their fees the universities have to recoup the costs of the grant that they have lost, but we are trying to open up competition on quality and in the volume of places universities can offer. We will gradually phase out the quotas that determine how many people go to each individual university: instead, the money will go to the university that the student chooses.

Controlling student numbers is one method of controlling public expenditure. So we need to establish some mechanism for contestability, choice and competition with an overall constraint on student numbers. We have done this in two ways: first with a tariff system, where the money will go with the student, starting with students who have AAB grades or better (about 65,000 students per year) [since revised to ABB from 2013 – Ed]. Then there are 20,000 places reallocated to lower-cost providers, particularly new entrants into the system.

Sir Richard Lambert makes three requests for government action. First, he wants more information provided to prospective students. I agree with him and we are acting on transforming the information available. Second, he said that the Department of Business Select Committee report was right to call for a delay in the process of change. But what does delay mean – delay introducing the fees and loans that cover the loss of the grant? Delay making 85,000 contestable places available next year? We feel that any delay would be a backward step.

Sir Richard's third challenge was that the Government should be bolder in its aspirations for universities. Our White Paper was about teaching in our universities because that is where the big financial changes were happening and where there is a challenge. Sometimes the very sharp incentives that we have for rewarding high quality research and the competitiveness of the funding for research has meant that that has become the focus of universities' attention, and they have not always given the same attention to their teaching responsibilities.

Science, Technology, Engineering and Mathematics

Fears for the future of STEM subjects have, I think, been exaggerated. For instance, University College London are looking to set up a second campus in the East End of London, indicating a growth and expansion agenda, while Lancaster University has announced the reopening of their chemistry department, having closed it in 1999. Universities that are confident they can recruit more students at AAB will be making those judgements. Neither of those decisions would have been possible if we had kept the old quota system.

When we came into office it was clear that in the Technology Strategy Board (TSB) we had inherited an institution that was doing a good job, bridging the gap between universities and upstream research and full commercialisation. We are wholeheartedly committed to the TSB: there is no reason to reorganise things just for the sake of it when there is a change of Government.

We have been able to offer cash protection to the science budget but our estimate is that by the end of this parliament, universities will have 10 per cent more cash than now with which to cover the cost of teaching.

For science we have the ring-fenced, cash-protected budget and a clear commitment to do better for science capital. Science capital is not in the ring-fence because we want to keep the resource and the activity flowing. When times are tough, tough decisions have to be taken on public spending. We have a continuing commitment to science capital, however: an extra £100 million in the budget, a further announcement of £50 million for work on graphene, and a further announcement of £145 million for e-infrastructure. We have already identified the capital funding sources for the eight priority capital projects highlighted by the Research Councils.

DISCUSSION

The challenge of successful translation

Some Higher Education institutions seem reluctant to recognise that the financial benefits from the translation of research into commercial activity need to be fairly shared between all the participants in any collaboration. HE itself produces public as well as private benefits and more effort should be devoted to communicating to the public at large the nature and extent of those benefits. The Technology Strategy Board also plays an important role in securing economic benefit from innovation.

For many of us who came into politics 20 years or so ago, there is a fear of 'picking winners'; as an industrial policy it had never worked. I still do not agree with picking winners, but I do think you should pick which races to be in.

Governments also need to be aware of the process of transferring knowledge from pure research. In the USA, there is an enormous amount of support to help products all the way from the purest research through to the market. The National Institutes for Health and the National Science Foundation fund projects further downstream than our Research Councils tend to, for instance.

Sectoral support

The Government is committed to supporting the life sciences, principally through the Medical Research Council, and to strengthening the connections through innovation and the application of the resulting advances in the National Health Service.

Then there is infrastructure. Academics often deal with very large datasets, requiring high-powered computer systems. The skills developed in order to handle the data that pours out of the Large Hadron Collider, for example, may be relevant to engineers wanting to model what happens in a Rolls Royce gas turbine or in a Jaguar Land Rover vehicle. Consequently we decided to make a major investment in e-infrastructure.

There is fascinating work happening in synthetic biology, already being actively sponsored by the Research Councils with investment to the tune of £45 million. This is the moment when we can set the international standards that will determine how this technology is going to be deployed around the globe. There are three countries and six learned societies that are going to set those standards — two from the USA, two from China, two from the UK.

Then there is nano–technology, where excellent work was done by the previous Government. We are now trying to bring this together and coordinate it. I am convening a group to ensure how we can take advantage of the research that has already happened in nano-tech and that was part of the background to the decision for the investment in graphene.

Also on my list is nuclear technology. We recently had a Select Committee Report and I know there is the debate over G3 nuclear fission and to what extent we have an in-house capacity. With my responsibilities I am looking further ahead, to G4 nuclear fission and nuclear fusion – that is where we have considerable scientific potential and opportunities. We will protect the Culham Centre for Fusion Energy for example. Unlike, say, the Large Hadron Collider, Culham is a scientific experiment that will shape an industry of the future. We must develop the business potential from the activity there. It is important that we press hard to ensure British business gets a fair share of the contracts in the International Thermonuclear Experimental Reactor (ITER) programme — based on quality, not on a willingness to sign up to unrealistic commitments of unlimited, long-term liability.

Finally there is space technology and space security. We have inherited from the previous Government an excellent structure – the Space Leadership Council. We commissioned a technology roadmap, written by Sir Keith O'Nions. On the basis of that roadmap the Government will put in funding provided that business will do the same. The Leadership Council provides an environment in which that kind of deal could happen. With a shared understanding of how the technology was likely to advance over the next five years or so, both sides could make commitments about the projects they are willing to back. ☐

Lords Select Committee Report on Nuclear Research and Development Capabilities: www.publications.parliament.uk/pa/ld201012/ldselect/ldsctech/221/221.pdf

The UK needs a strategy to adapt to climate change but how should it be framed and how will it work in practice. A meeting of the Foundation for Science and Technology explored this issue on 19 October 2011.

From a scientific-certainty to a risk-based paradigm

Rupert Lewis

According to the Hadley Centre and other world leading climate science groups, the CO_2 emissions already in the atmosphere combined with the inertia of atmospheric systems mean that the world will inevitably experience rising temperatures. The average temperature in 2040 will be similar to the unusually hot year of 2003, when a heatwave was responsible for around 35,000 deaths. There is therefore a significant change to which the world has to adapt. If all carbon emissions were to stop tomorrow, there would still be decades of change to come: mitigation too is vital.

The worst that could happen is that the climate changes and humanity takes no action: the cost would be huge. The next worst would be it does not happen and yet a great deal of money is spent in preparing for it. The Stern Review estimated that an investment of 1 per cent of GDP was required in addressing climate change. When the Review was published, this represented a vast sum and it was difficult to believe that anyone would spend that sort of money. Since then, we have lost 14-17 per cent of GDP due to the credit crunch and the ensuing financial crisis: 1 per cent suddenly looks achievable.

The science certainty paradigm – predicting the future, improving predictions until they are highly certain, making optimal decisions and relaxing – is no longer appropriate. As Professor Lenny Smith argues, what is needed is a more risk-based paradigm: assess the risks, hedge decisions on the best available evidence, then repeat this as data improve. That is a much more valuable paradigm for decisions and policy making.

Dr Rupert Lewis was Deputy Director of the Adapting to Climate Change Programme at the Department for Environment, Food and Rural Affairs (Defra) at the time of this talk – he is now deputy Chief Scientific Adviser in the Department for Business, Innovation and Skills (BIS). He has had strategy, policy, and delivery roles in Government mainly at the evidence/policy interface, and previously worked overseas on science development programmes.

Role of Government

Given the massive challenge of adaptation, what is the role of Government? Government owns many assets and manages many interests. Government uniquely generates large amounts of evidence with large numbers of highly capable scientists. Also, Government has a role in tackling market failures: flood defence and so on. Adaptation is an economic issue, the biggest part of which is infrastructure investment.

The UK's approach to climate change has a statutory framework set out in the *Climate Change Act*. The Adaptation Sub-Committee (ASC), an independent group of experts, advises, critiques and helps Government in this area. The Act requires the Government to complete a Climate Change Risk Assessment[1]. In 2012, there will be a new National Adaptation Policy Programme.

While not part of the statutory framework, the Government will also carry out an economic analysis. It is no good just knowing what the possible maximum vulnerability is: we need to know the cost! Echoing the view of the ASC, the analysis will attempt to identify no-regrets options: things that will be of benefit under any circumstances.

A central element of the Coalition's strategy is the focus on The Big Society and Localism. So local government has an important role to play in adaptation. Communities are, of course, heavily involved already, especially after events such as flooding.

Many of the risks and opportunities are for the markets and commercial players to judge. There are great opportunities in adaptation for business – there is a huge export market in helping other people to adapt. The insurance, construction and consultancy industries have a big role to play, both locally and overseas.

Identifying the risks

The Climate Change Risk Assessment (CCRA) aims to discover what needs to be done in the next five or 10 years and what can be put off until the future when there might be more and better information. Not surprisingly, flooding is presenting itself as the major risk. Water supply is another obvious risk. Traditionally, it has been assumed that that the South East was going to be dry and the North West relatively OK – it always rains in Cumbria! Actually, in terms of what water companies can supply, it is the other way around. There is plenty of ground water storage in

DISCUSSION

Politics and practicalities

There is a danger that governments may be dissuaded from taking action because of fears that these would be resented by individuals, even though such reactions are not rational. A good example is water metering: although this reduce the cost of water to individuals in most cases, and reduces overall water demand, compulsory metering has not been introduced; nor other measures which could reduce demand. The Government has a natural reluctance to impose regulations and controls; but the alternatives (if adaptation is to be achieved) are through either sharp price increases, as in the energy field, or through behavioural change.

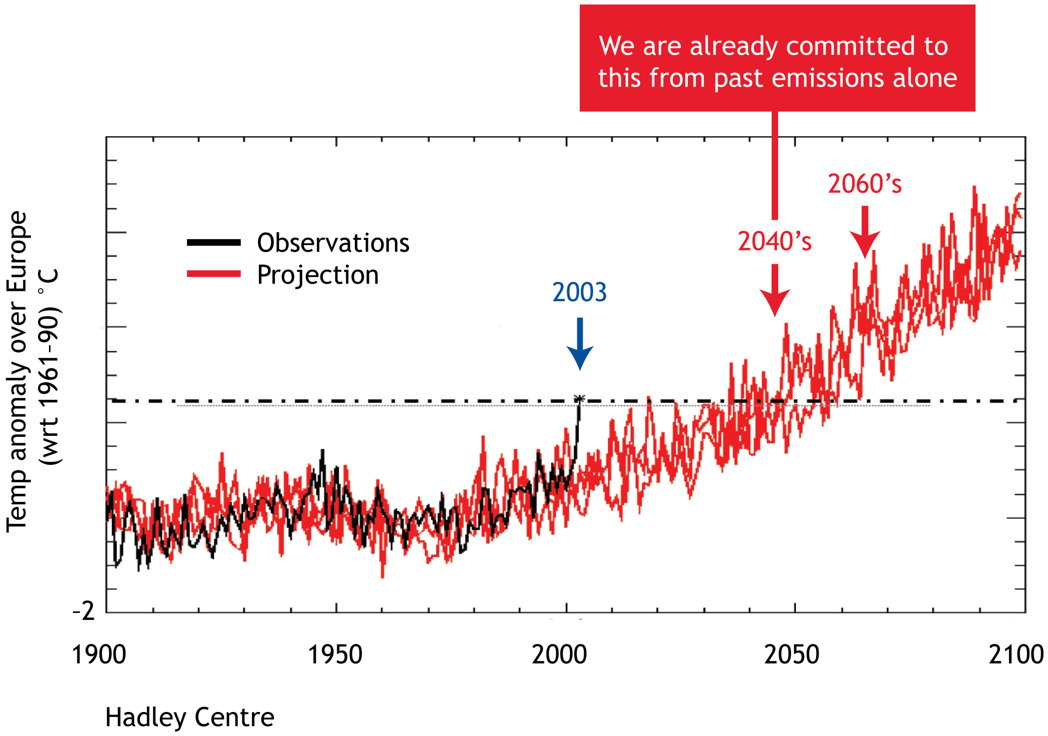


Figure 1. Mitigation is vital, but we also need to prepare for inevitable climate change.

the South East but little in the North West.

An economic approach would work in the following way. First, look at the potential vulnerability; then look at the policies already in place to tackle this and what the market itself might do to address this. The next step is to determine the remaining deficit and work out how to manage it. This approach is enshrined in the CCRA.

Collaborative policy-making

A scientific approach is all very well but how do people adapt to climate change in practice? We are now concentrating that effort on the Environment Agency, which has launched its own conversation with stakeholders. It is asking them: "How we can help you, what do you need?" Essentially, this is a journey from highly complex science to practical decisions at the simplest level. We are not trying to tell everyone to care about adaptation, though; we are trying to find the people who *need* to care about it.

The Government is committed to collaborative policy-making on this vital issue and there will be open debate. It is not going to tell everyone the answers, because frankly, it does not have all the answers. This is a highly complex topic and many people have expertise in specific aspects. By involving a broad range of stakeholders, we are going to try and exploit the innovation already out in the market.

This is all about co-creation. It involves identifying the elements of the problem and then helping those who need to take action to do what is required. Some of that will fall to Government and some of it will not. A great deal of this is about managing risks; and a large proportion is also concerned with exploiting opportunities. ☐

1. The UK Climate Change Risk Assessment (CCRA) was published on 25 January 2012. www.defra.gov.uk/environment/climate/government/risk-assessment

Flood risk and water resources

Graham Wynne

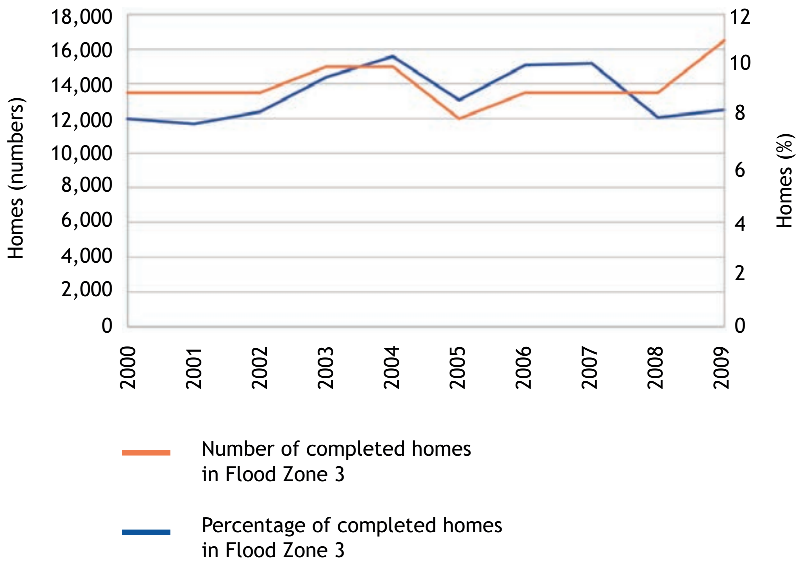
The Adaptation Sub-Committee was established by the *Climate Change Act* 2008 to advise on the UK's preparedness for climate change and to monitor progress in adaptation. It focuses particularly on the assessment of adaptation outcomes, in order to inform whether the risks from climate change facing the UK are being appropriately addressed. It is attempting to develop meaningful sets of indicators by which to measure adaptation progress.

This is not to suggest that the capacity building, where much effort has been focussed so far in adaptation, is not important. It simply seems to the Committee that the clearer the picture of the outcomes being targeted, the more effective can be the decision-making processes.

Flood risk

The ASC's second report (2011) found that over the previous two decades between 12-16,000 new houses a year had been built in high flood-risk zones. That represents 8-11 per cent of all new residential developments. Given that there is a total of around 1.3 million houses in high flood-risk zones, the figure is therefore growing by about 1 per cent a year – that is, the overall vulnerability of the housing stock to flooding is growing at that rate. This is not insignificant as around 4.5 per cent of the total housing stock is located in areas of high flood risk.

Adaptation should start by managing the risk of flooding. There is, in fact, significant uptake of adaptation measures for new buildings. Unfortunately, there is



Reducing flood risk: the location of developments

Sir Graham Wynne CBE is a member of the Adaptation Sub-Committee (ASC) of the Committee on Climate Change. Previously Chief Executive of the RSPB, he is a Special Advisor to the International Sustainability Unit, and a Trustee of Green Alliance. He was formerly a member of the Minister's Natural Environment White Paper Advisory Panel; the Foresight Land Use Futures High Level Group; the Sustainable Development Commission and the Policy Commission on the Future of Farming and Food.

much less activity on retrofit, but there is a cost-effective package of measures which the Sub-Committee believes ought to be promoted and taken up.

There has been an increase in expenditure on community-level flood defences over the last decade: the number of properties protected by new or improved defences has increased very substantially. We have not, however, been able to assess the scale of flood defences in terms of how commensurate they are either with the existing risk or the increasing risk. It is interesting in itself that those statistics should be so difficult to obtain.

Vulnerability has undoubtedly increased by building in high-risk areas. It has increased further due to the expansion of hard surfacing at the expense of green areas in our towns and cities. It is unclear, however, what this tells us about the overall preparedness for flood risk. This process, where the increase in vulnerability, or potential vulnerability, is weighed up against the actions that are taken to reduce it, is not transparent. The ASC recognises that local authorities have to address different sets of trade-offs when approving new developments. In many cases, development in the flood plain is almost inevitable and quite possibly rational. Yet these developments are occurring in the absence of an explicit decision-making process. The Sub-Committee concluded that building on the flood plain is not necessarily the wrong thing to do – but there is not enough assessment at present to ensure it is the right thing to do.

Managing water resources

The security of water resources has always been reasonably high in England and it has improved over the last decade to the point to where only 8 per cent of water resource zones were at risk of supply shortfalls in 2010. On the other hand, our water supply comes at an environmental cost. Once again, it is hard to get a precise picture, but it is reasonable to assume that that the environmental cost is quite significant.

It is likely there will be increased pressure on supply. It is also projected that there will be some increases in demand. The conclusion is that without further action on both the supply and demand sides of the equation, there will be greater shortages by 2035. Of course water companies have plans to deal with this, but the ASC found that the extent to which climate change was actively modelled in those plans was highly variable. This needs greater scrutiny in the future.

Most commentators would agree that the simplest and least-regrets place to start is on the demand side, although action will be needed on supply. The ASC looked at the costs and benefits associated with very simple water efficiency measures in the south-east of England and how could that affect the demand side of the equation. The resulting cost-curve demonstrated that an economically beneficial package of measures could be introduced which would bring individual demand down to the order of 115 litres per person, per day. That would be of benefit both to society and the individual. That consumption rate is substantially lower than the current water demand level and it is substantially less than projected for the future.

Water companies have plans to tackle both sides of the equation – none of them appears to have a target as low as 115 litres for domestic consumption. The best are around 120-125 litres; but some are still projecting individual demand at 160 litres by 2035. There is certainly more scope, then, on the demand side of the equation as well as the supply side.

To conclude: first, there is evidence that vulnerability to climate risks is increasing. Next, there are low-regrets actions being taken but, third, there is economic, cost-beneficial scope for more. Furthermore, it is not evident that long-term decisions are explicitly accounting for climate change and the risks, or indeed the opportunities, that may come with it. ❑

Insurance in a changing world

Tom Bolt

Climate change is an issue that Lloyd's takes very seriously as it significantly affects business. In order to tackle it and adapt to the wide-ranging and long-term impacts, governments, business, academia – everyone in fact – need to work together.

Lloyd's works with a wide range of different organisations, for example with the Geneva Association, the London Climate Change Partnership, the Department for Energy and Climate Change and the

Tom Bolt is Performance Director and a member of the executive team at Lloyd's of London. He is responsible for working with individual Lloyd's businesses to improve the commercial performance of the market. He has extensive experience in international insurance and reinsurance across the UK, USA and Europe, having spent 25 years at the Berkshire Hathaway Group.

Lighthill Risk Network. It was a founding member, in 2007, of the ClimateWise initiative, a global collaboration of leading insurers focussed on reducing the risk of climate change. This brings together over 40 international members from Europe, North America, Asia and Southern Africa, all of whom agree to abide by the ClimateWise principles. These include commitments to support and undertake research on climate change and to support climate awareness among our customers, as well as encouraging them to adapt to climate change.

In 2011, Lloyd's paid out a large sum of money for the Australian floods. Insurance pays people according to the events they have suffered, for example various types of flooding or precipitation, but sometimes it is hard to see exactly why the flood occurred. Determining who actually pays to repair the damaged caused can often be made simpler through a hydrology report such as the one Lloyd's commissioned on behalf of the market in this instance.

Climate change and insurance

Between 1970 and 2010, the number of natural catastrophes around the world increased by over 300 per cent. That included some earthquakes as well as weather-based events, but many scientists attribute a significant proportion of the increase in storms, temperature extremes, drought, wild fires and floods to climate change.

The highest ever economic loss from natural catastrophes occurred in 2010: $265 billion (£171 billion). Before this, the costliest year was 2005 – some $220 billion (£142 billion), largely due to three hurricanes: Katrina, Wilma and Rita. Insured losses have increased nearly 10 times between 1970 and 2010.

It is important to distinguish between economic losses and insured losses. Insurance does not cover everything. Yet insured losses have risen nearly ten times when the number of catastrophes – although this is hard to judge exactly – has gone up by something like three times. Part of the increase in insurance losses is due to the fact that more people live on the coast, so there is a demographic shift to more exposed areas. Climate change is not the only factor, however. One of the reasons the damage in Christchurch was so dramatic was the liquefaction on the delta where the city fathers encouraged people to build homes. In the earthquake, it proved to be a disastrous environment and nobody will be allowed to rebuild there.

One of the ways insurance works is to spread the loss of the few among the many. However, if people want to continue to live in Christchurch, Auckland or Wellington, it must be recognised that there is not enough money in the New Zealand economy to pay for the rebuilding of large sections of the country, should things go wrong. It is a similar story with the Thames. If there was a really material event along the Thames, the economic costs would be dramatic. Who in society would pay for it and how – would it be through insurance or Government? In the USA there is a flood programme which is sponsored by the federal government, and that encourages development in certain places. Some consider that not all of these locations are rational places to build homes. but if the cost could be spread amongst the taxpayers of the United States then it may be a perfectly sensible idea.

Climate change will bring wider risks. Issues of water scarcity, food security, scarcity of energy and natural resources may lead to geopolitical and security tensions. It is already having an impact today. Monitoring these impacts and risks is important, and we must adapt to them.

Adaptation and the role of insurance

The risk landscape is changing and insurers have a key role in helping businesses and society to adapt. However, insurance is not the sole solution to climate change. Mitigation is still vital.

Insurers do, however, have roles to play in all stages of the adaptation process. The industry has expertise in loss reduction and risk management, and it can encourage residential and commercial properties to focus on their resilience and resistance to risk. One of the significant impacts of climate change is sea level rise. Owners of coastal properties rely on insurance to manage the risk of flooding. A sea level rise of 30cm may more than double average losses for some exposed properties, but adaptation can bring losses to below current risk levels.

Adaptation strategies must of course be tailored to individual locations and circumstances. Risk-based pricing is critical in ensuring adaptation to extreme events, but it is important too that this pricing reflects the true risks. If it does not, there is no incentive to put in adaptation measures. Property-holders should introduce resilience measures before a flood or other extreme event happens. Governments have an important role to play in adaptation by rewarding appropriate measures, but Government intervention in private insurance markets should be kept to a minimum.

Insurers can perform a signalling role. Prices and risk grids should be set in such a way they can encourage people to make changes to their properties to mitigate the cost of insurance. Insurance also works as a tax: it sets the premiums so that those people who want to live in areas that are more at risk do pay more. Lastly, insurance protects. The impact of these changes is not going to be gradual, over a long period of time – it will often be sporadic and sharp. In fact, it is in these circumstances that people seem to come to a greater sense of a problem. While it can help, insurance is only one part of dealing with climate change. We cannot insure our way out of the climate-induced challenges ahead. □

DISCUSSION

Future strategies

Climate change will affect some families adversely, while others may even benefit. Given such different situations, it is difficult to see how the relation of risk to price can apply widely. Behavioural change is difficult to achieve except over the long term, and it will not come about without much Government action. Therefore, more regulation, pricing signals and a campaign to educate and enlighten people about the possible effects of global warming, must go together.

What barriers still remain to prevent women playing their full part in science and technology and how can they be eradicated? The issue was debated at a meeting of the Foundation for Science and Technology held at the Royal Society of Edinburgh on 27 October 2011.

Still more to be achieved

Jocelyn Bell Burnell

Dame Jocelyn Bell Burnell DBE FRS FRSE FRAS FInstP is Chair of the Royal Society of Edinburgh Inquiry into Women in STEM and Visiting Professor of Astrophysics at Oxford. She was previously a professor at the Open University and then was Dean of Science at the University of Bath. She is a Fellow of the Royal Society and the Royal Society of Edinburgh.

Advice to women from *Housekeeping Monthly* in May 1955 includes the following: "In anticipation of your husband's return, have dinner ready, put a ribbon in your hair, tidy the house, clean up the kids. Listen to him; his topic of conversation is much more important than yours. Don't complain if he is late or stays out all night – remember he is the master of the house, you have no right to question him. A good wife always knows her place." Now, this was written less than 60 years ago. We have come some way, undoubtedly, but there is further to go.

As recently as 2009 only 27 per cent of women graduating in Science, Technology, Engineering or Mathematics (STEM) in Scotland were employed in STEM professions, compared with 53 per cent of their male counterparts. In the universities we see the proportion of women in STEM departments falling with each step up the academic ladder. At undergraduate level, more than half of STEM students are women, but once we reach the level of full professor, the proportion of women has fallen to about one-tenth. Much of our investment in the STEM education of women is being lost through attrition.

In my own field of astronomy, membership figures from the International Astronomical Union paint an interesting picture. The proportion of women members of the IAU averages 15 per cent across the globe, ranging from 37 per cent in Argentina, through 12 per cent in the UK, down to only 6 per cent in Japan.

Why are the numbers (mostly) low? Part of the reason may be that members are elected by the professional astronomers in their own countries, most of whom are white males who tend to elect people similar to themselves. Another factor may be the low proportion of women holding tenured posts. It is generally more likely that a person with a tenured position will be elected to the Union. Thus the large number of female astronomers without professorships who are working at PhD and postdoctoral level are overlooked.

Discrimination

It is generally agreed that the discrimination women face comes from both sexes and is usually inadvertent. It is clear that women do not receive the same career opportunities and encouragement as men. Both men and women hold implicit biases and both judge women more harshly. Formal evaluation criteria often contain arbitrary and subjective components that disadvantage women. Recruitment panels are frequently dominated by men and their membership is most comfortable recruiting somebody like themselves. In addition, there are more subtle institutionalised instances of sexism, such as application forms that request the sex or gender of applicants always offering the male option first. These seemingly small things send out messages that discourage female participation, drip by drip by drip – and we all know that a steady drip can do a lot of damage.

Removing these types of institutional bias can produce surprising results. A good example of this can be seen in the composition of modern orchestras. When candidates for orchestras were auditioned while playing behind screens that extended to floor level (hiding even the candidate's feet) the number of women appointed rose dramatically. As a result, we now see orchestras with a much higher proportion of female players than in the past. It is clear that when the recruitment panels were blinded to the candidate's gender, far more women were judged to be of a high enough standard to join the orchestra than when the candidate's gender was known.

Even once they have attained a post, women face a number of barriers. One of these is the culture of the workplace, which can be very male-oriented, particularly in fields where men dominate in terms of numbers and seniority. Women today are a bit like the canaries that used to be taken down into the mines – they are more sensitive than men to the atmosphere, the ambience and the ethos in a workplace. If there are few women, it is often an indication that something is not as healthy as it should be.

The Athena SWAN Charter for Women in Science recognises and celebrates good employment practices as well as the promotion of women's advancement in STEM in universities and research institutes. In summer 2010 Dame Sally Davies, Director General of Research and Development as well as Chief Scientific Adviser at the Department of Health, announced that

DISCUSSION

Speeding up change

The urgent need to tackling the extra challenges faced by women in STEM has not yet been recognised. There is a danger that by the time the UK makes significant progress in addressing these challenges, its economy will have been overtaken by dynamic economies in Asia, such as those of India or China. They are dynamic precisely because they seek to use all the talents available in their workforces. The UK cannot risk taking 50 years to resolve these problems. We must move faster.

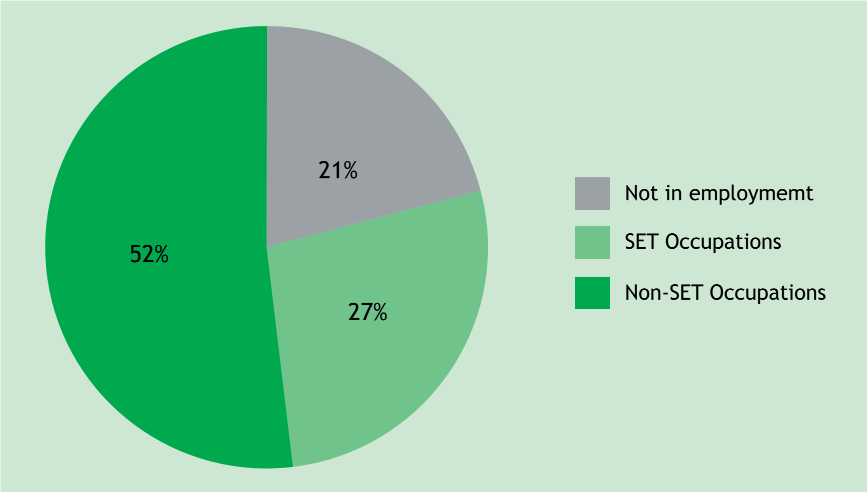


Figure 1. Female STEM graduates by occupation and economic activity, Scotland 2009 (52% of male STEM graduates are in Science, Engineering and Technology occupations).

National Institute for Health Research funding would go only to institutions or departments that hold Athena SWAN Silver Grade awards. This will ensure that departments achieve a recognised standard of women-friendliness before they are eligible for this funding.

There have been many recommendations issued to improve the situation for women in STEM. They include recommendations on mentoring, networking, role models and the visibility of women, gender-'balanced' interviews and promotion panels, good management practices, parental leave, flexible working and affordable child care, to name a few.

They are all good ideas, but they have not been implemented consistently or thoroughly. If they had, we would be in a very different place today.

The Royal Society of Edinburgh Inquiry

In its draft recommendations, the working group for the Royal Society Edinburgh Inquiry into Women in STEM has concluded that:

- The Scottish Government should commit to a national strategy for meeting the public sector equality duty, using procurement opportunities and working with stakeholders, and with cabinet minister responsibility;
- The UK Government should introduce legislation that recognises the co-responsibility of mothers and fathers in parenting;
- Business and industry should introduce more quality part-time employment opportunities at all levels for men and women;
- Heads of organisations should take responsibility for changing the culture for women within their organisations;
- Research councils and other funders should make the achievement of an Athena SWAN Silver Award or equivalent a condition of a grant;
- Higher Education institutes should ensure that women's research does not suffer because of high levels of committee work;
- Learned and professional bodies should agree and publicise a statement welcoming and encouraging the full participation of women in that body and its academic discipline. They should make the qualities expected of successful candidates publicly available, ensuring language is gender-neutral and does not use adjectives or verbs more usually associated with one gender only. ☐

The Royal Society of Edinburgh Inquiry into women in STEM: www.royalsoced.org.uk/877_WomeninStem.html

The Athena Swan Charter: www.athenaswan.org.uk

A life in STEM

Dr Ellen Williams is Chief Scientist at BP. Before joining BP she worked for over 30 years in academia in the USA. She was a Distinguished Professor in the Institute of Physical Science and Technology and the Department of Physics at the University of Maryland. She also provided technical advice to the US Government Departments of Energy and Defense.

While I am currently Chief Scientist at BP, I have spent most of my career in academia. In the late 1960s and early 70s, the women's movement in the USA was very active and had a militant edge. I was a member of one of the first cohorts of women to attend the California Institute of Technology, which had denied admission to women until 1973. When I went there to study chemistry in 1976, the women students felt like pioneers entering a previously forbidden field. It is very different today, when young women are encouraged to go into science. Then, we were treated more like guinea pigs in an experiment – 'let the women in and see what happens'. We were not supported nor taken very seriously – for example, there were no dormitories for women. We felt we had to prove ourselves by working twice as hard and being twice as good as the men.

I switched to physics and began my academic research career at the University of Maryland. Physics was even less friendly to women than chemistry. I became involved in a committee of the American Physical Society called the Committee for the Status of Women in Physics. It was set up by some of the women in the generation above mine who had truly struggled to forge their careers in science. Whereas my generation felt like pioneers, these women were heroes. They had grown up in a world where women were not just excluded or ignored in science; they suffered active and methodical discrimination.

The Committee was invited to other universities to talk about ways to encourage more women to enter and remain in science. What we found was that the environment in university science departments was often very unfriendly to women. It made them feel like outsiders who did not belong and were not wanted.

DISCUSSION

Changing attitudes

Universities and businesses need to be more aware of the problems that women in STEM encounter, particularly those of unacknowledged bias. Marginalising women in discussions by not allowing them sufficient time or priority in speaking, or using language demeaning to the other gender such as the word 'girls', are habits that can only be addressed through proper training and changes in social and business attitudes. However, even that will not cover all areas. A US study has shown that male names receive more favourable attention than female names when applications are being considered. Would a requirement that all applications be anonymised help to tackle this?

We suggested ways these universities could make their science departments more welcoming places for women. Sadly, to this day one of the problems women encounter when moving through a career in STEM is a sense of 'otherness' – a feeling of being different and a strong awareness of unfriendliness in the environment.

In 2010 I moved to London and joined BP as Chief Scientist. The company employs 80,000 people in over 70 countries. Although industry is a very different place from academia, it faces some similar challenges retaining and promoting women.

Support strategies

There are a number of strategies that can be used to support women in STEM enterprises. Networking is one such strategy, and BP has several internal networks that provide mentoring and encouragement for women, such as BPWIN (our global women's network) and WISE (Women in Science and Engineering).

Training is also an important means of support for women. BP has a number of required training programmes, including one entitled *Inclusive leadership* that teaches employees how to transcend issues arising from differences in gender or culture. The company also has various training programmes covering how to deal with a difficult employee, how to conduct a performance discussion and how to go through a review process, to name just a few examples. I have found these training programmes very powerful in terms of career development and I would recommend them as effective tools that can help women entering a difficult field to adapt to their new environment.

Communication is vital. During my career I have often felt that I was not communicating effectively or was having misunderstandings when I talked to other people. I then discovered the books written by the linguist Deborah Tannen about the different communication styles of men and women. Reading those books helped me understand how I was engaging with other people. They showed me why things that I said or the way that I behaved, although perfectly normal to me, did not always have the results I hoped for. Similarly, WFL (Women as a Foreign Language) training can help women succeed in a hostile environment by teaching them how to engage more effectively and understand how others perceive them.

Women need the confidence to cope with social pressures that often work against them – for example, the attitude that they should stay at home and look after the children; or the suspicion that they are being given preferential treatment. I have certainly seen that sort of thing in my career. Women need to have a strong sense of who they are and be true to their own set of rules. They also need to learn how to network actively and engage with people who can support their careers. ❐

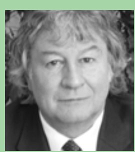
Encouraging a diversity of talent

Adrian Smith

My responsibilities at the Department for Business, Innovation and Skills include overseeing policy and budgets for English universities, UK Research Councils and the Technology Strategy Board (TSB). At BIS I am also the equality and diversity 'champion', charged with promulgating equality and diversity throughout the Department and all its partner organisations.

In England over the past few years, there has been a dramatic increase in the uptake of mathematics and further mathematics at A level, with recently a rising uptake in the sciences. But a disproportionately high share of entries in these 'hard' STEM subjects comes from students in private schools, who are across the board more than twice as likely as students at comprehensive schools to achieve an A* or A grade.

The picture is more encouraging in Higher Education. In 2002-03 just over 170,000 university entrants were studying for STEM degrees – around 42 per cent of the total entrants for first degrees. By 2009-10 this had increased to over 200,000, more than 44 per cent. However, there remains a great deal of work to do in securing the initial 'pipeline', before university level. We need to look at how opinions are formed at 12 or 14 years of age. For example, what are the formative influences – are they parents, teachers, or are there other factors?

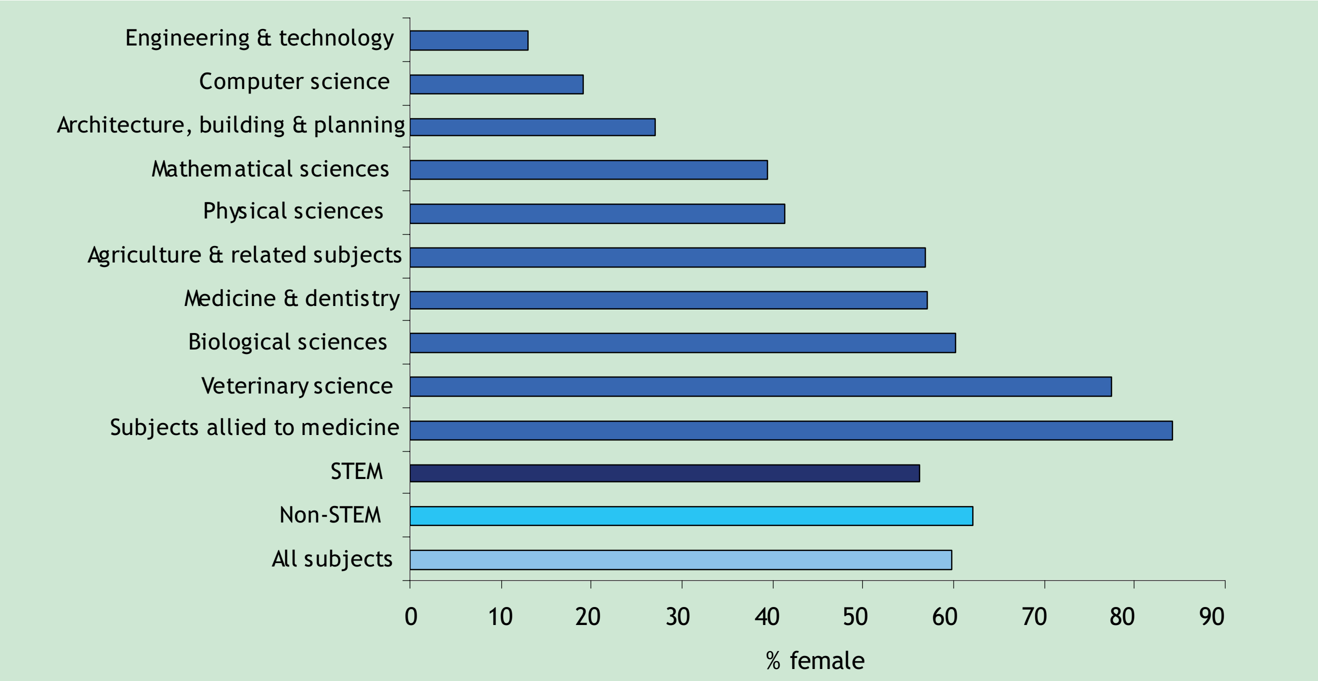


Professor Sir Adrian Smith FRS is Director General, Knowledge and Innovation, Department for Business, Innovation and Skills (BIS), where he leads on Science and Society policy. Previously he was Principal of Queen Mary, University of London and prior to this he was at Imperial College as Professor of Statistics, Head of the Department of Mathematics, Member of the Management and Planning Group and a Company Director of ICON (the Imperial College Consultancy).

Relatively few females take A levels in mathematics, further mathematics and/or physics, but those who do perform at a similar level to males. In biology and chemistry, participation levels are much more even, biology indeed showing greater participation and proportionally better performance by females.

Universities

Less than a fifth of undergraduate entrants in engineering and technology are female. In mathematics the figure is around 45 per cent. It rises to around 60 per cent in subjects associated with the life sciences such as medicine, dentistry, biology and biological sciences. Why do females



Percentage of UK-domiciled, female undergraduate entrants to UK Higher Education Institutions, 2009-10.

DISCUSSION

The benefits of increased diversity

Research shows that mixed groups produce better results. Businesses fare better if their staff reflect the diversity of their customers. The benefits of increased diversity both in academia and in business need to be stressed. Yet the issue is not just one of economics: it is concerned with enabling people to live their lives in a way that meets their wishes.

participate more in life science fields? This must reflect some subtle difference in choice mechanisms and motivation. One might assume that the same information about the different fields of study is available for males and females, but clearly it is not having the same effect.

There are a number of initiatives designed to excite young people about the nature of science and engineering as well as careers in these fields. For example, attendance at the Big Bang Fair has risen sharply, from just 5,000 in 2009 to 29,000 in 2011. At the 2010 event, the Young Scientist of the Year and many of the prize winners were female. It is important to discover what happens to discourage these talented young women from continuing to advance their careers in science. This is not only right in terms of equality, it makes good business sense – it is important to retain the best talent and to recoup our investment in their education.

Another outreach programme is STEMNET's STEM Ambassadors programme. This has a network of 29,000 volunteers across the UK, including 2,980 in Scotland. These people are from universities and business; they go into schools and act as role models, showing students what they could achieve in STEM.

Another important area is public engagement with science. The Government has been evaluating public attitudes to science through its three-yearly surveys. In 2011, this included the first survey of young people's attitudes to science. The results were revealing – although young people thought that science itself is terrific, very few thought that a scientific career was a good idea. What can be done to persuade them otherwise?

Engineering

Engineering faces some of the greatest, often historically based and ingrained, diversity issues. In the UK, women make up 12.3 per cent of those employed in STEM occupations, but only 6.9 per cent of engineering professionals. This percentage is the lowest in the EU and has fallen from 8.7 per cent in 2007. The leadership of organisations such as the Royal Academy of Engineering has to be challenged to take responsibility for delivering the changes needed to promote equality. The Royal Academy is the focal point for engineering in the UK and has excellent relationships with a diverse mix of engineering institutions. It is very well placed to help us deliver the changes needed to encourage individuals to pursue careers in engineering.

Should STEM, or universities, be considered in isolation? Or is there a wider issue with society in general and in particular the number of women on the boards of companies and in director and high-level posts? The current figures are dire. Within FTSE 100 companies from 1 October 2010 to 1 September 2011 there were 1,092 FTSE 100 directors, of whom 155 (14.2 per cent) were women. In the FTSE 250 over the same period, there were 1,192 directors, of whom 178 (8.9 per cent) were women. Board appointments over the period 1 March to 1 September 2011 totalled 93 in FTSE 100 companies, of which 21 (22.5 per cent) were women. In the FTSE 250, board appointments totalled 158, some 28 (18.0 per cent) of which were women. So the problem is not limited to the STEM sector. Although the number of women in senior positions in FTSE companies is creeping up slowly, it is still very low.

Then there is the public sector. Here there is a public sector equality duty that places certain responsibilities on public bodies. There is now greater emphasis on them to actively consider equality in the work they do and the decisions they make. Could – and should – more be done, perhaps in a more targeted way? Despite some recent encouraging trends, it is clear from the statistics that much more needs to be done. □

Fracking and the increasing use of other 'unconventional' forms of gas supply are causing significant public concern. But what is the reality behind the hype? The topic was investigated at a meeting of the Foundation on 9 November 2011.

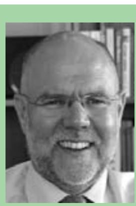
The gas supply revolution

Malcolm Brinded

It is vital that the UK has a well-informed and balanced discussion about tight gas – one based on hard evidence and rigorous analysis, rather than speculation. The gas supply revolution provides an opportunity to meet surging demand for energy while helping to safeguard the environment for future generations. That is because natural gas offers the fastest and cheapest route to reduce CO_2 emissions in the global power sector: the larger the world's natural gas supplies, the more quickly and economically coal-fired power can be displaced.

Tight gas, shale gas and coal bed methane are all gas deposits trapped in very tight or impermeable rock. Only 10 years ago, the industry considered them too difficult and costly to access. But since then, there has been huge progress in drilling and fracturing (or 'fracking') the rock to release this gas. As a result, North America now has more than a hundred years' worth of natural gas supplies at current consumption rates. Worldwide recoverable natural gas resources are estimated at 250 years of current production, of which roughly half is tight gas, shale gas and coal bed methane. Many countries outside the USA, including China, are starting to access their tight gas resources. Europe, too, has its share of these gas deposits, but it will be some years before they are produced on any significant commercial scale and their potential becomes clear.

To see why this revolution matters, consider that global energy demand is likely to double in the first half of the century, driven by rising population and strong growth in the emerging economies. The International Energy Agency estimates that the world will need to invest some $38 trillion to meet projected demand in the period to 2035: that means $30 billion every week. Over the same period, the world must tackle its CO_2 emissions. The consensus of climate scientists is that the atmospheric concentration of carbon dioxide should be limited to 450ppm to avoid the worst consequences of climate change. It has



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now passed the 390ppm mark, and continues to rise at some 2ppm every year.

Gas versus coal

Displacing coal-fired power with natural gas is the fastest and cheapest way to reduce CO_2 in the global power sector over the next 20 years. In 2010, coal was responsible for as much as 44 per cent of energy-related CO_2 emissions, and usage of coal continues to rise. Indeed, the increase in emissions from coal in India and China alone is expected to be roughly double the increase from the entire global transport sector to 2020.

Modern gas plants emit half the carbon emissions of new coal plants, and up to 70 per cent less CO_2 than the old steam turbine coal plants, of which there are still hundreds in Asia, Europe and the USA.

Gas-fired power is also quicker and much less costly to install than any other source of electricity. It represents:

- less than half the capital cost of coal per MWh;
- one-fifth the cost of nuclear;
- less than 15 per cent of the cost of onshore wind;
- less than 10 per cent of offshore wind.

Gas holds much promise in the transport sector too. Liquefied Natural Gas (LNG), for example, can be used to fuel lorries, ships, barges and trains.

And as well as reducing CO_2, natural gas is effective in reducing emissions of damaging local pollutants such as sulphur oxides and particulates.

Natural gas could play a critical role in low carbon energy systems for many decades to come as gas-fired power stations can be switched on and off much more swiftly than other power sources. They are thus the ideal back up for intermittent energy from renewable sources such as wind and solar.

Another long-term benefit is that carbon-capture and storage (CCS) technology has the potential to reduce emissions from gas-fired power to near zero. CCS is also more effective in combination with gas than coal, because it only has to deal with half the CO_2 emissions.

The tight gas revolution is poised to become a global phenomenon. China, Latin America, Australia, Eastern Europe and South Africa all hold significant tight gas deposits. Coupled with the rapid expansion of the global LNG market, this is giving more governments the confidence to back natural gas. As a result, according to the IEA, between 2008 and 2035 gas demand is expected to grow:

- 60 per cent globally;
- eight-fold in China;
- five-fold in India.

Public concern

Nevertheless, public concern about the safety and environmental impact of tight gas continues to mount. In response, several governments have already imposed moratoria on hydraulic fracturing.

One major public concern is that hydraulic fracturing could lead to the contamination of fresh water supplies, either by the fluid used to fracture the rocks, or by the gas itself. A study published last year by the Massachusetts Institute of Technology found no documented evidence that contamination by fracturing fluids is occurring. However, it did find "evidence of natural gas migration into freshwater zones in some areas, most likely as a result of sub-standard practices by a few operators" in designing and constructing wells. The critical message is that when a well is designed and constructed correctly, groundwater will not be contaminated. Shell would like to see strong regulation and enforcement that requires everyone in the industry to do it properly.

A second major public concern is that hydraulic fracturing depends on excessive and unsustainable freshwater consumption. Now, sound operational practices can keep water consumption to a minimum. And while the extraction of shale gas indeed requires twice as much water as conventional gas production, this phase only accounts for a small fraction of the total amount of water used to generate power. Further, the water intensity of conventional gas power is far lower than nuclear and all other fossil fuels. So across the entire lifecycle, from production to use, shale gas-fired power only uses half the volume of fresh water consumed by coal and nuclear per MWh.

Greenhouse gases

Another concern is that greenhouse gas emissions from shale gas far exceed not only those from conventional gas, but also even those from coal. Now, there is no doubt that the question of emissions is a complex one, and that further research is required. To this end, Shell is participating in a University of Texas study to determine the total amount of methane emitted in the course of tight and shale gas production. The study is expected to publish its findings early next year in a peer-reviewed scientific journal.

It is, however, now widely accepted that the 2011 Cornell University report which sparked this controversy exaggerated the emissions released during the production and distribution of shale gas. Other studies take a more measured view. For example, the International Energy Agency found that on a well-to-burner basis, emissions from shale gas exceed those of conventional gas by as little as 3.5 per cent in the best case scenario and by 12 per cent in the worst. Sound operational practices can do much to keep this to the low end of this range. In any event, the greenhouse gas emissions from shale gas-fired power are still only around half of those from coal across the lifecycle. And that is the critical point to remember, as public discussion about the gas supply revolution intensifies.

The reality is that this revolution provides the best chance for many countries to make immediate and substantial progress towards a much cleaner, lower CO_2, more secure and more affordable energy supply. ☐

The global potential of shale gas

Paul Stevens

Defining conventional and unconventional gas can be controversial but the simplest definition is that with conventional gas a hole is drilled in the ground and the gas just flows. Unconventional gas has involved the application of techniques to create a flow such as horizontal drilling and hydraulic fracturing. These are not new technologies, though; hydraulic fracturing was first carried out in the late 1940s and horizontal drilling also has been around for a long time.

The term 'shale gas revolution' applies really to the USA and this 'revolution' has been a long time in the coming – in the order of 20 years. The technology came to public attention in 2007-08, when the USA dramatically increased its estimates of recoverable reserves.

In 2000, shale gas made virtually no contribution to domestic gas production in the USA. In 2010, it accounted for around 25 per cent and respectable estimates put the future contribution at around 50 per cent. The consequences of this change have been significant. Gas prices have more than halved since 2008 (although the recession has had some influence). There has been an impact on European markets as well. Here gas prices are traditionally linked to oil but increases in international prices have started to erode that connection.

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Can it continue?

Can the shale gas revolution continue in the USA and can it be replicated elsewhere? Given the dramatic fall in prices in North America in the last couple of years, current shale gas operations look rather uncertain from an economic point of view. However, many of the smaller players have used a hedging-mechanism to protect themselves against lower prices. The larger international oil companies who have recently entered US shale gas have much deeper pockets and can stand lower prices for some time. The speed of technology development has also brought cost savings.

There is public concern over the environmental consequence of hydraulic fracturing. The 2005 US *Energy Act* explicitly excluded hydraulic fracturing from the Environmental Protection Agency's *Clean Water Act*. This became known, somewhat cynically, as the Halliburton Loophole. The result is that most shale gas operations have not yet had proper environmental impact assessments. At the moment the *FRAC Act* is making its way through Congress and this is intended to bring hydraulic fracturing back under the control of the EPA. Meanwhile, a number of states have introduced drilling moratoria, awaiting the outcome of the environmental impact assessments. An EPA investigation into the technology is now expected to be published in 2013.

The better studies on this topic so far suggest that the problems are to do with poor well-completion rather than hydro-fracking *per se*. The issue can be readily solved given sufficient regulatory clout to make sure that the wells are done properly.

Horizontal drilling and fracking can also be applied to 'fallow oil fields' which were abandoned many years ago. Some people are talking about domestic oil production in the USA rising by around 2.5 million barrels a day within five years. In this context, it is unlikely that federal authorities are going to come down very heavily on these methods.

One of the characteristics of shale gas operations is that they are all different and for regulators this could be a serious

DISCUSSION

The threat to renewable energy

The emphasis on a fossil fuel such as gas, even if less harmful than others, could inhibit the development of renewables and lessen the drive to achieve greater energy efficiency in industry and the home. We should not try to pick winners, but be aware that change will happen more quickly than we expect (as with shale gas) and be able to seize opportunities. Nothing should get in the way of improving energy efficiency.

problem. Different shale 'plays' are different; even wells on the same shale play are different. A rigorous scientific investigation on, say, the environmental impact of the Barnett shale play may not be relevant to other contexts.

Is it replicable in Europe?

Can the shale gas revolution happen in Western Europe? While shale gas will be important in Europe it will take much longer. Shale plays in Europe tend to be deeper, more fragmented and with less material than those in the USA. Shale in Europe also tends to have a much higher clay content; given that gas is produced through fracturing the shale, this makes the process more difficult. In America, the operators had access to huge amounts of geological data based upon existing core samples from the thousands of oil and gas wells. This is not the case in Europe.

There are regulatory issues. Petroleum regulations do not mention unconventional gas. Drafting new regulations will add to the time before things can really take off. In the USA there were significant tax credits on unconventional gas and oil, at least until 2002. In Europe, apart from Hungary, there are no tax breaks or subsidies associated with unconventional gas.

Access to a pipeline network is another important factor. In Europe pipeline access is third-party carriage and if the pipeline is already up to full capacity, then the only option is to build a new pipeline. Yet the economics of transport are absolutely crucial to gas operations.

Industry capacity is vital too. In 2008, at the peak of operations in the Barnett shale play in Texas, there were 199 rigs drilling. In summer 2010, there were only 34 rigs in the whole of Western Europe. Of course, if the projects become very profitable, companies will build rigs, but once again this takes time. Access to water is also an issue in certain regions, although advances in technology mean that the amount of water needed for hydro-fracking has fallen dramatically.

Another factor delaying progress is that there are moratoria in various parts of Europe while environmental impact assessments are awaited.

Then there is the issue of property rights. In the USA, sub-soil hydrocarbons are the property of the land owner. If you find shale gas, it is yours and you can make a lot of money out of it. Outside the USA, hydrocarbons are the property of the state and so a land owner may be less enthusiastic about someone drilling on their property.

So, whether the 'revolution' can continue in the USA and whether it be replicated elsewhere are both uncertain. That fact is beginning to affect and inhibit investments in conventional and unconventional gas as well as LNG. Future gas demand will increase very significantly though and if the current uncertainty stifles investment then there could be real supply problems five or 10 years from now.

Finally, the availability of vast quantities of cheap gas with relatively low carbon emissions is likely to call into question the levels of investment currently being directed towards renewable energy. ☐

The Shale Gas Revolution – Hype and Reality: www.chathamhouse.org/publications/papers/view/178865

Shale gas risks

Mike Stephenson

Shale gas has been a success story in the USA. Yet fracking has had some bad press, the main concerns being earthquakes and the contamination of groundwater with gas. In the documentary film *Gasland*, for example, a man is shown igniting water from his kitchen tap.

Some of the worries are justified. Badly managed fracking has recently been shown to have contaminated water wells in Wyoming, though this involved a shallow sandstone reservoir rather than much deeper shale. With so many vested interests, getting reliable information is difficult, though. So peer-reviewed science must play a big role in deciding what the risks are.

In a shale gas well (see Figure 1), the cement casing seals the emerging gas from aquifers and other layers of rock. It is rare – although not unknown – for casings to fail or leak. But there are also risks which are

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new and which require examination – for example, earthquakes related to fracking, and the escape of methane into aquifers from fracking or shale gas operations.

Which kind of methane?

One of the main concerns about fracking is the risk of methane contaminating aquifers. There are two kinds of methane in the sub-surface. Thermogenic methane is generated through the action of heat on old sedimentary organic matter buried in shale, usually deep underground. Natural thermogenic methane is often present in ground water, and not necessarily down deep. In the UK, USA and Germany we also store natural gas (which is usually thermogenic) in underground sandstone reservoirs as a means of managing energy demand.

Biogenic methane is generated by modern bacteria at the surface, or close to the surface in shallow rocks or in the soil. Biogenic methane also occurs in water wells. So there are various kinds of methane in the subsurface, some natural some not.

If there is a leak from fracking deep below the surface, is it possible to distinguish 'fracking methane' from natural methane? Certain indicators can help: the $\delta^{13}C$ and ^{14}C of the carbon in CH_4, and the gas mixture signature of any stored methane. We can also measure background or baseline

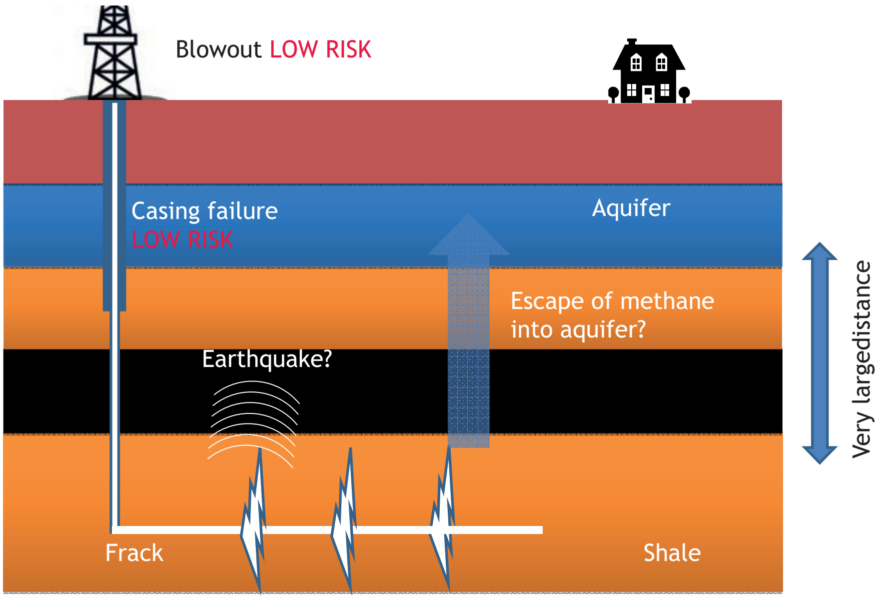

Figure 1. Fracking and the potential risks.

The water wells in the area are shallow – around 100m deep. The shale gas wells in the same area are around 2km deep. Osborn *et al* suggested that the shale gas wells may have had leaky or defective casings and that this caused the methane in the shallow aquifer.

Baseline or background data on natural groundwater methane is rather patchy in Pennsylvania, but rather high levels of methane in groundwater have been noted well outside fracking areas. It is likely that the wells studied by Osborn *et al* already contained natural methane before fracking. A new study by Molofsky *et al* (2011), which was not peer-reviewed, illustrates the widespread occurrence of natural methane in Pennsylvania groundwater and also seems to indicate that the water well methane is unlikely to have been produced by the Marcellus shale which is being fracked.

amounts of methane in groundwater before fracking begins.

The first indicator is perhaps the most useful. The ratio of the 12 and 13 isotopes of carbon in the methane (the $\delta^{13}C$ of the C in CH_4) tends to be around -50‰ or less in biogenic methane and more than -50‰ in thermogenic methane (i.e. less negative). In ideal conditions, it should be possible to distinguish thermogenic and biogenic methane. But this does not mean that we can distinguish 'fracking methane' and natural methane, if natural methane in the rocks is thermogenic. Stored gas mixtures will have a known signature and ought to be readily identifiable if gas leaks from a storage reservoir. Carbon ^{14}C has a short half-life so it will be found in biogenic rather than thermogenic methane.

Leaks into shallow aquifers are unlikely because shale is so impermeable and because fracking is done deep. However, if a leak occurs, or if someone claims a leak has happened, we can use these and other techniques to monitor effectively.

Peer review

At the moment, there are very few peer-reviewed studies in this field. That may reflect the speed with which the technology has developed: the science community, outside the few companies that are involved in shale gas, has not really caught up yet.

Révész *et al* published a study in 2010 which was not about shale gas and fracking, but about gas storage and methane contamination of a shallow aquifer above the storage site. In the study, the authors used the indicators described above to study the methane. They found biogenic methane, probably generated by bacteria, and they also found thermogenic gas which they thought probably leaked from the storage reservoir far below. The paper did not go into much detail about how the leak occurred, if there was one. But the paper did indicate the possibility of leakage.

The best-known paper covering purported shale gas leakage into water wells is that of Osborn *et al*, published in 2011, which deals with an area of northern Pennsylvania. This time the focus was on water wells close to where hydraulic fracturing was taking place. The authors studied shallow water wells, measuring methane content and $\delta^{13}C$.

They found higher methane concentrations in water wells close to shale gas wells. The $\delta^{13}C$ of the methane suggested it was thermogenic. Their conclusion was that the methane was likely to be shale gas leaking from fracking far below.

They also reported that there was no evidence of contamination of the aquifer by fracking fluids, or deep formation brine – very salty water that exists down at fracking levels.

The earthquakes

In Blackpool, there have been two earthquakes close to periods of fracking. The largest was on 1 April 2011, magnitude 2.3; the second on 27 May. The traces of the seismic activity were very similar. This and other data enabled BGS to determine that the earthquakes were a direct consequence of fluid injection during fracking. The company that was fracking subsequently agreed.

It was also possible to show that surface damage is very unlikely from earthquakes of this magnitude. Claims people made for damage in the area are very inconsistent with what we know about the earthquake.

So to conclude: the risks concerning well design and drilling are well-known, well-understood and manageable. We have, in this country, very good regulations to deal with this. There are a few new risks which need to be looked at and science can help to distinguish between what matters and what does not, what is risky and what is not. Peer-reviewed science will be absolutely vital to this process. ☐

DISCUSSION

Getting public buy-in

The biggest problem is public acceptance. Government needs to make the case about energy demand, GHG emissions and fuel security, but sustained effort is needed by companies and regulators too. However, the public do not understand the different responsibilities of bodies such as the Health Protection Agency, the Environment Agency and local authorities. Industry has not been clear about what risks they understand and those where further work needs to be done. They have paid inadequate attention to the fear of earthquakes, for example, and have failed to convince people of their rarity. There has to be some acceptable independent, scientific analysis of risks and consequences.

The way in which new technology is revolutionising drug development was debated at a meeting of the Foundation for Science and Technology on 7 March 2012.

Turning inventions into medicines - and businesses

Greg Winter

The field of therapeutic antibodies is revolutionising the pharmaceutical industry. Therapeutic antibodies are used today for the treatment of a number of diseases, in particular cancer and immune disorders. In the past two decades, this area has grown to be worth nearly $50 billion a year, and of the top 10 pharmaceuticals by global sales, more than half are antibodies. UK science and translational activities have played a major role in its development.

Antibodies are part of our natural defence against viruses and bacteria: they are normally raised by encounter with a foreign antigen in the course of a disease. They are huge molecules compared to traditional drugs – an antibody can have a molecular weight of 150,000, compared to about 500 for a typical pharmaceutical.

By binding to an antigen, the antibody blocks its action; for example, it can prevent viruses, bacteria or their toxins locking onto human cells. In addition, it can act as a flag to the immune system, directing killing activities onto the pathogen. It turns out that neutrophils, macrophages and NK cells can all mediate such killing through a variety of mechanisms.

Antibodies can also be used for the treatment of non-infectious disease. For example, the antibody Humira blocks the action of a mediator (TNF) of rheumatoid arthritis, and has transformed the treatment of rheumatoid arthritis. The antibody Rituxan kills B-cells and is used for treating non-Hodgkins lymphoma in which these cells proliferate.

Sir Greg Winter CBE FRS FMedSci is Master-elect of Trinity College, Cambridge and former Deputy Director of the Laboratory of Medical Biology. He graduated from Trinity College in 1973, and has been a Senior Research Fellow since 1991. A genetic engineer, he is best known for his research and inventions relating to therapeutic antibodies. He has founded three biotech companies: Cambridge Antibody Technology, Domantis and Bicycle Therapeutics. He consults for several start-up biotech companies, and received the BioIndustry Association Award in 2008.

The antibody advantage

There are a number of differences between antibodies and traditional chemical pharmaceuticals. Several are directly related to size – antibodies are large molecules and engage with their target antigen over a large contact area. There are consequently many interactions and these can lead to a high binding affinity. By contrast, chemical drugs are much smaller and tend to bind more weakly; they often bind to small hydrophobic pockets in other (non-target) molecules, so unexpected toxicities may emerge at a late stage clinical trial. Similarly, the large size of antibodies readily blocks the interactions between proteins, such as between ligands and receptors.

Antibodies are also too large to be cleared by filtration of the blood through the kidneys, and this is one of the factors leading to their long serum half-life – in fact up to a month. That can allow dosing intervals of several weeks or more. By contrast, small molecules are cleared much more rapidly by the kidney and have to be taken daily.

Given the benefits, it is reasonable to wonder why antibodies are only now coming to the fore. The reason is that they also have significant disadvantages. In particular, they are digested in the gut so they have to be given by injection and they struggle to get to targets outside of blood vessels or to targets inside cells. In addition, they can be immunogenic.

The evolution of therapeutic antibodies

Immunogenicity was one of the biggest problems. Modern therapeutic antibodies started off as animal antibodies and had to be evolved to a human form. The first step in their evolution was the rodent monoclonal antibody, made in 1975 by Milstein and Kohler at the MRC Laboratory of Molecular Biology by immunising mice with antigen, and fusing the antibody-producing cells from the spleen to a cell line. These hybrid cells, or hybridomas, produced a single species of antibody (or monoclonal antibody). Although mouse monoclonal antibodies could be developed to kill tumour cells, they were recognised as foreign in patients, and provoked blocking human anti-mouse antibodies. It was clear that human antibodies were needed but at first these proved impossible to make.

Several solutions emerged from outside the field of immunology, starting in the early 1980s. The first solutions involved

DISCUSSION

Striking a balance

There is a balance to be struck between open access to data, which would allow researchers to collaborate and use information, and the need to protect intellectual property for exclusive use in order to achieve commercial success and profits. There is no universal solution for this problem - it has to be treated case-by-case. But, if commercial success is to be maintained on the basis of exploiting existing research, whether patented or not, it has to be through the development of new ways of using the research or 'tweaking' it , through an understanding of its potential. An example might be the development of a 'super antibody'. The difficulty of protecting IP internationally, with today's communication technology, is already great.

using genetic engineering to transplant the antigen-binding regions from mouse to human antibodies; in chimeric antibodies the entire antigen-binding region was transplanted (to give antibodies that were 2/3 human) and in humanised antibodies only the antigen-binding loops were transplanted (to give antibodies that were 95 per cent human).

By the late 1980s, solutions were emerging to make fully human antibodies. One involved the creation of an artificial immune system. In 1989, we had started experiments to create huge repertoires – more than 10exp8 – of different human antibodies by genetic engineering. We then, somehow, hoped to find those that bound the target antigen.

The other solution involved the engineering of 'human' mice. Again in 1989, Michael Neuberger at the MRC and Marianne Bruggemann at the BBSRC started experiments to introduce human antibody genes into transgenic mice, such that on immunisation the mice would make human antibodies.

By the mid-1990s, there were several working technologies (hybridoma, chimeric, humanised and human) for making therapeutic antibodies. Each of the technologies had originated in the UK, or had a major UK contribution. Each of the technologies led to major therapeutic antibody products. However of the 29 or so therapeutic products approved to date, only seven had a significant UK input in their development: the technological leaps in the UK did not carry through to the development of antibody products in the UK. Understanding how the technology transfer took place helps to make sense of that anomaly.

Translation through licensing

Let us start with the story of mouse monoclonal antibodies. This began in the days of the National Research and Development Corporation (NDDC), a monopoly responsible for commercialising all research emerging from the Research Councils. They did not file a patent on hybridomas, even though they were alerted before publication. A later letter from the NRDC to the MRC said: "It is certainly difficult for us to identify any immediate practical applications which could be pursued as a commercial venture … and it is not immediately obvious what patentable features are at present disclosed in the *Nature* paper."

The BBC was interested, though, and news of the discovery was broadcast around the world. With no patents, other labs and businesses were free to take up the technology. Translation was not an issue, it translated itself! The commercial possibilities were mainly picked up in the USA. Late in the day, attempts were made to capture value for the UK and the National Enterprise Board set up Celltech, the UK's first biotech company. The MRC assigned future rights on the IP of antibodies to Celltech for a limited period, and Celltech became an early player in the field of recombinant antibodies.

The UK had another shot on goal with humanised antibodies and did better. In this case, we filed a patent in 1986 but the next step in translation was not through Celltech, but through an academic collaboration between my group and that of Herman Waldmann in the Cambridge Department of Pathology. By 1988, we had humanised a rat antibody against white cells – the Campath antibody – and used it to destroy a large mass of tumour in patients. The demonstration had a dramatic effect – a number of biotech companies suddenly wanted to learn the technology and take out a licence.

The patent position was complicated, though. By the late 1980s, Celltech and Genentech had both filed general patents on recombinant antibodies. These potentially blocked the whole field of therapeutic antibodies. With Genentech also controlling access to the chimeric antibody format, Celltech needed a licence from the MRC to make humanised antibodies, as their automatic rights to MRC IP had expired – their particular interest was in making antibodies against TNF.

The MRC wanted to see its humanising technology more widely applied, and reached an agreement with Celltech by which the Celltech patent on recombinant antibodies and the MRC patent on humanised antibodies were licensed together to third parties. In addition, Celltech was given an exclusive licence for making humanised antibodies against TNF. The effect was immediate and between them the MRC and Celltech licensed more than 40 companies – including Genentech!

In the late 1980s, the MRC had also set up a Collaborative Centre for working with industry. The Centre developed a focus on antibody humanisation and two of the antibodies developed there became important pharmaceuticals: Actemra (from a programme with Chugai) is used to treat rheumatoid arthritis; and Tysabri (from a programme with Elan) is used for treating MS and Crohn's Disease.

The impact of this technology has been huge. Humanised antibodies are used to treat a wide range of diseases with combined sales in the region of $20 billion per year. This has brought more than $500 million in royalties to the MRC. The saddest aspect of all this was the failure of UK industry (other than Celltech) to capitalise on the technology – there was no interest from the major UK pharmaceutical companies even though the technology had been developed locally and was available to license. Furthermore Celltech's own efforts to develop antibody products were slow and largely unsuccessful.

Translation through start-up companies

The development of human antibodies took another path, and here I only have space to describe those made by antibody repertoires. By 1989 we knew how to produce antibody repertoires of huge size, by scrambling the heavy and light chain pairings from populations of lymphocytes. Patents had been filed, but we did not know how to identify those rare antibodies binding to the target antigen, at least not on the scale required. Then we became aware that the Scripps Research Institute had arrived at the same idea and had linked up with a local San Diego company called Stratagene. Their team was growing and we needed to move very fast.

UK industry – Celltech, Wellcome and Unipath – regarded the project as too 'blue sky'. So I asked the MRC for permission to set up a company. Management appeared

DISCUSSION

Falling between two stools

The way in which universities exploit their research and encourage their staff to set up start-up companies was questioned. There is too great a concentration on securing income for the university, and not enough on looking at the ultimate impact of the technology. Moreover, because researchers starting up companies still continue in their academic posts, they lack the ability to do two very different jobs - i.e. run a company and continue research. This system was contrasted with the MIT system where researchers who want to exploit their research through a start-up are required to choose - either they leave and run the company or they stay in post.

in the form of David Chiswell, an antibody engineer from Amersham International. Money came from a speculative Australian biotech company called Peptech. A research collaboration was set up between the MRC and the company to share the core science and the intellectual property; our business plan was to work with industrial partners to make enough money to fund our own products. That was how Cambridge Antibody Technology (CAT) was born. In a few months, a company researcher working at the MRC discovered that antibodies could be displayed on a bacterial virus; this provided a means of interrogating our vast repertoires. CAT was flying.

At this point, the MRC set up an Interdisciplinary Research Centre (IRC) for Protein Engineering and appointed me Deputy Director, providing extra resources for the project. The Centre worked on the technology, patents and underlying research while CAT focussed on developing and commercialising products.

One of the first partners for CAT was BASF Pharma who had wanted to make a humanised antibody against TNF but discovered that the MRC had licensed this technology exclusively to Celltech. So they decided to take a chance with our new and unproven technology for making human antibodies. The collaboration culminated in Humira, a blockbuster human antibody which this year became the world's top-selling pharmaceutical.

Like the humanised antibodies programme, the strategy for human antibodies was successful, CAT developing two human antibodies – Humira for treating rheumatoid arthritis, and Benlysta for systemic lupus erythematosus (SLE). The royalties to the MRC from that portfolio come to around $250 million to date.

CAT was acquired by AstraZeneca for more than $1 billion; GSK also profited from CAT as it now markets Benlysta with Human Genome Sciences. So although the two large UK pharmaceutical companies showed no interest in the technology at the beginning, in the end both came round to it and are using it to fill and develop their product pipelines.

DISCUSSION

Lost in translation?

Is industry now more prepared to work with blue skies research? The pharmaceutical industry may well be, because it understands the speed with which new developments come about, and how (as with antibodies) existing commercial success can be undermined. Indeed, they now understand the need for research which leads to disruptive technologies, which may transform the market. Yet it is important for researchers to understand that they need to present a package of research which has scale and impact: it is no use just suggesting potential. There is a need for leadership in academia, to motivate researchers and help them understand commercial reality.

Conclusion

The antibody technologies described here emerged from blue skies, curiosity-driven research. They were translated in completely different ways:

- with hybridomas, no patent was filed, the technology translated itself and the main impact was on research and diagnostics. The National Enterprise Board set up Celltech as the UK's first biotech company and that turned out to be very important for later developments;
- with humanised antibodies, patents were filed, and the technology was widely licenced as a package leading to a large class of therapeutic antibodies. In the UK, Celltech developed Cimzia (an anti-TNF antibody) and the MRC through its Collaborative Centre helped develop Actemra and Tysabri;
- with human antibodies, patents were filed and the technology licensed exclusively to a start-up company, CAT, which worked with multiple industrial partners to develop antibodies leading to Humira and Benlysta.

Public money was used for both research (through the MRC) and translation (through the MRC Collaborative Centre and the IRC for Protein Engineering); public returns came through the MRC from royalties on sales of antibodies and sale of shares in CAT, and through CAT by the creation of more than 300 jobs.

Technologies were translated through commercial licensing agreements, and/or by providing centres for working with industry partners, with humanised antibodies through the MRC Collaborative Centre and with human antibodies through the start-up company CAT. Such centres, whether public sector or private, are valued by industry; in these examples the industry partners paid most of the costs. Such centres act as a focus for the creation and training of specialists in the technology, and are available for the development of future inventions. It is therefore important to locate such centres in the UK.

It is clear that for successful translation of high technology it is necessary to bring together several ingredients: research, public funding, private funding, and commercialisation. In the case of the antibody examples, most of these elements were brought together sequentially. It is not clear whether this was ideal, or whether it would have been better to bring them together in a more concerted manner, or even simultaneously, for example by setting up of 'technology exploitation centres' (TECs) funded as companies by both government and non-government sources (e.g. private investors, industry, VCs) and working with researchers and industry to develop and translate novel technologies into products. ❒

A tale of two revolutions

John Savill

There are really two revolutions here. The first lies in the way that previously untreatable disorders – such as inflammatory diseases – are now susceptible to treatment. There has truly been a revolution in improving health in patients with these crippling disorders. Yet there is also a second, one in which medical research is able to drive the economy in the UK. These gains in wealth are just as important as the gains in health. That has been reflected in the recent Government strategy for UK life sciences. The MRC has a role in driving the productive interaction between industry and the MRC family. It is vitally important to get that right. How the UK could have benefited if that relationship had been stronger over recent decades.

The net commercial income to the MRC over the last decade or so, from assets like antibody patents, has risen year by year, from £15 million in 2003-4 to £75.2 million in 2011-12: these are significant sums of money. The MRC was able to do some really quite creative things with this stream of money. Today, this forms part of the overall expenditure limit and so substitutes for public money, but it is an important element in our overall budget.

Now Cambridge does not officially have a cathedral, but the MRC's new Laboratory of Molecular Biology, built with the aid of a £200 million Government grant, may count as one: a cathedral to the concept that MRC research can drive both health and wealth.

Sir John Savill FRSE FMedSci who is Chief Executive of the Medical Research Council. Between 2008 and 2010, he worked part-time as the Chief Scientist for the Scottish Government Health Directorates. In 2002, Sir John was appointed as the first Vice-Principal and Head of the College of Medicine and Veterinary Medicine, University of Edinburgh. He retains an ongoing, research active involvement with the University of Edinburgh.

MRC Technology has become a very powerful organisation. Although closely linked to the MRC, it is now beginning to spread its wings. It will leave the nest and develop its own portfolio of interactions not just with the MRC, but also with universities and other organisations.

MRC Technology is probably the best technology transfer organisation in the world: it has generated more than £500 million of income, licensed over 400 technologies to industry, managed the formation of some 18 start-ups and managed or developed the technology leading to a number of major new drugs. In all, this has led to industry-generated revenue of around £40 billion. It is a model of the kind of translation that is going to generate companies of scale in the UK. ❑

Collaboration is the way forward

Neil Brewis

Monoclonals (mAbs) are potent, specific and a great deal about them is now understood. Yet the hurdles to successful application are high – these are intricate, large structures, made by engineered cells in large fermentation tanks.

There is a great deal of complexity involved. The manufacturing regulatory submission for market authorisation for a small molecule pharmaceutical or 'white pill' would be several hundred pages long. That for a mAb regulatory submission would form a stack several feet deep.

Moreover, the development of new medicines is extremely expensive, upwards of £1 billion. While mAbs have a higher chance than New Chemical Entities (NCEs) of successfully passing the various stages of clinical development, there are more failures than successes. At the same time healthcare budgets are under intense pressure, which impacts directly upon the way medicines are developed.

The old R&D model where a pharmaceutical company produces a portfolio of medicines whilst operating independently of the outside world is no longer viable. Companies cannot do all the necessary R&D alone, hence the increased focus on externalisation. The industry must look for relationships which create synergies between academia, pharmaceutical companies and the SMEs.

There are several ways in which the UK can create the vibrant biosciences sector needed for the discovery and development of novel medicines.

Dr Neil Brewis is Vice President of Research, Biopharm R&D at GSK. He is also site head for GSK in Stevenage. He is responsible for all preclinical and clinical biopharmaceutical projects up to clinical proof of concept and he oversees a portfolio of monoclonals, antibody fragments and protein therapeutics. His group incorporates drug discovery, an innovation group, early process development and a discovery medicine function.

First, large pharma companies need to work collaboratively with SMEs and academia. This involves sharing risk and reward, something which companies do and which is becoming more acceptable to academia.

Second, pharma companies must promote the growth of the sector through a more open approach to innovation. For example, AstraZeneca has given the academic community, via the MRC, full access to 22 experimental medicine drugs. GSK is making land available next to its research centre at Stevenage and working with the Wellcome Trust and Government to establish the Stevenage Biosciences Catalyst (SBC). GSK will share expertise and spare equipment with future SBC tenants if this aids success in the wider UK biosciences sector.

Third, whether around Cambridge, London, Oxford, the North West of England or in Scotland, clusters of academia, biotech and large pharma companies provide benefits to the individuals working there. People can then move jobs from one sector to another without the need to uproot their lives – like many, I have experienced the advantages of moving from biotech to pharma without relocating.

Cambridge has the biggest concentration of biotech in Europe. Clusters like this will continue to bring benefits not only to individuals but to local economies too.

The monoclonal technology wave has been highly impressive and further innovation will come along to improve patient benefits. This is a world stage and although countries such as China are making great progress, I see positive signs around us in the UK too. The MRC is really 'open for business' and pharma is looking for ways to encourage external innovation.

It is also pleasing that the UK Government is looking seriously at what can be done to strengthen the biopharm sector – both big and small companies. GSK believes a priority is establishing a strong SME biotech sector in the UK. ❑

Changes in the Arctic are raising economic, social and environmental issues. A round table discusssion at the Foundation for Science and Technology on 14 December 2011 discussed the opportunities the new situation presents.

A changing landscape

Charles Emmerson

Science is key to the Arctic. Supporting science as part of UK policy is critical in order to:

- better understand macro-level processes which will affect the world;
- better understand macro-level processes which will ultimately affect the UK;
- better influence Arctic diplomacy.

The strength of British scientific research is a key element supporting Britain's role in both poles.

Changes of state

While the Arctic is undergoing an environmental 'state change' (chiefly as a result of climate change), it is also experiencing a 'state change' in the socio-economic and political spheres. The relationship between the environmental and socio-economic state change is not linear or one-to-one. The reduction of sea ice in the Arctic, for example, is a necessary but insufficient condition for large-scale Arctic shipping: other elements have to be in place, from insurance and infrastructure to, importantly, certainty about where and when the Arctic will freeze in the winter months.

Some environmental change in the Arctic makes access harder, not easier. In some areas, melting permafrost will incur infrastructure costs while in others later freezing and earlier thawing will shorten periods of ground-transport access. Coastal infrastructure may be more subject to coastal erosion and storms.

In addition, while changes in environmental conditions may be generally more promising for economic activity, plenty of challenges will still remain: low temperature, wide variations in temperature levels, relative isolation, and so on.

Research and development of Arctic-specific technologies and processes will take time. There will be costs but these innovations will be necessary for Arctic development.

Charles Emmerson is a Senior Research Fellow at the Royal Institute of International Affairs at Chatham House, where he works mostly on issues related to resource security and broader geopolitical trends. He is the author of *The Future History of the Arctic*. Prior to this Charles was an Associate Director at the World Economic Forum leading their global risk work.

Just as environmental state change in the Arctic involves moving from a relatively predictable natural environment to one where things are changing but not with a defined final state, so socio-economic and political state-change involves plenty of uncertainty and again has no pre-destined path.

Oil and gas

Towards the end of 2011, two stories underlined the levels of uncertainty in the Arctic and the dependence of much Arctic economic development on external factors. Questions were asked about the development of the Shtokman natural gas field off the north coast of Russia and there were reports about Cairn's unsuccessful experience in finding commercially-viable oil off Greenland.

While the Shtokman development was originally conceived to provide LNG to the US market, the boom in North American shale gas has harmed the economics of this project. Tax breaks provided by the Russian state, gas demand elsewhere, as well as the prestige and technology elements associated with the project, may mean that it does ultimately progress, although over a longer timescale.

Other projects are going ahead and Cairn, or other companies, are likely to return to Greenland. Shell's developments in offshore Alaska appear to be progressing with US government backing. Statoil has announced plans to drill a new well near the Snøhvit, and the Norwegian government is highly supportive of the northward shift of the country's oil and gas industry (including into the areas recently delimited as Norwegian and Russian in the Barents Sea). Statoil has made two substantial finds in the Barents Sea, proclaiming that it has 'cracked' the geological code, and the company is seeking to produce 400-500,000 barrels per day by 2020.

In Russian waters, Prirazlomnoye should come on stream in 2012. In Norway, Goliat may come on stream in 2013 and a new and substantial find from this year, Krugard, may be producing from 2018. Onshore, the Yamal peninsula may be the future both of Gazprom and of Novatek: it could also include an LNG component. In the longer-term the South Kara Sea is expected to be developed, with ExxonMobil in prime position to exploit this.

These developments offer opportunities for UK companies.

DISCUSSION

Tensions

There is an inevitable tension between development and the preservation of the fragile environment of the region. Development will not take place, or would be hindered, unless environmental concerns are fully addressed to the satisfaction not only of international NGOs but, more importantly, of local communities. It is only then that the vital trust between local communities and developers can be achieved, and a licence to operate obtained. This trust must rest on a belief that developers fully understand fears about accidents and the potential for oil pollution, and have put adequate response measures in place. Failure to deal effectively with a disaster will affect not only the current developer, but all subsequent development activities.

DISCUSSION

Industry and academia

There is further scope for developing knowledge transfer between industry and academia. The UK Government is making efforts to encourage, through the Research Councils, research which is of benefit to business and knowledge transfer. The Natural Environment Research Council (NERC) itself has a very wide spread of interests. However, it is difficult to meet them all; funding decisions have required a focus on selected areas of research, although these do include Arctic research questions. It is important to maintain research over time, and not react to cuts by stopping pieces of long term observations, or research which underpins other research - that would be the worst form of salami slicing.

While BP has been excluded from the South Kara Sea for the present, British companies have considerable offshore and technical experience, as well as experience of Arctic conditions through the sub-Arctic Sakhalin development (in addition to BP's operations in Alaska). As North Sea output declines, UK companies may need to look to these new locations. Moreover, the UK will be increasingly dependent on Norwegian gas in the future, a rising share of which may come from the Arctic.

Shipping

The fact that the Arctic is becoming more ice-free than in the past does not mean that large-scale trans-oceanic shipping in the area is imminent. However, several high profile cargos have transited the Northern Sea Route over the last few summers and the volume of shipping along this route is increasing (although from a relatively low base). The first LNG cargo is scheduled for summer 2012. Dense point-to-point shipping within particular parts of the Arctic is more likely to occur in the medium term.

Factors such as the prevalence of ice, the balance of interests of the coastal states and the likelihood of supporting economic activity, mean that the Northern Sea Route around the top of Russia is more likely to become a major shipping route than the North-West Passage across the top of Canada.

The commercial viability of shipping depends not just on ice conditions. There are a range of factors including ship-design, a favourable regulatory environment and economic rates for any accompanying vessels. Commercial calculations for large-scale shipping will be based on using ships through the year, not just on ships navigating the Arctic for a few months annually. Ice formation will remain an issue.

While shipping associated with oil, gas and mining developments will most likely increase in the near future (and act as a spur for infrastructure investment which may support shipping neither originating nor terminating in the Arctic) this will take time.

The UK also has a role to play here. It is a major shipping nation, with a major financial services industry to help manage maritime risk. It is significant that a polar shipping code is currently being discussed in the International Maritime Organisation, based in London.

Politics

The politics of the Arctic are much more cooperative than generally reported. All Arctic coastal states agree upon the essential role of the UN Convention on the Law of the Sea (UNCLOS) in helping resolve the question of how far a state may extend its ownership of the continental shelf from its coastline (this even applies to the USA which is not a signatory to UNCLOS).

Russia will finalise its submissions on its continental shelf in 2012. Canada and Denmark (Greenland) are yet to submit their claims. Again, this process will take time. The committee tasked with processing claims submitted under UNCLOS has a backlog that may take a long time to clear. Its pronouncements may be taken as having consultative rather than binding force. And the existence of UNCLOS does not, by itself, necessarily resolve overlapping claims, or disagreements about where maritime borders of adjacent states should lie (as was the case with Norway and Russia over the Beaufort Sea before they reached agreement, and is still the case in the US/Canada dispute over the Beaufort Sea).

There will be disagreements over the status of particular waterways. While the North-West Passage is considered internal waters by Canada, US and UK policies explicitly state that this, along with the Northern Sea Route, is an international strait. There are differences of opinion about the extent to which UNCLOS applies to the Svalbard archipelago. Is the extensive and potentially hydrocarbon-bearing continental shelf associated with Svalbard subject to the equal access stipulations of the Svalbard Treaty (to which the UK is a signatory) or does this Treaty only apply to a much more limited zone?

The Arctic Council is evolving, signing its first legally binding agreement in 2011 and creating a permanent secretariat in Tromsø. A decision on how to engage with non-Arctic states (e.g. China and the European Union) which have been seeking permanent observer status has in effect been postponed to 2013 through the introduction of criteria by which suitability will then be judged.

The UK is an observer to the Arctic Council, but much of its engagement touching on Arctic issues will take place through Government departments other than the Foreign and Commonwealth Office (FCO), and will occur bilaterally rather than through the Arctic Council itself.

Although the FCO has produced a very useful summary of UK government policy[1], such a summary should not be equated with a UK Arctic strategy. A question, then, remains as to whether an explicit UK Arctic strategy is necessary, or suitable, or useful. □

1. www.fco.gov.uk/en/global-issues/polar-regions

DISCUSSION

The longer term

Long-term monitoring of developments and long-term thinking by business is essential. There is a danger that existing databases and monitoring arrangements will not continue. The timescales necessary to understand issues such as climate change are different for research and for business. Business may need an assessment of conditions for a development very quickly, but long-term issues demand lengthy data-gathering and an acceptance that outcomes will not appear for considerable time (and even then may be uncertain). Environmental baseline studies are essential to measure the changes caused by development.

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