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THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

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EU commits to 20 per cent cuts in emissions

The Council of European Union environment ministers, meeting in Brussels on 20 February, agreed to commit the EU to a reduction of at least 20 per cent (on 1990 levels) of greenhouse gas emissions by 2020. This is described by the Council as a "firm, independent commitment".

However, the EU is willing, says the Council, "to commit to a reduction of 30% of greenhouse gas emissions by 2020 compared to 1990 as its contribution to a global and comprehensive agreement for the period beyond 2012, provided that other developed countries commit themselves to comparable emission reductions and economically more advanced developing countries adequately contribute according to their responsibilities and respective capabilities."

Several member states – including Poland, Hungary and Finland – were reported to have opposed aspects of the decision. The EU has agreed to a burden-sharing arrangement to try to reach the emissions cuts required under the Kyoto Treaty but many countries are struggling to achieve their targets. ❐

www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/envir/92864.pdf

Call to strengthen intellectual property rights

The final report of the Gowers Review on intellectual property (IP) was published on 6 December 2006. While the Review concludes that the UK has a "fundamentally strong IP system" it sets out a number of reforms.

In order to provide support for businesses using IP, the review recommends that:

- the UK Patent Office be restructured as the UK Intellectual Property Office, with recommendations for it to provide greater support and advice for businesses using IP domestically;
- business representatives sit on a new independent Strategic Advisory Board on IP Policy, advising the Government;
- the Government improve support and advice internationally – including in India and China - to enable UK businesses to protect their investment around the world.

To ensure the correct balance in IP rights the review recommends:

- ensuring the IP system only proscribes genuinely illegitimate activity. It recommends introducing a strictly limited 'private copying' exception to enable consumers to format-shift content they purchase for personal use;
- enabling access to content for libraries and education establishments – to ensure that the UK's cultural heritage can be adequately stored for preservation and accessed for learning. The Review recommends clarifying exceptions to copyright to make them fit for the digital age.

The Review was commissioned by the Chancellor of the Exchequer in December 2005. The UK's economic competitiveness is increasingly driven by knowledge-based industries, especially in manufacturing and science-based sectors as well as the creative industries. ❐

www.hm-treasury.gov.uk/pre_budget_report/prebud_pbr06/press_notices/prebud_pbr06_pressgowers.cfm

Research budgets suffer from funding revisions

The Spring Supplementary Estimates published by HM Treasury on 20 February show significant revisions to DTI budgets, including those of the Research Councils. The Councils' end of year flexibility (EYF) has been reduced, on a one-off-basis, from £196 million to £128 million, resulting in an effective reduction in their combined resources of £68 million in the current spending review period.

Research Council chief executives have been made aware of the pressures on other DTI budgets; nevertheless, they say they are disappointed that any shortfalls have been made at the expense of investments in research. Research Councils fund projects over many years and large proportions of the budgets are committed several years in advance.

The EYF reductions for each Council are:

- Arts and Humanities Research Council – £5.3 million;
- Biotechnology and Biological Sciences Research Council – £6.7 million;
- Council for the Central Laboratory of the Research Councils – £0.5 million;
- Engineering and Physical Sciences Research Council – £29.0 million;
- Economic and Social Research Council – £3.0 million;
- Medical Research Council – £10.7 million;
- Natural Environment Research Council – £9.7 million;
- Particle Physics and Astronomy Research Council – £3.1 million. ❐

www.rcuk.ac.uk

Science in the service of Government

To determine how effectively Government departments are using science in planning and policy-making, the Government's Chief Scientific Adviser, Sir David King, has set up a rolling programme of reviews. The third of these – into the Health & Safety Executive (HSE) – was published on 21 February.

To formulate a view on the quality and use of science in HSE, the review focused on 10 success criteria that underpin good practice in the use of science by Government departments, to identify both areas of good practice, especially those that could be adopted elsewhere, as well as areas for improvement.

According to Sir David King, "Every Government department needs to draw on the highest quality science and research as part of the policy-formulation process. Policy solutions which are based on no science or bad science can be costly, both in terms of resources and reputation. Through reviewing each Government department's use of science we can improve the way science is managed, understood and drawn-on as the basis for better policy making."

The first Science Review, of the Department for Culture, Media and Sport (DCMS), was published in October 2004. The review of the Department for Environment, Food and Rural Affairs (Defra) was published in December 2006 and the review of the Department for Communities and Local Government (DCLG) is expected early in 2007. ❐

www.dti.gov.uk/science/science-in-govt/works/science-reviews/review/hse/page24820.html

Nuclear consultation conclusions quashed

The Government's consultation on nuclear power, prior to the publication of a report in July 2006 favouring a new generation of nuclear power stations, was in some aspects "not merely inadequate but also misleading" according to the judgement of a judicial review given on 15 February. Greenpeace had challenged the Government's decision in favour of nuclear power arguing that the consultation process had been flawed. Mr Justice Sullivan agreed, saying that "something has gone clearly and radically wrong". Accordingly, he granted a quashing order.

While Greenpeace argued that the Government would now have to go "back to the drawing board", the DTI issued a statement saying: "This judgement is about the process of consultation, not the principle of nuclear power. We will of course consult further."

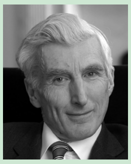
The Department added: "We will press on with publication of the Energy White Paper and we are confident in the strength of our arguments to engage in further consultation."

The White Paper is due some time in March. ❐

The question of what purpose universities in the UK serve and how they should be structured and funded was considered at a meeting of the Foundation on 25 October 2006.

Promoting excellence in teaching and research

Martin Rees



Lord Rees of Ludlow PRS is President of the Royal Society, Master of Trinity College, and Professor of Cosmology and Astrophysics at the University of Cambridge. He is also a Visiting Professor at Leicester University and Imperial College London. He was appointed Astronomer Royal in 1995, and was nominated to the House of Lords in 2005 as a cross-bench peer.

For centuries, the aim of universities was a vocational one – to prepare students for positions within the church, law and medicine. During the 1850s John Henry Newman published his *Idea of a University*, a manifesto for disseminating knowledge for its own sake. The first real 'research university', with the overt aim of seeking new knowledge, was Humboldt University of Berlin, founded in 1810 by Wilhelm von Humboldt. Newman, however, disagreed with Humboldt's concept, believing that: "To discover and to teach are distinct functions; they are also distinct gifts, and are not commonly found united in the same person."

These issues are still debated today. Although the 'research university' model tends to prevail, at least as an aspiration, the world's universities now span the entire spectrum from pure teaching to pure research. The sector has expanded immensely, with unprecedented rises in participation levels and in costs. The contribution made to society by universities has never been greater. So the question, 'What are universities for?' has an even wider resonance today than it did in Newman's time.

The Royal Society is undertaking an ambitious study to determine whether UK higher education will be fit for purpose in 2015. It will be conducted over the course of a year and will look at: the implications of changes in student numbers, including greater numbers of mature students; the revisions to the curriculum for 14-19 year-olds; the issue of general versus specialised degrees; the significance of the Bologna process (a European reform initiative aimed at establishing a European Higher Education Area by 2010); the impact of international movements of both students and professional scientists; and the needs of employers and the wider economy.

A pilot study, 'A degree of concern: UK first degrees in science, technology and mathematics', has already been carried out. Its aim was to identify trends in the popularity of different subjects – not as straightforward an exercise as it may seem. For example, while the number of graduates per year in 'biological sciences' has risen, the number graduating with degrees in straight 'biology' has not. The subject with the largest number of students in the biological sciences category is psychology. The story is the same with the physical sciences: the proportion of degrees granted in chemistry has fallen from 29 per cent to 21 per cent since 1992, while forensic and archaeological sciences now represent 8 per cent of degrees, compared with 2 per cent in 1992. It is worth noting, too, that medicine, dentistry and veterinary sciences hive off many of the best A-level chemists.

The data also highlight the growing mismatch between what university entrants have learned at secondary school and the prior knowledge required by university departments if they are to attain degree standard within three years. The lack of adequate fluency in basic mathematics is especially troubling.

There is one important postscript, however. The most recent figures show a rise in applications to study physics, chemistry and mathematics – 'green shoots', one hopes, signalling that the educational initiatives of recent years are beginning to yield results.

The remainder of my comments are personal views and do not necessarily represent those of the Royal Society. There is another set of data that receives much public attention – the international rankings of universities compiled by the *Times Higher Education Supplement*, Shanghai Jaio Tong University and other bodies. Cynicism is in order about the precision of these league tables and the criteria upon which they are based. However, there is one gratifying feature shared by all the league tables: outside the US, only the UK has several universities in the 'first division'.

We are fortunate to have adopted the 'research university' model and we should cherish it. Most of the UK's best research teams work within universities, where the researchers are kept in touch with students and the atmosphere is more conducive to cross-disciplinary dialogue than in free-standing laboratories. We owe our advantage over mainland Europe to a funding system that is both more diverse and more selective. Some income comes from student fees but there are also several public funding streams and substantial non-governmental channels for research support, especially in biomedical fields (such as the Wellcome Trust and cancer charities).

One distinctive feature of our system is the way our higher education funding councils allocate funds for related research, using the Research Assessment Exercise (RAE) to identify quality-related research. American colleagues are bemused by our 'dual support' system. I tell them that, for all its problems, it is better than the US system where professors need to compete for grants in order to meet even basic academic needs. If we want to retain this dual support while fostering research excellence within a diverse university system largely dependent on public funds, then there must be selectivity. Although it still looms too large in university planning and strategy and distorts the work patterns of individual academics, the RAE is a necessary evil.

There are, however, a number of concerns. First, undue emphasis is placed on academic publications compared with applied work. Second, little credit is given for popular writing and outreach; consequently, heads of science departments discourage staff from such engagement with the public, essential though it is if the country is to apply science wisely. Third, the system is not designed to reward an element that is surely part of a university teacher's remit: broad learning and scholarship. Some of us are old enough to remember the classic Robbins Report, which was published in 1963 and led to the cluster of new universities in that decade. Robbins said that university staff had three duties: teaching, research and 'reflective enquiry'. Reflective enquiry is worthwhile for its own sake, as well as for the way that it enriches both teaching and research.

If we endorse the need for selectivity – the rationale for the RAE – we must accept that there is no easy 'fix'. On the one hand, simple procedures for assessing excellence are crude and often inaccurate; on the other hand, highly refined discrimination would be burdensome. A fair picture of the research being undertaken in any institution cannot be achieved by merely plugging numbers into a formula. We need a subject-based approach based on peer review and supported by a more targeted set of indicators – a system with a 'lighter touch'.

We know that a few universities attract the lion's share of research funding from all sources. That is likely to be the case whatever system prevails. Despite this trend towards concentration, there is at least one top-rated department in more than 50 of our universities. It is crucial to avoid formalising the 'pecking order' and to retain a system that allows excellence to sprout and bloom anywhere in the university sector.

Let me give an example. Leicester University, where I am a visiting professor, is world-class in genetics and in space science. That was not planned. Outstanding young lecturers in these two fields happened to have jobs there 30 years ago, and had the enterprise to build a major research group. The system that then prevailed allowed that to happen. It is important that selectivity is not so harsh that such opportunities are choked off in less-favoured universities.

As we are all aware, in recent years there has been welcome growth in public funding of university research. High on the agenda of universities and research councils, especially in the months leading up to the comprehensive spending review, are efforts to show that good value for money has been obtained by quantifying, as far as is possible, the benefits that have accrued from increases in funding. A report published on behalf of Research Councils UK attempted to address this issue, citing specific examples of research that has led to a direct 'spin-off'.

However, direct 'spin-offs' are not the only benefits to be gained from university research: a study by the Science and Technology Policy Research Unit (SPRU) at the University of Sussex identified an additional six channels of benefit. Its authors argued that, taking all seven together, university research offers incontrovertible benefits to the economy and to society, but that there is "a danger that a focus on the more easily measurable exploitation channels...may distort science policy, to the detriment of longer-term benefits."

'Research universities' benefit society partly through direct knowledge transfer from university laboratories to industry. However, their indirect benefits, which are more difficult to quantify, may be even more important. The dynamic knowledge base within them is a crucial resource for the nation. While we must optimise the transfer and exploitation of academic research, we also need to be careful not to dilute or divert from the core mission, which is to produce outstanding graduates. And we should surely proclaim loudly, in the style of a latter-day Newman, that learning is worthwhile for its own sake. We are a better nation if we are an educated nation.

How well the students are taught depends on the quality of the faculty. Traditionally, universities have attracted outstanding faculty by promising that, in return for teaching, they can devote a fraction of their time to curiosity-driven research. It is increasingly difficult to recruit adequate talent into academia, which is a less alluring career than it used to be. Aside from salaries, which are low compared with those offered in the City, one deterrent is the increasingly pervasive 'audit culture', of which the RAE, the Teaching Quality Assessment and others of that ilk are symptomatic. Some individuals will become academic scientists come what may – the 'nerdy' types (I am one myself) – but academia cannot survive with only these individuals.

Now that our overall enrolment is rising towards 50 per cent of 18-21 year olds, we must learn from the exceedingly broad and diverse university and college system in the US. Their higher education sector has developed organically, with liberal arts colleges, four-year junior colleges and numerous other types of institutions.

Our system is still in transition and moving toward that type of diversity. We must carry on debating issues such as the graduate/undergraduate balance, local versus national catchment, part-time versus full–time and e-learning versus traditional teaching.

In this context, I would like to venture an heretical opinion. I think there is an undue focus on so-called 'wastage'. Universities are too defensive about drop-out rates. An American will say 'I had two years of college', and will often rightly regard the experience as positive. It is surely better to take risks on admission, give students the chance and let some leave after two years with some 'credits' without necessarily being typecast as failures: and without the universities feeling pressured to see unwilling students through to graduation.

As Baroness Blackstone has emphasised, teaching quality in all universities is crucial, not only for the proper education of our own students, but also for those from overseas. The attraction of our universities for these students, who pay high fees, is an important competitive advantage, but will disappear if they decide they are not receiving value for money. Our universities need sufficient funding to compete successfully with their counterparts in the US and the Far East. Public spending on higher education is comparable with that in the rest of Europe at 1.1 per cent of gross domestic product (GDP), but contrasts starkly with that in the US – 2.5 per cent of GDP (and GDP per head is higher in the US), although much of that is private. In a recent speech, Chris Patten highlighted these figures, saying: "It's ironic that we should be condescending about US culture when that country spends twice as much on the acquisition of knowledge and its transmission to students. It would be tragic if research universities declined in the countries where they originated at a time of unparalleled prosperity." It is in our own interest to ensure that, on the contrary, we build on our strengths. We can surely afford it. ❐

The university in contemporary society: lessons from history

David Eastwood

Professor David Eastwood is Chief Executive of the Higher Education Funding Council for England (HEFCE). He was previously Vice-Chancellor of the University of East Anglia, Chief Executive of the Arts and Humanities Research Board and held a chair in modern history at the University of Wales Swansea, where he was also head of department, dean and pro-vice-chancellor. While at Swansea he co-founded the National Centre for Public Policy.

The peculiar history of English universities tells us a lot about why we are where we are today. Essentially, the English university system developed very late. Until the late 1820s, there were only two universities in England. Patterns of development elsewhere were very different. In Europe, by the end of the 18th century there were 66 universities, while the US had around 50 by the time of the American Civil War in the 1860s. The early universities in pre-unification Germany were founded partly as a means of strengthening its small states, while those in the US were an offshoot of that country's expansion during the 18th and 19th centuries. Although England developed a scientific tradition, it flourished outside of the universities, rather than within them. Crucially, English universities played no role in our industrial revolution.

The idea of the university began to change in the 19th century. Lord Rees referred to Humboldt and the concept of a research-led university – the German idea of a university, if you like. He also touched on Newman's separation of teaching and research. At the University of Oxford, this distinction was formalised: the college fellows taught while the university professors engaged in research. The tension between teaching and research has long been problematic within English higher education.

England's university system did not emerge until after the industrial revolution. It began to grow as the big civic universities were established in the second half of the 19th and the early 20th centuries. As late as 1900, however, the English university system was comparatively small when measured in terms of the number of institutions or the proportion of the population who participated. Most universities saw their role as training for Empire, by which I mean the governance of the country and of the Empire, in order to sustain the civic ambition that had developed within the industrial cities during the late 19th century. One very important characteristic of early 20th century universities was their reliance on public funding: the University Grants Committee was established in 1919.

This peculiar history is important to our understanding of the present system, particularly the transformation of England's universities that began in about 1960, when real expansion started. Engagement of the universities with science, research and knowledge creation did not occur until after 1900. In a way that is uncharacteristic of some systems, England moved very quickly from a system of elite education (up to and including the early 1960s) to mass higher education.

The 1997 Dearing Committee of Inquiry defined the purposes of higher education as follows:

- to inspire and enable individuals to develop their capabilities throughout life to contribute to society and achieve personal fulfilment;
- to increase knowledge and understanding for their own sake and to foster their application to the benefit of the economy and society;
- to serve the needs of an adaptable, sustainable, knowledge-based economy at local, regional and national levels;
- to play a major role in shaping a democratic, civilised, inclusive society.

I think this definition nicely captures the essence of the transformed university system that emerged through the expansion of the 1960s, 70s and 80s. It highlights the emphasis on research, the transformation of individual lives and, very strongly, the economic and social functions of the university. This definition would not have

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'Soft' versus 'hard' sciences. 'Softer' sciences such as psychology and sports science are not necessarily – as some claim – unsuitable university subjects. All university students, regardless of specialism, should be trained to use their minds to the best of their abilities and to engage in 'reflective enquiry'. A narrow focus on market demand and career prospects must not inhibit pursuit of the core aim of a university education – to produce outstanding individuals who can absorb knowledge and use it well, to the benefit of all.

discussion

The dangers of complacency. It is risky to rely on high numbers of overseas students paying large sums to help fund our universities. This will continue only if the sector maintains its position as a leader in world-class research, and ensures that students benefit from that. UK higher education is in a fragile state and inadequate or restrictive funding is likely to drive outstanding people away from the universities and into the City or abroad.

had any resonance in the English system of the 19th century.

The story of English universities since the 1960s is one of dramatic growth. In 1961, just 5 per cent of 18 and 19 year-olds entered university. By 2004, that figure had risen to 35 per cent, and 42 per cent of the population aged between 18 and 30 were in higher education in 2006. This expansion transformed the university system, the cultural impact of universities, the people involved in them and wider society.

One of the key drivers of this expansion was the foundation of a number of research-led, 'entrepreneurial' universities. The prototype was the University of Warwick, which began to look outside the state for alternative forms and sources of funding, actively sought to diversify its activities and pro-actively engaged with the local manufacturing base. The entrepreneurial university is now very prevalent, with economic engagement one of the *leitmotifs* of the past 20 years. This development has occurred hand-in-hand with the move towards mass higher education and novel forms of pedagogy such as new media for teaching and innovative approaches to student learning.

Despite all of these changes, we have retained some of the essential characteristics of the English university structure, which I would describe as 'autonomous universities in a national system'. We rightly value the autonomy of individual universities, and that is reflected in the way, for example, that the Higher Education Funding Council for England (HEFCE) funds universities. The majority – 92 per cent – of our funding is in the form of block grants that allow universities to decide how they will distribute the funds.

The story of our universities is also one of success. The quality and impact of the research done by English universities is profound. In addition, we have made enormous progress in increasing and widening participation, while maintaining the quality of learning and teaching during a period of very substantial expansion.

This has been achieved in spite of a diminishing proportionate investment in higher education and has been sustained through periods when those of us working in higher education were utterly convinced that the funding of higher education was inadequate. There is no escaping the fact that we need the right level of investment if we are to compete. This includes public investment through the state, industry investment through employer engagement and, post 2006, students' investment in their own education.

The system is also heavily dependent on international students who pay a premium to study here. The higher education sector is now worth some £45 billion to the UK economy, while public investment in it is of the order of £15 billion. These are functions of the 1:5:12 rule: the UK has 1 per cent of the world's population, carries out 5 per cent of world research and produces 12 per cent of all cited papers. These indicators suggest a system that is efficient and highly performing.

What should be the essential characteristics of English higher education? The view of HEFCE is that the ability to pursue 'blue-skies' research remains paramount. In the absence of major private endowments, our dual-support system is a way of creating the circumstances in which fundamental research can be undertaken. From that research base we are continuing to improve our applied, or translational, research. There have been interesting debates, not least in the context of the Research Assessment Exercise, about the way in which applied and translational research should be measured and funded. Nevertheless, it seems to me that these two activities – fundamental research and applied research – are profoundly complementary and highly important.

This is not to ignore the social and cultural value of university education, both to the individuals receiving it and to the country as whole. The new political economy of higher education, which seeks to balance public investment with an individual's own investment in his or her higher education, is both sustainable and defensible. The emphasis on widening access is about extending that kind of 'graduateness' to a greater proportion of the population.

Finally, and here I think most challengingly, the sector is working hard on developing relationships with industry, including the hard to reach small-to-medium size enterprise (SME) sector. Consultancy income has grown from £112 million in 2000-01 to £211 million in 2003-04, and income from collaborative research rose from £447 million to £541 million over the same period. By 2003-04, 90 per cent of UK higher education institutions had established enquiry points for SMEs.

The relationship of HEFCE with the higher education sector reflects the maturity and autonomy of universities, and a great deal of discretion is given to universities in the matter of funding and local management.

HEFCE shares the concern about the dwindling number of students opting for STEM (science, technology, engineering and mathematics) subjects and has recently launched four major initiatives in chemistry, physics, maths and engineering in order to try to work with schools, colleges and learned societies to drive up demand for these key disciplines. This is a cultural and educational challenge, but we believe that we will see the 'green shoots' referred to by Lord Rees begin to emerge over the next three or four years.

Our universities will remain critical to our ability to operate in an increasingly challenging global environment, and the research carried out within them will remain a key engine in the modern economy. They are fundamental to the maintenance of our liberal, democratic culture. As history shows, their success lies in their capacity to evolve and to balance their traditional aims with the needs of contemporary society. It could be said that universities were the most significant creation of the second millennium, and I think there is a strong argument for saying that they will remain the most significant organisations in the third. ❐

discussion

Applying the research. There was some doubt expressed about the ability of the UK economy to absorb the knowledge that universities were producing; much more effort was needed to have well trained people in business who could commission and use the research universities provided. Some of those present poured scepticism on the idea of the European Institute of Technology. Autonomous and competing institutions would do better, they argued.

Universities in the wider world

Nick Butler

Nick Butler is Director of the newly created Cambridge Centre for Energy Studies. He also chairs the Advisory Board of the Centre for European Reform. He joined BP in 1977 after leaving Cambridge where he graduated with an honours degree in economics. He has worked in a series of economics and policy posts in BP since then, and served as Group Policy Adviser from 1995 to 2003 and from 2003 to 2006 as Group Vice President for Strategy and Policy Development.

Universities have fulfilled different roles historically. Today in the UK, universities serve four purposes. First, they exist to advance knowledge through pure research – in all fields, not just science. That knowledge is fact-based and universities bring a commitment to 'fact as the fundamental source of policy'. That is very important.

In science, I believe that the importance of knowledge means that research funding should be concentrated. The resources needed are considerable – therefore there is value in doing some work on a European scale.

There is value in choosing areas of focus. I also believe there is value in a sensible research assessment exercise which rewards the best but which also enables new and thriving departments to move up the league table. I see very little value in a process which encourages gaming.

There would be great value in encouraging multidisciplinary work because the interplay across the sciences and even with non-sciences such as economics can be very interesting and important. Climate change is a prime example of an issue on which such multidisciplinary work is needed.

Above all we should recognise that this is now an international sector. Assets are mobile: academics, the best students and industrial research funds can all move geographically. That is a good thing but it means that pay and the availability of funds matter. Universities are not immune from market forces.

A second element is the support of universities in linking research to application, which is usually a function of business. Much progress has been made in this area, but the link can still be a matter of sensitivity.

The links between universities and business need to be open and transparent and should work at different levels. Local business across different regions can benefit just as much as big business working internationally. European universities are probably more integrated into local communities and regions, and in some cases business, than many in the UK.

Third, universities exist as instruments of social mobility and meritocracy – in the best sense of that word. Universities are not just about research. They are concerned with the development of individuals and of opportunity. I would be the deputy assistant librarian in Blackpool public library if I had not managed to get to Cambridge.

Universities need to be diverse. There is an illusion that all degrees are the same and that all universities can be measured on a single league table. That is a trend where universities have followed business schools.

I believe this is a false process of measurement. It is damaging to the morale and achievements of many universities which are not world-leading centres of research but which do a tremendous job with a different focus. There is room for the practical as well as the academic: let a thousand universities bloom!

Fourth – and this may be too idealistic – I believe that universities have a role beyond the boundaries of a nation state. Knowledge should know no boundaries. Many of our problems (environment, security) are international in scope. The academy should be international in its search for knowledge and the application of that knowledge.

I believe universities are a very important force in society and that we are fortunate in this country to have a very strong base from which to build. ❐

discussion

Promoting diversity. The existing diversity in UK higher education often seems to go unrecognised. Our institutions range from the research-intensive, highly selective Oxbridge type to those whose research work is targeted at local industries and who have far less demanding entry requirements. The majority, however, lie somewhere between these extremes. All have different roles and it is an error to rate an institution that is trying to fulfil one role as inferior to one trying to do another. A wide variety of courses, full-time or part-time and ranging from one to three years in length, are already on offer but are not being adequately publicised.

Have changes to the curriculum in England and in Scotland made the sciences any more attractive to students? A meeting of the Foundation at the Royal Society of Edinburgh examined the issue on 25 October 2006.

Science education – are we losing the plot?

Anne Glover

Professor Anne Glover FRSE is Chief Scientific Adviser for Scotland, and continues her work at the Institute of Medical Sciences at the University of Aberdeen. Her main research areas are molecular microbial ecology, microbial signalling and biosensor technology. The biosensors have been applied to diagnose environmental pollution and have been commercialised by a university spin-out company.

At university, I see first year undergraduate students arriving and I am not encouraged. My impression is that today's university entrants are less well prepared for a university science course than they were, say, 25 years ago. That is the situation we need to remedy.

In Scotland we have the advantage of a broad curriculum: in general, you can study up to five subjects to higher level, whereas in the rest of the UK, you narrow down to three main topics after GCSE. Our system compares well with the best, including the French Baccalaureate which has a number of core subjects – French, another modern language, history, mathematics, physics and biology. The sciences are an important part of that package, because every aspect of modern life is dependent upon science, engineering and technology.

We could consider making science a mandatory part of the core curriculum, but we should also consider why many people do not seem interested in science. When does natural curiosity and interest in science start to wane? It seems to be about the age of nine. To quote from a 2001 report: after that age they start perceiving science as "authoritarian or dogmatic". They also feel that science is "the learning of facts with little opportunity for reflection and discussion". This is seen to be in marked contrast to English and history where they can discuss things in a more open environment.

If that is truly the case, we must address the educational system and find out how to reverse that impression, making people more open to the opportunities that science can give them. In terms of science in school, how do we educate people? Science is a practical subject. We cannot learn it by talking about it. Take the periodic table: you can study it, learn all the elements and be able to draw it and reproduce it, but would that tell you anything about what the periodic table was for? Would it help you interpret the natural world, or understand the particular properties of the individual elements? I doubt it.

One of the most memorable things for me in chemistry class was a demonstration of how sodium interacts with moisture. Some sodium was brought into the class and we were shown how, if you expose it to moisture, there were violent reactions. I will always have an imprint of the properties of sodium because I saw it in real life.

The first year students I meet at university are the products of science education at secondary level. What disappoints me is that I can give a 50-minute lecture to 250 of them and I will be asked afterwards, "How much do I need to know of what you've just told me?" I answer that they need to know all of it, that is why I spoke for 50 minutes.

That disappoints me because we are giving them all the information that they need in order to then go off and explore. They need to develop knowledge for themselves. Instead, they are driven by the idea that there is a fixed set of facts that they must know, and they are not looking beyond that. I am worried by this: is their lack of intellectual curiosity a result of the secondary education system with its drive for continuous assessment?

It is easy to measure how many facts you know; it is not so easy to measure understanding and application of knowledge. We must strive towards the latter goal in order to develop a better educational system.

Science subjects are still popular in schools. We see students retaining their interest in science subjects and taking them at higher level. We must ensure that we can make science even more interesting for them, because the future of our economy depends on us having properly trained scientists.

The public should also be active in the debate on how we can achieve this. It is impossible for us to make rational decisions about stem-cell technology, nuclear power, genetically modified crops, climate change and so on if the public are not engaged in that discussion. We need to interest the public more in science and technology if society as a whole is to be equipped to make informed choices on technical matters in the future. ❐

The purposes of science education

John Holman

Professor John Holman is Director of the National Science Learning Centre. The centre, funded by the Wellcome Trust, opened in York on 1 November 2005 and is dedicated to the professional development of science teachers. In October 2006 Professor Holman was seconded half-time to the Department for Education and Skills as National Science, Technology, Engineering and Mathematics (STEM) Director.

Science at GCSE level in English schools has seen a steady improvement in rates of attainment, with the percentage attaining A to C grades going up steadily. At A level, it is a different story. Entries are steady for biology, declining (but with a small rise in recent years) for chemistry, and in steady decline for physics. Decreasing numbers are choosing to study sciences, with physics being particularly unpopular.

Looking at the trends in science education in England in recent years, the 'dual mandate' stands out. The phrase, coined by Lord Jenkin, refers to the need to both educate the next generation of science specialists (necessarily a minority of the population) and to equip other students with the basic scientific literacy necessary in the modern world. Getting both these things right is the challenge lying behind some of the current science curriculum controversies.

This new curriculum was introduced in England in September 2006. Called 'Twenty First Century Science', it is intended to provide access to scientific literacy. It was developed at the University of York in partnership with the Nuffield Curriculum Centre in London, and has been piloted with 8,000 students. It is based on the idea that it is not enough to know scientific facts and theories, but that it is also necessary to have an understanding of how scientists work and how society uses scientific evidence to make policy decisions.

Twenty First Century Science has two pillars: science explanations and ideas about the way scientists work. Core science (scientific literacy) is compulsory. Students can also choose to take another GCSE if they want to take their study of science further and there are two varieties: one is called Additional Science (General), which is basically a preparation for AS Level and therefore pre-university study, while the other is a more applied and vocational option. This is an attempt to provide something for both the future specialists and those who will take their study of science no further.

In England the National Curriculum carries with it a strong assessment framework, which means that there is a tendency to 'teach to the test'. When Michael Tomlinson reported on post-14 education, he calculated that out of the six terms spent preparing for GCSE, one term was spent on revising for, or taking, examinations. The more time you spend on revision and getting ready for examinations, the less time you have for engaging and interesting practical work, or for your teacher to tell you about the excitement of science. So, a second concern is that we are testing too much and this may be having a negative effect.

Since the introduction of the National Curriculum, we have had a great deal of curriculum development. A whole set of resources has been introduced but it is clear from all the studies that it is the teachers who make a big difference. The most recent survey on the qualifications of maths and science teachers in schools shows that we have a serious problem in the supply of physical science teachers. Only 19 per cent of science teachers are physics specialists; given that our pre-16 curriculum is roughly a third physics, this means a great deal of physics and chemistry is being taught by non-specialists.

We have a new programme in preparation which will give a diploma in the teaching of physical science to people who are not physics or chemistry graduates; we will retrain (mainly biology) graduates for teaching physical sciences.

Some think that if we have students studying separate sciences, there would be more chance of them going on to take A level. In most English schools the students study either one or two GCSEs combined across the three subjects, but some schools (particularly independents) offer the opportunity to study three separate sciences. The latter means a total of 30 per cent of curriculum time is devoted to science and there is a strong correlation between this choice and going on to study to A level. The Government is encouraging this option.

There is also a strong correlation between attainment in earlier stages (Key Stage 3 at 14, and Key Stage 4 at 16) and the tendency to go on and study further. So we have a programme to raise attainment.

Much public money is invested in schemes to support the teaching of STEM subjects (science, technology, engineering, mathematics). But it is not just about Government money. The learned institutions also invest, as do charitable sector organisations. There is some private sector investment too. If we can coordinate the public and private sector initiatives, then we have a good opportunity of giving teachers even better support. ❒

Science teaching in Scotland

Bob Kibble

Bob Kibble is Senior Lecturer at The Moray House School of Education, University of Edinburgh. He taught in London for 22 years. He is now an active curriculum developer and has produced learning materials for the Open University, the Salters-Horners Physics Course and the Institute of Physics 11-14 Supporting Physics Teaching project.

I will start with some observations from working both sides of the River Tweed. The science department in every Scottish school includes specialist teachers in physics, chemistry and biology. The same cannot be said of English schools. Scottish teachers are trained to teach physics, chemistry and biology as individual subjects, but they also take a course in general science. The number of trainees does not seem to be falling, but while the overall figures look healthy there are some underlying problems. For instance, in some schools, physics teachers are teaching exam courses at higher levels, but younger children do not meet a trained physics teacher.

In Scotland, science classes have a maximum of 20 pupils and a specialist teacher. In England, classes of around 30 are the norm, and chances are that the physics teacher is perhaps a retrained geographer or biologist.

I was a Chief Examiner for one of the exam boards in England. The five examination boards in England and Wales each offer a choice of syllabuses, so there are about 10 possible A level physics courses on offer. In Scotland there is one board with one Higher and one Advanced Higher physics course. Everyone knows the system, the textbook and the exam format. That is a great strength, but also a possible cause of conservatism and complacency.

Science courses are not very different in Scotland and England. The laws of physics hold in both systems. In England a student in school or sixth form college might choose four or five AS levels in their first year. That is similar to somebody who does five Highers.

More people study in sixth-form colleges in England than in Scotland. Such colleges are not a feature of Scottish education. I taught in a sixth-form college in England offering a choice of 28 A level subjects (including philosophy, psychology, a number of different biologies and geology). Students might take physics, perhaps biology and maybe media studies and business studies with philosophy as well. That is fine, but you will never get a degree in physics out of it; you will never be a scientist. Such a broad portfolio of subjects mitigates against studying separate sciences at university. In Scotland, students are more likely to study a coherent group of subjects such as maths, physics, chemistry plus something else. We are more likely to get people who are more tailored, in their choices, to move to higher education in sciences.

Finally, in Scotland there is a strong culture of respect for science, permeating the public domain and parents' attitudes. Science seems to have a higher profile in the public awareness in Scotland.

Why is science education so important? The stories that are within science education represent perhaps the single most significant cultural legacy of mankind. If we can give anything to those who will come after us, it is a window into those arguments, discussions, challenges, paradigm shifts, hard work and pain that represent over 500 years of science enterprise. That is why it should be on the curriculum.

The Scottish Science Strategy document included a chapter on education, with the message that there was a dual purpose for science education: one purpose is to give all children the skills and confidence to act as informed citizens. That is what science education for all learners should be about.

A recent report[1] asked 11 institutions of higher education (the 'science gatekeepers'), "What sort of students do you want through your doors?" The clear reply was that they are not happy with many of the students that they now receive. Many students appear to have a great appetite for facts; they know all the equations but they expect to be spoon-fed. They tend to have knowledge without much understanding. The time is right for a reappraisal of what constitutes an education in science.

Science education in Scotland is in a period of transition. Will the Curriculum for Excellence[2] solve our problems? I support the Curriculum for Excellence initiative, but its values are generic: its principles apply to all education, not just science.

The Curriculum Review must tackle the important question of whether we need one sort of science education for those people becoming scientists and a separate one for 'the rest'. I do not have the solution to this issue. I have spent 10 years working in Scotland and I have not noticed a big move forward on this question; I have only seen tinkering. We need to be less insular and to take note of what other countries struggling with the same problem have done. ❐

1. Coggins J, Finlayson M and Roach A (2005) Science education for the future, The School to University Transition in STEM Subjects Project Report, Universities of Glasgow and Paisley.
2. A Curriculum for Excellence – The Curriculum Review Group.

The economic issues surrounding the challenge of climate change were considered at a meeting of the Foundation on 8 November 2006, centring on the findings of the Stern Review.

The economics of climate change

Nicholas Stern

Sir Nicholas Stern FBA is Head of the Government Economic Service. From 2003-2005, he was Second Permanent Secretary to Her Majesty's Treasury and from 2004-2005, Director of Policy and Research for the Prime Minister's Commission for Africa. He is currently Visiting Professor of Economics, London School of Economics and Political Science, and Visiting Fellow of Nuffield College, Oxford. From 2000-2003 Sir Nicholas was World Bank Chief Economist and Senior Vice President.

This Review treats the economics of climate change as a challenge in understanding international collective action and as a challenge in understanding international economic policy-making.

A key element is the issue of externalities. An externality arises when you act (in terms of some economic production or some economic consumption) and it has an impact on other people. It can be beneficial, it can be damaging. Taking your car out slows other road users; that is an externality with an immediate effect and when cars slow to walking-pace we introduce congestion charges. Externality is a fundamental and valuable concept in the whole story of environmental economics.

The externality we are concerned with is:

1. *Global.* Carbon emitted in Australia is the same, in its effects, as carbon emitted in the UK.
2. *Long-term.* Emissions build up in the atmosphere. They stay there for a very long time but the effects of greenhouses gases in the atmosphere take time to appear.
3. *Uncertain*, practically every step of the way. Without the economics of risk and uncertainty, you will miss the challenge of the economics of climate change. We just do not know exactly what will happen, but science has recently given us a range of probabilities which help in applying the economics of risk and uncertainty.
4. *Potentially large and irreversible.* Much of economics deals with marginal change. That concept is useful, but not for all of this subject because we have to contemplate non-marginal, very large changes. Science is leading us into an area of economics which actually involves a great deal of difficulty, some of which is quite unfamiliar.

There are a number of basic questions to address. What are the risks? What are the probabilities? Who do they affect? What are the options for mitigation? What can we do about these risks? How can they be reduced? What does it cost to take action? Having then narrowed down the options that make sense, we can start to ask about how to get there. What kind of incentive structures will work to support the reduction of carbon? Adaptation will be crucial, so what kinds of approaches will be most important? Most importantly, how can they be financed?

Now we do not know exactly how emissions will build up. All sorts of things could happen, because it is hard to predict what will happen to economies, it is hard to predict the relationship between economies and carbon emissions, and different kinds of policies can arise. Take the link between emissions and atmospheric concentrations. The issue of how much of the emissions is left in the atmosphere over time is not a straightforward adding-up exercise because there is some lack of predictability in how the carbon cycle and the sinks involved work. Stronger sinks mean the stock rises a little less, but of course if those sinks deteriorate then larger stocks build up for any given path of emissions.

There is a stochastic relationship between temperature rise and global climate change. Stochastic links involve probability distributions and it is those distributions that science has recently started to provide. This allows us to work with the economics of risk. It is not, however, absolutely clear which kinds of probability distribution to choose; that is another kind of uncertainty.

There are also uncertainties about the effects of climate change. Take global cereal production: we do not know what assumptions to make about the effect of CO_2 on productivity. More CO_2 can increase productivity in agriculture but how strongly? It appears the answer is different for field trials than for actual practical planting. More uncertainty.

Then we have to look 100 to 150 years ahead because these effects build up over time. The climate of the next 20 or 30 years will be affected by what has already happened. Policy must span more than a few decades and will have effects over centuries. Does that mean that whatever is done is speculative? The alternative, doing nothing, is very risky many of us would argue.

Let us look at the science and its economic implications as we understand it. What does the build up of stocks in the atmosphere tell us? Figure 1 shows 90 per cent confidence intervals. The green bars, the 5-95 per cent confidence intervals,

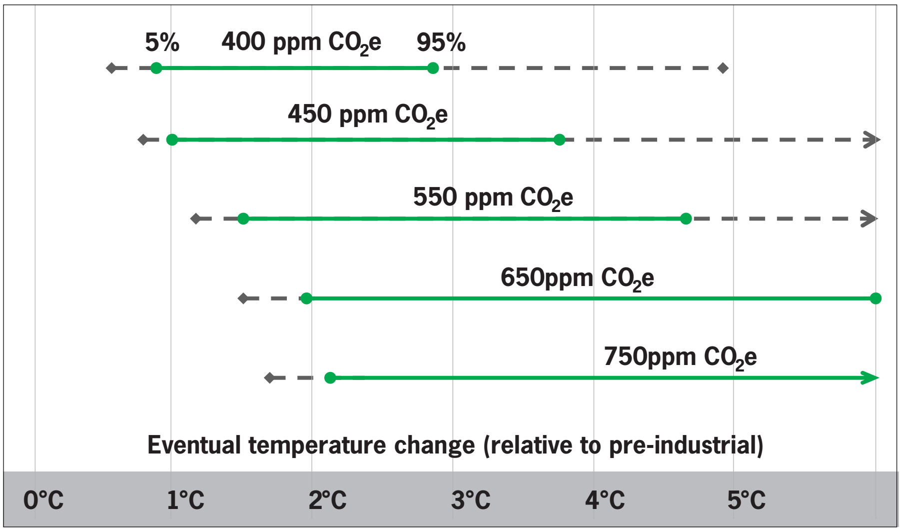


Figure 1. Stabilisation concentrations and resultant warming.

focus on two particular distributions from the IPCC's Third Assessment Report and a recent Hadley Centre study (the dotted lines stretching out are just there to draw attention to other probability distributions). We chose these two because it seemed to us (and we were advised on this) that they were fairly central to the science estimates of the probability distributions.

We are already past 400 parts per million (ppm) of CO_2 equivalent: we have reached 430ppm. That gives a confidence interval centred more or less between 1°C and 3°C. At 450ppm then, roughly speaking, there is slightly more than a 50/50 chance of being above 2 °C. But in that stabilisation range for the stock of greenhouse gases, there is a strong likelihood of being under 3 °C. At 550ppm, you would be pretty confident to be under 4 °C, but not certain.

Now most of the economics of climate change (and for understandable reasons) have focussed on 2-3 °C increases. Using empirical data, there is some chance of understanding what the effects might be, so it is understandable why people focus on this range. Yet from the diagram it is clear, if you take these analyses of risk seriously, that you have to start thinking about rather higher temperatures. At 650ppm the change is centred around 4 °C or so, for 750ppm it is still higher. At 800-850ppm you get, as far as we understand it, a 50/50 probability, or higher, of being above 5 °C.

With business as usual, the world could reach 800-850ppm by the end of the century. Simple mental arithmetic is reasonably reliable here. We are at 430ppm and adding between 2.5 and 3ppm a year. Ten years and that means 25 or 30ppm, so we will be above 450ppm. That growth rate under business as usual is increasing, though – with economic growth and with changes in societies like China and India. The rate could average 4ppm over the century. Add that to 430 and the total will be somewhere between 800 and 850ppm. This is not fancy economic modelling, this is back of the envelope stuff.

If we all ignore the problem and do nothing, we would have to consider these high concentrations with temperature rises of 5-6 °C and above. I suggest that such an increase is dangerous territory, probably very dangerous territory.

The numbers should not be taken literally, but we do have to think about the very big risks and what might happen. The last ice age, 10 or 12,000 years ago, was about 5 °C cooler than today. The world has surely been transformed since then in terms of its physical geography, its human geography, where we live and how we live our lives. A 5 °C increase will produce a transformation as well and, although it is difficult to know just what that would be, it is worrying.

There is a lot in the report about disaggregated impacts. I spent most of my life as a micro-economist, much of it working in developing countries, and these disaggregated micro-impacts are the most telling when thinking about different temperature increases.

The developing countries are especially vulnerable here. Geographically they are located in hotter places, so extra heat is more damaging. They have less diversified economies, a particularly strong emphasis on agricultural employment and they lack resources to invest in their own protection. The kind of example which could arise under business as usual is that over 1 billion people would suffer water shortages by the 2080s, many of those in Africa. It looks as if the west side of Africa would dry out, perhaps quite severely. The Himalayas would be far less effective at absorbing snow and rain and the rain would run off these mountains very quickly. We do not know what will happen to the monsoon.

It is quite likely that there will be population movements if parts of the world become very difficult to live in and that would cause dislocation and disruption. Developed countries are not immune, either; parts of Florida could be submerged. Hurricane intensity would increase pretty strongly and there are some very important 'convexities' here, where you get rising marginal damages. The intensity speed of the hurricane goes up very rapidly with water temperature and the 'destructivity' of the hurricane goes up very sharply with the wind speed. With convex effects you cannot simply extrapolate out from 2-3 °C to 5-6 °C.

In some models, there are drops in precipitation of up to 75 per cent predicted by the end of the century under business as usual. The Amazon might suffer major die-backs. Two hundred million people live in coastal areas and would be vulnerable to storm surges, and so on. These kinds of things are very difficult to quantify at an aggregate level.

We have taken one particular model which allows us to deal with uncertainty in a rather explicit way (that is why we chose the model), the PAGE model developed by Chris Hope at Cambridge. We very much hope that other people will try out the kinds of effects that we have been considering in their models. The reason we chose PAGE was that it is very well adapted to dealing with uncertainty. It is very easy to alter the parameters; it is rather a transparent process.

Essentially (for the mathematicians), we look at an integral of utility of consumption over time, with a small discount rate attached to it. We then take the expectation of that integral. So we are averaging over time, we are averaging across states of nature, averaging across possible outcomes. We ask ourselves "You've got the expectation of an integral of a utility, how do you summarise a path which is evaluated in that way?" and we say "Well, just imagine a consumption which, if it was definite and grew at a constant rate associated with the model, would give exactly the same integral." We call that the Balanced Growth Equivalent. Jim Mirrlees and I did a paper on this over 30 years ago, and it is the tool we use simply to calibrate the expectation of a utility integral. But it allows us to talk about the percentage changes of the effects embodied in a whole path.

Figure 2 is a sketch of a balanced growth equivalent. The light green path is the one which initially proceeds quite

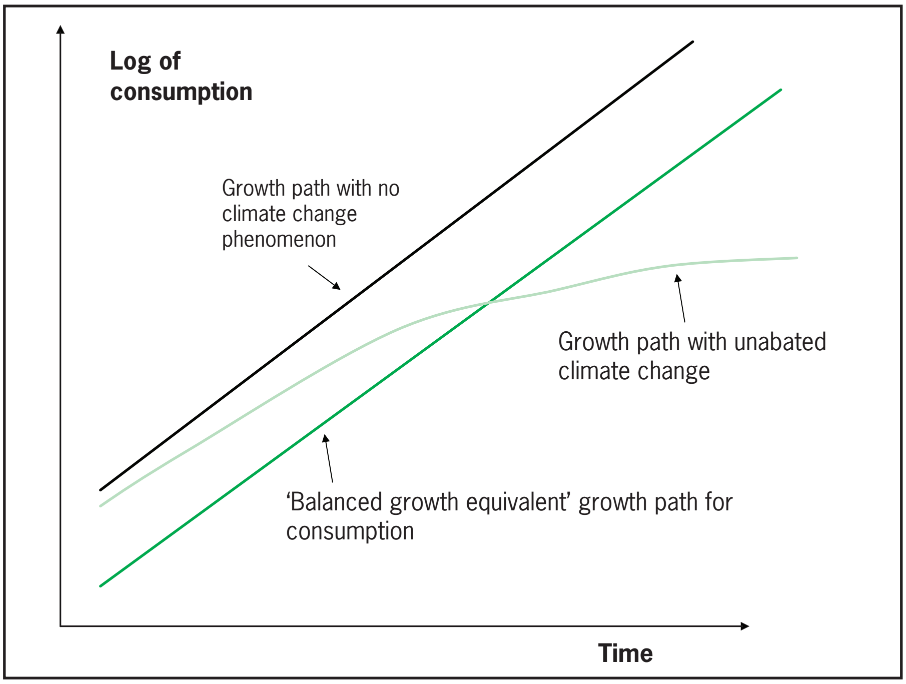


Figure 2. Balanced growth equivalents.

Scenario		Balanced growth equivalents: % loss in current consumption due to climate change		
Climate	Economic	Mean	5th percentile	95th percentile
Baseline Climate	Market impacts + risk of catastrophe	5.0	0.6	12.3
	Market impacts + risk of catastrophe + non-market impacts	10.9	2.2	27.4
High Climate	Market impacts + risk of catastrophe	6.9	0.9	16.5
	Market impacts + risk of catastrophe + non-market impacts	14.4	2.7	32.6

Figure 3. Losses in per capita consumption.

happily (imagine this is the business as usual path). Then it runs into trouble with climate change, and the dark green line is the average across that development. You can imagine little fans about the green line if you want to introduce probability. What we do then, in the PAGE model, is to build in the stochastic elements; we look at percentage losses in terms of this balanced growth equivalent, and we look at different kinds of possibilities.

The Baseline Climate scenario in Figure 3 is a climate involving a relationship between concentrations and temperature which more or less fits with current knowledge. It is a very crude approximation because PAGE does not have the sophistication of modern climate change models. Yet the kinds of probability distributions for greenhouse gases in the atmosphere are similar to those from the much more sophisticated models. The High Climate adds a little bit for methane feedbacks.

For reasonably narrow market impacts, together with some element of risk of catastrophic events, 5 per cent losses in per capita consumption are associated with business as usual (the Baseline Climate) and around 7 per cent – well 6.9 per cent – for the Higher Climate scenario. If you add in non-market effects (which are attempts, and only attempts, to value the environment and to value health) then you make a significant addition. These are not our evaluations, they are simulations, through the PAGE model, of the kinds of valuations which other people have used.

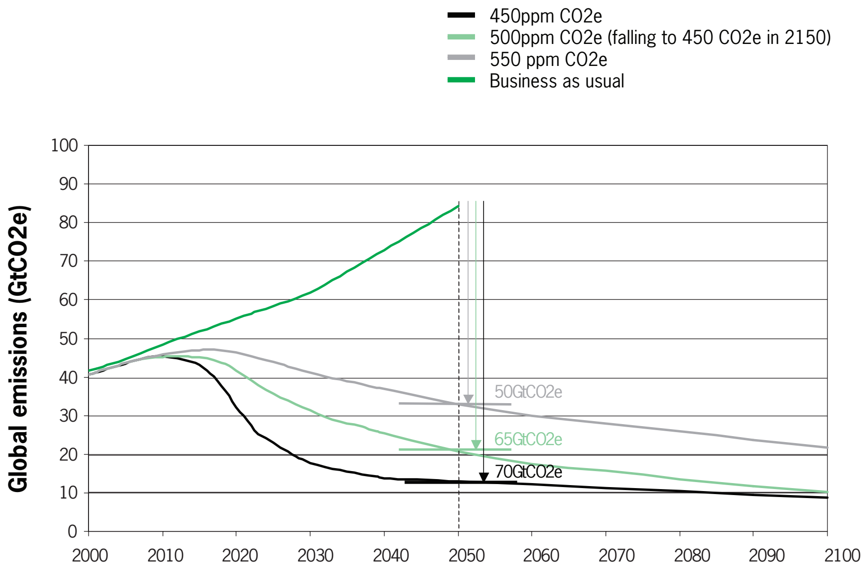
The results that we get are somewhat higher than those in the literature focussed on 2-3 °C increases, for the obvious reason that we have allowed the possibility of much higher temperature increases. Second, we have used the Expected Utility Theory, the explicit analysis of risk, while previous studies have, on the whole, used means of consumption or means of output rather than means of utility. These are the two reasons why our numbers are larger. But the really important reason is that we are beginning to contemplate very high temperature increases.

I have said before that the figures should not be taken too literally, but we have to start thinking about the consequences of the damage from very high temperatures; we have said enough already to suggest from these disaggregated analyses that those risks are very big. My own view is that some of the functional forms used in the PAGE model are probably underestimates.

The reason that we have published something a bit higher for the upper ranges is because the calculations here (Figure 3) do not include intra-temporal income distribution. We know from the work of Nordhaus and others that if you bring in intra-temporal income distribution considerations, i.e. considerations of greater damages in poorer countries than rich countries, then the estimates are larger. So we have a step-up from 14.4 per cent to 20 per cent, and we have worked deliberately in very round figures to take into account intra-temporal distribution in the analysis.

Of course there are some things that matter a great deal in all of this. Economists know the difference between discount rates and pure-time discount rates; we argue that the pure-time discount rate should be very small. That is the discounting you apply to somebody's utility simply because they come later. If you stand with your grandchild who let us suppose is 60 years younger than you, can you look her or him in the eye and say "Well you're coming 60 years after me, so you only get half of what I get"? That is the kind of ethical consideration you have to confront. There is some discussion of pure-time discounting under the heading of 'Ethics' in the Review. It is one of the few pieces of economics where we have consulted the Professor of Moral Philosophy at Oxford. However, many other economists of philosophical bent, Frank Ramsey, A C Pigou, Amartya Sen and so on, have actually come to the same position, which is that there should be low pure-time discounting.

This is important. You can always



Stabilising below 450ppm CO2e would require emissions to peak by 2010 with 6–10% p.a. decline thereafter.
If emissions peak in 2020, we can stabilise below 550ppm CO2e if we achieve annual declines of 1–2.5% afterwards.
A 10 year delay almost doubles the annual rate of decline required.

Figure 4. Economics of stabilisation.

find a pure-time discount rate – i.e. a devaluation of the future purely because it is in the future – that will stop you caring about climate change. If you put sufficiently low rates on effects that are going to happen 50 or 100 years from now, simply because of the timing and not because of the consumption levels, you can always eliminate any concern.

Higher rates of economic growth will make a difference in these models; they will increase emissions. Although emissions go up faster, people grow wealthy more quickly, so less weight needs to be given to consumption changes: these two effects might, in fact, balance out. Lastly, let me emphasis the point again that the kind of disaggregated analysis that we have been doing leads us to suppose that the damage from very high temperatures is underestimated.

What can be done to stabilise the situation? You have to act across the board because emissions come from everywhere – from power, transport, land use and so on. Again there is uncertainty here, but the costs seem to average out around one per cent of GDP. So generating power is a bit more expensive, for example. It is like a one-off, one per cent increase in the price index. That is why we argue that it is manageable. We cope with one per cent blips in price indices; they are significant but do not stop growth. It is business as usual which will eventually have to stop.

So, strong mitigation is fully consistent with growth; the costs will vary, they will be different for carbon-intensive industries and we just note here that there will be new markets, too. The various estimates of new markets the IEA has looked at suggest that they could be worth up to $500bn a year. Shell's estimates are a bit larger than that. We argue, too, that mitigation policy is consistent with other energy policies which are concerned with energy security, air quality and so on; and of course forestry has its benefits as well.

There are several important elements of policy. An effective carbon price: you can achieve this through taxation, through carbon trading and you can get it implicitly through regulation of product standards and so on. R&D: well energy R&D has fallen by around half in the last 20 years. We argue that this should be restored. We argue that the public element should go up by a factor of two (to around $10 billion worldwide this is) and the private R&D market is likely to follow. This should not just be about R&D, though, it should include deployment.

Beyond pricing and technology, standards are very important to give people confidence. You cannot do everything with prices and R&D; you also have to think about the imposition of standards and the kind of incentives that will create. On the other hand, although economists love to talk about sticks and carrots, you can also discuss and persuade. John Stuart Mill argued for the value of government by discussion; people change what they do as a result of talking about it and this is important as well.

Adaptation is absolutely crucial. There is no way we can avoid climate change. It is going to be tougher for developing countries and development itself – diversification, building up flexibility through human capital and so on – is at the heart of adaptation. However, there will be extra costs for more robust infrastructure, for developing new crops, for disaster relief, and so on. Adaptation will involve costs, and that reinforces the importance of delivering on promises of aid.

For international action to work, there have to be quantitative goals. These would be the organising principles for stabilisation targets, around which other policy would be formed. The economics of risk entail stabilisation goals, the economics of cost requires flexibility wherever possible. Action must be equitable and we argue that, because rich countries are able to bear the burden and they are responsible for the bulk of past emissions, they should bear the bulk of the cost. That is nothing more than the Kyoto principle of common differentiated responsibility.

How to get people to agree? First, I think, we need a common understanding that we will all be affected and that we can be much more effective if we work together. We have to understand and respect what other people are doing. The United States is not doing nothing; there is a great deal of R&D in the United States. California is involved in trading. The Chinese are not doing nothing; there are two big targets in the 11th 5 year plan beginning this year (one is the growth rate, the other to reduce the energy intensity of output by 20 per cent over the planned period). It is essential to understand what other people are already doing as a basis for doing more together. We must look for structures that bring mutual benefit, like carbon trading and sharing of technology. If we brought the top 20 emitting countries into trading of the kind covered in the EU ETS, it would multiply the market by five. It is crucial to work inclusively.

There is a very good argument for stabilising between 450 and 550ppm. It is possible to achieve. I am optimistic; we understand enough about the risks to formulate policy. We understand enough about the economics of incentive, the role of regulation and different kinds of economic instruments to see which way we should go.

Basically, at relatively modest cost, we could do this. Whether we will or not, of course, depends on how good we are at taking international collective action. ❐

Stern Review: www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm

The challenge to the energy sector

James Smith

James Smith is Chairman of Shell UK. He has been with Shell since 1983 and has worked in all the Group's major businesses. Until the end of 2003 he was on the global board of Shell Chemicals as head of technology, strategy and sustainable development.

The economics of climate change are sophisticated and the message stark. The arithmetic of climate change is relatively simple and equally stark. According to the World Business Council for Sustainable Development (WBCSD), demographic and economic growth can combine to produce a global economy by the middle of the century that is 3.5 to 4 times the size of today's. An energy system that simply replicates today's but is three and half times to four times the size may not be tenable.

There are two means to tackle this. The first is energy efficiency and the second is the decarbonisation of energy. If we can double the energy efficiency of economies and halve the carbon intensity of energy, then a global economy 3.5 to 4 times the size of today's can be supportable.

Technologies are available that can deliver the required energy within the necessary carbon limits. Fossil fuels will remain a substantial portion of the primary energy mix into the middle of the century. So carbon capture and storage (CCS) is going to be important.

The transport sector will have to change. There are about a billion vehicles in the world today: by the middle of the century there could be two billion. They will need to be twice as energy-efficient. The fuel mix will also have to contain a substantial amount of second-generation biofuels that are truly low carbon.

Now, the Stern Review has shown that the cost to the global economy could be around 1 per cent of GDP. That ought to be manageable, but it is not a trivial number: it amounts to about $350 billion. Effective management of that expenditure is extremely important. The sooner new technologies can be deployed, the sooner the costs of their application can be reduced. On timing, we may have just about enough time to achieve the changes required.

We must also recognise that the energy industry needs skilled people. The demographics of Europe and North America are not in our favour. We need to excite a global generation of young people to take up the energy challenge.

As individuals we need to support the political consensus for change. We also need to change our behaviour in support of energy efficiency. Business has two roles. First, it must recognise opportunity. New markets and new competitive opportunities are opening up not just in energy but in a whole range of industries. Second, business needs to advocate change and earn the right to consultation on the necessary policy instruments. These instruments encompass the establishment of effective markets for carbon, including giving appropriate credit for CCS.

Political leadership is important both nationally and internationally. In the next few years, there needs to be international agreement on a carbon path through to the middle of the century. This needs to be supported through the establishment of international markets for carbon. ❐

Tackling aviation emissions

Andrew Harrison

Andrew Harrison joined easyJet as Chief Executive on 1 December 2005. He was previously the Chief Executive of RAC plc prior to its acquisition by Aviva plc. At RAC plc he was responsible for delivering strong growth in a variety of consumer services, including BSM, financial and legal services.

Let us keep aviation in perspective. It currently accounts for around 1.6 per cent of total global greenhouse gas emissions. By 2050, emissions are projected to rise to 2.5 per cent and, taking into account non-CO_2 effects, will account for 5 per cent of the total warming effect. So aviation can only ever be a small part of the solution.

Technology is unlikely to provide an immediate benefit. A new generation of carbon-fibre composite aircraft will deliver a 20 per cent improvement in fuel efficiency, but will not be in widespread use until 2020.

And there are already massive incentives in aviation to drive fuel efficiency and minimise carbon emissions. Fuel is already one of the biggest costs to easyJet and we have more than enough incentive to optimise our efficiency.

Another crucial aspect of aviation is that it is central to one of the main drivers of wealth creation, which is the growth of international trade. Undoubtedly, anything which restricts the growth of aviation will have a substantial economic cost. And on a social note, I believe that aviation is a primary facilitator for peace in the world by bringing together different cultures.

As the review acknowledges, aviation is a truly international business so any environmental tax or regulatory measures will need to be driven by concerted international action to avoid distorting the market.

So what can we do? The first priority is to bring aviation within the European Emissions Trading System as soon as possible. We believe that this is the only way to deal with such an international business and to put it on an equal footing with other sources of carbon emissions. We should make this our number one aim and avoid knee jerk, ineffective local taxes.

Our second is increased efficiency. EasyJet's success is due to a radically different business model which uses the latest technology in a fundamentally efficient way. We fly the most modern aircraft in terms of fuel efficiency, emissions and noise footprint. The average age of our fleet is 2.2 years. We have an 85 per cent passenger load factor. This means that we create fewer greenhouse gas emissions per passenger kilometre than our traditional competitors.

The point is that economic efficiency drives environmental efficiency. Contrary to popular belief, low cost airlines are part of the solution, not part of the problem. We like to think of easyJet as the smart car of short haul air travel.

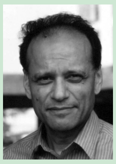
For this reason, we strongly oppose airport passenger tax which applies the same levy on efficient airlines as it does on operators with aging aircraft and low passenger load factors.

The European air traffic control system is a parochial patchwork of over 40 different agencies. Such inefficiency increases fuel consumption by 8-12 per cent and creates significant delays for our customers. We desperately need to create the political will to tackle this problem much faster.

Our third area of focus in easyJet will be to increase consumer awareness of environmental issues. We are looking to use the power of the easyJet brand to launch a voluntary carbon offsetting scheme for our passengers. Our goal is to persuade 50 per cent of our passengers to adopt carbon offsetting over the next five years. ❐

Accounting for well-being

Partha Dasgupta



Sir Partha Dasgupta FBA FRS is the Frank Ramsey Professor of Economics and past Chairman of the Faculty of Economics at the University of Cambridge, and Fellow of St John's College, Cambridge. He taught at the London School of Economics during 1971-1984 and moved to the University of Cambridge in 1985 as Professor of Economics. During 1989-92 he was also Professor of Economics, Professor of Philosophy, and Director of the Program in Ethics in Society at Stanford University.

The Review is a long and impressive document. It is possible though that readers will not notice that the authors have treated one important aspect of the economic analysis cavalierly.

When economists analyse public policy, they take two sets of considerations into account. First, they identify the ways in which the world might work (the ways which people would choose under various circumstances, the pathways Nature chooses, and so on). Once that task is done, they are able to chart the consequences (perhaps long term consequences) of alternative policies. Second, they value those consequences so as to be able to judge the relative desirabilities of the alternative policies.

Reading the Review gives one the impression that the case has been made for strong, immediate action in the form of an annual expenditure of about 1 per cent of global GDP. Yet, the conclusion I have reached is that *the strong, immediate action on climate change advocated by the authors is an implication of their views on intergenerational equity; it is not driven so much by the new climatic facts the authors have stressed.*

I should say at once that the ethical *framework* advanced by the authors is standard in modern economics. The authors conduct a Cook's tour of contemporary ethical theories, but pretty soon get down to the modern economist's mode of ethical reasoning. This framework was proposed by Frank Ramsey in his great 1928 paper in the *Economic Journal* ('A Mathematical Theory of Saving'). As might be expected, though, the numerical figures for the ethical parameters in the framework are not given by the framework: to arrive at them requires further deliberation.

Even the meaning of the ethical parameters is not self-evident, because there are several alternative philosophical underpinnings of the Ramsey framework and each interprets the parameters in its own way (see my 'Three Conceptions of Intergenerational Justice'[1]). The Review is curiously silent about differences in the views experts hold about what those figures ought to be and about the various philosophical underpinnings. It is silent too on the huge literature about those views and their justifications.

Assume, as the Review does, that a generation's well-being is the sum of the well-beings of the members of that generation. Assume too, as the Review does, that each person's well-being depends on his or her level of consumption. By the *ethical values* that reflect the idea of intergenerational equity I mean two things:

1. The tradeoffs that ought to be made between the well-beings of future generations and our own well-being, given that future generations will be here only in the future;
2. The tradeoffs that ought to be made between the well-beings of people regardless of the date at which they appear on the scene.

Technically, (1) is reflected in the *time/risk discount rate* which, following the Review, I shall call *delta*; and (2) is reflected in the *elasticity of the marginal value of the social weight that ought to be placed on individual well-beings*, which, following the Review, I shall call *eta*. Both terms are defined in the Review.

The Review, rightly in my view, asserts that the tradeoff between the present 'us' and the future 'thems' should be, roughly speaking, one-to-one. In other words, we should not discount future generations' well-beings simply because those generations will appear only in the future. The Review assumes that delta ought to be set equal to 0.1 per cent per year, which is a very low figure if we are to compare it with the values advocated by other climate economists. This is to adopt a very egalitarian attitude across the *time* dimension.

Yet the Review adopts a very *in*egalitarian attitude with regard to the distribution of well-being across the generations when futurity is not the issue. The Review's central case is based on the assumption that eta ought to be unity which, I shall show, reflects a fairly indifferent attitude toward equity over the distribution of well-being among people, *qua* people. The distinction between the two parameters is crucial. As the numerical figures that are assumed for them influence estimates of the economic costs and benefits of action, delta and eta are hugely significant parameters.

In fact, the very same ethical values that have been adopted in the Review were the basis of a pioneering 1992 study on the economics of climate change (aptly titled *The Economics of Global Warming*) by William Cline of the Institute for International Economics, Washington DC. In a symposium on Cline's book in *Finance and Development*, a quarterly publication of the World Bank and the International Monetary Fund, Cline summarised his finding in an article ("Give Greenhouse Abatement a Fair Chance") thus: "My central scenario shows that ... if risk aversion is incorporated by adding high-damage and low-damage cases and attributing greater weight to the former, benefits comfortably cover costs (with a benefit-cost ratio of about 1.3 to 1). Aggressive abatement is worthwhile even though the future is much richer, because the potential massive damages warrant the costs" (*Finance and Development*, March 1993, pp 3-5). Despite the striking similarities between the numerical figures adopted for the pair of ethical parameters (delta and eta) in the two studies, there is no mention of Cline's work in the Review.

I then turned to the work of William Nordhaus, who has been studying the economics of climate change for over three decades. By contrast, the most remarkable conclusion of his studies – conducted on his Dynamic Integrated Model of Climate and the Economy (DICE) – has been that, despite the serious threats to the global economy posed by climate change, little should be done to reduce carbon emissions in the near future. He argues instead that controls on carbon should be put into effect in an increasing but gradual manner, starting several decades from now. This conclusion has withstood the many modifications Nordhaus and others have made to the climate science embodied in DICE.

Their idea is not that climate change should not be taken seriously, but that it would be more equitable (and efficient) to invest in physical and human capital now, so as to build up the productive base of economies, and divert funds to meet the problems of climate change at a later year. These conclusions are reached on the basis of an explicit assumption that global GDP per capita will continue to grow over the next 100 years even under business as usual, an assumption the Review appears to make as well.

Where then is the real difference between the economics in DICE and those in the Review? No doubt DICE differs from PAGE (the acronym for the Review's climate model) in its climatic specifications. But I looked for the underlying ethics. Nordhaus and others have used a considerably higher figure for delta. In contrast to the Review's figure of 0.1 per cent per year, Nordhaus in recent years has used a starting value of 3 per cent a year for delta, declining to about 1 per cent a year in 300 years' time. Interestingly, Nordhaus also takes eta to be unity. He reports that the first-period social price of carbon (which is a measure of the social damage a marginal unit of carbon emitted today inflicts on humanity) is about $13 per ton, whereas the figure reached in the Review's central case is about $310 per ton.

If the Review's figure for delta is put to work on DICE, the first-period social price of carbon becomes about $150 per ton. This is about half the figure offered by the Review, but it is enough to suggest that the driver behind the Review's findings is the very low values of the two ethical parameters, delta and eta. Indeed, modifying DICE slightly, so as to take a more alarming view for the worst case scenario under business as usual, raises the figure for the social price of carbon to $400 per ton, in excess of the figure recommended in the Review.

Are the numbers taken in the Review to reflect the two ethical parameters compelling? I have little problem with the figure of 0.1 per cent a year that the authors have chosen for the rate of pure time/risk discount (delta). However, the figure for eta – the ethical parameter reflecting equity in the distribution of human well-being – is deeply unsatisfactory. To assume that eta equals 1 is to say that the distribution of well-being among people does not matter much; that we should spend huge amounts for later generations even if, adjusting for risk, they were expected to be much better off than us.

As an example, suppose we set delta equal to 0.1 per cent per year and eta equal to 1 in a deterministic economy where the social rate of return on investment is, say, 4 per cent a year. *It is an easy calculation to show that the current generation in that model economy ought to save a full 97.5 per cent of its GDP for the future*! Yet the aggregate savings ratio in the UK is currently about 15 per cent of GDP. Should we accept the Review's implied recommendations for this country's overall savings? Of course not. A 97.5 per cent saving rate is so patently absurd that we must reject it out of hand. To accept it would be to claim that the current generation in the model economy ought literally to impoverish itself for the sake of future generations.

The moral of exercises such as this is that we should be very circumspect about accepting numerical values for parameters of which we have little *a priori* feel. What we should have expected from the Review is a study of the extent to which its recommendations are sensitive to the choice of eta. A higher figure for eta would imply greater sensitivity to risk and inequality in consumption, meaning that it could in principle imply greater or less urgency in the need for collective action on global warming. Whether it is greater or less would depend on whether the downside risks associated with the warming process overwhelm growth in expected consumption under business as usual.

To put it more sharply, a higher value of eta could imply that the world should spend more than 1 per cent of GDP on curbing emissions, or it could imply that the expenditure should be less. Only a series of sensitivity analyses would tell. Curiously, the Review does not report any such sensitivity analysis.

Ethics, like facts, raises questions for which there are no easy answers. I certainly have none to offer. But the authors of the Review could have spent a lot more space discussing the various implications of its choice of the two ethical parameters. For that is where the Review's particular intellectual action lies. ❐

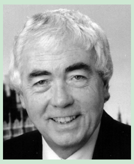
A full version of Professor Dasgupta's comments appears in the National Institute Economic Review, No 199. **www.niesr.ac.uk**

1. Lillehammer H and Mellor D H, eds (2005) *Ramsey's Legacy*. Oxford: Clarendon Press.

The need for policy to make effective use of available scientific knowledge was discussed at a dinner/discussion of the Foundation on 15 November 2006.

Scientific advice and evidence-based policy making

Phil Willis



Phil Willis MP is Chair of the House of Commons Select Committee on Science and Technology. He joined the Liberal Party in 1985 and was elected to Parliament in 1997. He held the position of Shadow Secretary of State for Education and Skills for the Liberal Democrats from 1999 to 2005. He also chairs the All Party Group on mobile communications, is treasurer of the All Party Group on medical research and is a founding member of the newly formed All Party Group on scientific research in learning and education.

The latest report from the House of Commons Select Committee on Science and Technology is entitled *Scientific advice: risk and evidence-based policy making*[1]. Our decision to pursue this inquiry reflects the key role that scientific advice and risk assessment increasingly play in policy making.

Whether we are considering securing economic prosperity through the knowledge economy or tackling obesity, few would deny that successful policy development requires an effective scientific advisory system, an appropriate use of evidence and an effective way for Government to deal with risk.

We also point out that the Government has every right to promulgate policies that are not evidence-based. Some policies have a mainly political or ideological basis, like the ban on fox hunting, or are introduced simply in response to public clamour, like removing the fuel escalator at the time of the fuel protests.

What the Committee feel is unacceptable is where ministers or opposition spokespeople claim their policies are evidence-based when clearly that is not the case. It is also unacceptable if evidence is commissioned, published or cited in a biased way simply to affirm a policy decision.

Indeed, as successive governments have found to their cost, unless the evidence underpinning policy is robust, capable of rigorous scrutiny and communicated convincingly to the public, public confidence can be undermined (as with MMR), scientific progress damaged (GM crops), or disaster ensue (going to war in Iraq to deal with WMD programmes).

There has been, and I suspect there always will be, a constant tension between scientific advice, risk and policy making. Sir Robert (now Lord) May's *Guidelines on the Use of Scientific Advice in Policy Making* of 1997 are regularly updated by the current Government Chief Scientific Adviser (GCSA). The recommendations from the Phillips Report in 2002, and the recommendations from Lord Jenkin and the House of Lords Select Committee, provide an excellent basis for the use of scientific advice, and our report recognises them as such.

When New Labour came to power in 1997, they promoted the mantra of evidence-based policy making, saying they were interested in 'what works', not in ideology. We launched our inquiry a year ago and decided to test the new commitment to evidence-based policy making by using case studies to underpin the central themes. Evidence to support public policy requires a good scientific research method. We found a mixed picture emerging.

In our inquiry into drug classification, we observed that the Government had made little investment in research into addiction and drugs policy. There was little evidence to support the current policy objectives underpinned by the ABC drug classification system. Some drug users were not deterred by the classification system and the police service claimed they paid little attention to it. Yet proposals by Professors Nutt and Blakemore to bring forward a new classification system based

discussion

Independent advice. It is not always clear when pure science advice is being tendered, or whether it is being combined with political judgments. It is important that, if advisory committees are reporting on scientific issues, they are composed of scientists who have the respect of their peers. It is equally important that the advice is published and subject to peer review and comment. The Departmental Chief Scientific Advisers have a vital role here, not only in ensuring that members of such committees are of the right calibre, but that unpopular views are supported against political or public pressure. They also have to understand the differing timescales of scientific research and political action. This means that they have to exercise considerable foresight in identifying problems, on which evidence needs to be produced, well before politicians see the need for action.

on degree of harm were sidelined without explanation by the Home Secretary, as was the promised review of drug classification. The Government's rejection of our recommendations in our Drugs report was hardly a ringing endorsement for evidence-based policy!

Our inquiry into identity card technologies demonstrated a lack of research into emerging technologies, even though the entire programme depended on these being available within a time span that meets the Government's plans.

We have again highlighted the problem that policy-orientated research has not generally been supported through the Research Assessment Exercise because it tends not to be published in prestigious journals. This is a very important issue and we expect to return to it in the future.

One of the most disturbing aspects of our inquiry was the accusation by some academics that their work, commissioned by the Government, was selectively published in order to 'prop up' policies. Thus, Professor Tim Hope at the University of Keele told us: "It was with sadness and regret that I saw our work ill-used and our faith in the Government's use of evidence traduced." Professor Hope went further, alleging that the Home Office had interfered with other papers – even to the point of telling academics not to present their papers at a Criminology Conference in 2003. These are serious allegations which our Committee clearly has no authority to investigate; but someone should.

There was certainly no shortage of examples where the disconnection between evidence and policy was pretty stark! Ruth Kelly's use of evidence was somewhat missing when she announced her ban on junk food. Sir John Krebs in his Sense about Science lecture was scathing in his dismissal, saying the policy had been developed with no evidence that it would work, no scientific definition of junk food, no cost/benefit analysis and no public engagement. In fact, this policy initiative broke every one of the GCSA's rules of engagement! Although there was a Departmental Chief Scientific Adviser (DCSA) in the Department for Education and Skills, the initiative was allowed to run unchallenged.

On the Precautionary Principle …
"One cannot change all this in a moment (…) but from time to time one can even, if one jeers loudly enough, send some worn-out and useless phrase into the dustbin where it belongs."
George Orwell

There are many examples of excellent practice to be found in our scientific advisory service. However, there is also a bewildering array of scientific advisory bodies, from the mysterious Council for Science and Technology that directly advises the Prime Minister to the *ad hoc* groups that advise on subjects like GM science and animal science. There does not, though, appear to be an overall sense of coordination and direction.

We therefore recommended that the GCSA should cease to be head of the Office of Science and Innovation (OSI), and should instead have an enhanced cross-departmental role in the Cabinet Office with a seat on the Board of the Treasury. We have also recommended that DCSAs have greater independence to challenge departmental thinking. This is why we have recommended that, where possible, DCSAs should be external appointments from individuals who have occupied senior positions in their scientific communities, and who command the respect of their peers for their current research.

One of the most worrying findings from our inquiry was the decline of scientific capacity within the civil service itself. A classic example of how things can go badly wrong was the Health and Safety Executive (HSE) leading on Magnetic Resonance Imaging (MRI) with the EU Physical Agents Directive. The HSE failed to understand that the Directive could potentially halt the use of MRI for research and its use in invasive procedures from 2008.

It was our concern for the loss of scientific capacity and the need to enhance the status of scientists and engineers within the civil service that led us to recommend the establishment of a Government Scientific Service (GSS). The GSS would sit alongside the Government Social Research Service and the Government Economic Service. It would be able to take the lead in identifying good practice in professional development for scientists and engineers (including those of secondments) as well as promoting good practice across government.

As far as our recommendations go, we make the point very clearly that where there is an absence of evidence, or even where the Government is knowingly ignoring or contradicting the evidence that exists, as we saw with our inquiry into drug classification (and maybe for good reason), they should say so. Where policy is based on evidence it should be published and reviewed. What is more, we urge the Government and indeed opposition parties to accept that good research and the use of pilots or trials may well result in a change of policy or a change of direction. This should be seen as good use of evidence in policy-making and not, as it so often is now, a failure of policy altogether.

It is crucial that academics supplying research for government departments should have the same academic freedoms as those in universities or institutes, unless there are special circumstances that prevent it.

Finally, in terms of research we have recognised the very considerable efforts made by Sir David King and the OSI to embed horizon scanning in relation to science and technology across Government through the Foresight Programme. We must admit, however, that horizon scanning is a pretty futile exercise if departments ignore its findings and concentrate solely on the immediate vista.

Our report does not attempt to deal with individual areas of risk, though our case study on ID cards considered risk management, and our drug classification inquiry looked at degree of harm. Instead, we chose to look at the communication of risk to the public, the dissemination of best practice and that pesky perennial, the 'precautionary principle'. We are in favour of good science and open communication; an approach which we commend across government. The idea that if there is any risk there should be avoidance is clearly absurd. We therefore take the advice of George Orwell, and condemn the precautionary principle to the dustbin. ❐

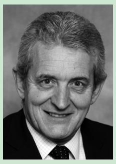
1. www.publications.parliament.uk/pa/cm200506/cmselect/cmsctech/900/900-i.pdf

discussion

The role of government scientists. The Government might make more use of independent inquiries, such as the Stern Report, and the outside academies, such as the Royal Society or the Academy of Engineering. However, this should not be at the expense of devaluing the work done by scientists in government. Scientists working in government departments were first and foremost scientists: it would be against their training and ethos, and they would lose respect from their peers, if they compromised the conclusions they drew from evidence because of political pressure. But they did need to be embedded in government, so that they could understand what ministers needed, what were their priorities, and their problems in explaining policies to colleagues and to the public. In short, there had to be an organisation which would pull the science base through government to ministers. The task was to do this and yet retain public confidence in the science produced by government.

The civil service and scientific advice

Paul Wiles



Professor Paul Wiles CB is Chief Scientific Adviser and Director of Research, Development and Statistics at the Home Office. Before joining the Home Office he was Professor of Criminology at the University of Sheffield, and formerly Dean of the Faculty of Law, as well as Director of the Centre for Criminology and Socio-Legal Studies. He was previously at the Institute of Criminology at the University of Cambridge.

Let me start by pointing out the very real progress that has been made recently to improve the use of science by Government. First, many departments now have Chief Scientific Advisers (CSAs) in post. Second, many departments have now published Science & Innovation Strategies. Third, the Office of Science and Innovation is in the middle of carrying out external and independent reviews of the scientific work of each department. Fourth, we have a framework for cross-departmental horizon scanning in place and a series of influential *Foresight* reports has been completed. Fifth, we have a 10-year investment framework for science. Sixth, the full economic costs of research are now being given to the universities, so improving the long-term support for the science base. Finally, in spite of some setbacks we have managed to conduct public debates on important issues of scientific policy, and on some of these we have led internationally.

There are, of course, things that could be improved and it is to those that I want to turn.

When the present Government came to power it made a commitment to evidence-based policy; and science in government has moved from being a potentially useful tool to being one of the key aspects of government responsibility, alongside defence, social order and the provision of a stable structure of economic exchange.

Such a shift does nothing to change the primacy of ministerial decision-making, but does raise the question of whether the scientific arrangements in the civil service to support that decision-making are adequate to the task.

We have separate professional groups and structures for natural science, social research, economics, statistics and operational research. It is not always clear at either a departmental or government level how these different sources of evidence are to be brought together so that ministers are not left with conflicting and potentially confusing advice. We ought to find a way to bring more coherence to the range of scientific advice.

Neither does the departmental organisation of government reflect coherent evidence needs. Given today's problems and what we know about the interrelationships of the risk factors behind them, I doubt anybody would come up with the current structure of government. The result is that many issues need cross-government solutions and the marshalling of cross-government scientific evidence and advice. The Chief Scientific Adviser (CSA) network has informally helped in this regard, but we still have not found a successful formal solution. The suggestion by the Select Committee on Science and Technology that there should be a cross-government research fund is interesting since, so far, other recent attempts of this kind have yet to prove their success.

Clear advice to ministers ought to be based on a systematic review of the available published and peer-reviewed evidence that is widely accepted within the relevant scientific community. The Government has long had a CSA to ensure that such advice is available. However, the appointment of departmental CSAs is more recent – they, like the Government's CSA, are usually seconded for a fixed term from universities to ensure they bring to their role the evidence standards of the broader scientific community and inject some fresh thinking. The Committee's support for this structure of CSAs is welcome, but I think we need to expand it to cover all departments and give CSAs oversight of all science.

In order to ensure that ministers do receive appropriate scientific advice, the CSA needs to have access to the range of departmental decision-making in order to identify when such advice is needed. This can be achieved if the CSA sits on the departmental board or if departments have a systematic process for policy decision-making which includes a scientific gateway (which the Treasury advocates). However, neither of these is currently common – my estimate is that only about a third of CSAs sit on their board.

Departments vary greatly on how much science they fund. As a percentage of total resource, this varies from almost 18 per cent in the Food Standards Agency (perhaps a special case), or 7 per cent in the Department for Environment, Food and Rural Affairs (Defra), almost 2 per cent in the Ministry of Defence (MoD) to just 0.5 per cent in the Home Office (HO) or 0.2 per cent in the Department for Education and Skills (DfES). In terms of amounts, the MoD spends £595 million (excluding development), whilst the Home Office spends £64 million in an equivalent year. I wonder whether the variations between departments have a rational explanation? We do not seem to have a mechanism at present by which departments explain and justify their science spend. Indeed, in most departments the science spend is not even a separate budget line and in some there is no science budget; just science spend that can be identified retrospectively.

Identifying future science needs is, of course, not easy. There are structured ways to try and do so, such as horizon scanning and scenario planning. Here my experience is not so much the difficulty of using such techniques (although they are not easy) but rather of getting a department to think beyond immediate issues or even crisis management. The Office for Science and Innovation has been encouraging such work by setting up an horizon-scanning centre of excellence, and Foresight has had some success in this regard; but the effective use of horizon scanning in many departments is in its infancy. We ought to require that forward risk-focused science plans exist, and that the use of such techniques is a part of the new professional skills for government training.

Scientific advice, of course, does not – and indeed should not – be based only on research carried out by a department. One could argue that, since departments will never be perfect at predicting their future needs, it is better to rely on the rich diversity of research carried out in the broader scientific community. However, there are situations where Government needs an internal scientific resource in order to respond to crises. University research on chemical or biological threats is most valuable and can be the source of advice during a terrorist attack, but we also need scientists available as part of our frontline response and crisis management.

During the next few years, budgets are going to be very tight or reducing. We need to be clear sighted to ensure that apparently easy budget savings through a reduction in science spend do not inadvertently remove this strategic resource, or remove the scientific work upon which future advice will depend. We do not want to find ourselves facing, say, a future foot and mouth crisis without the scientific resources under Defra's command to be able to respond quickly and effectively.

More generally, departments need to draw on the work of the broader research community. One role of the CSA is to foster external research links. All departments ought to have a range of independent scientific advisory committees reflecting their current needs. However, such structures are not yet universal in government.

External advice can be seen as problematic. I have found, during my period working in the Government, an interesting cultural problem. As scientists, we know that scientific knowledge is probabilistic, that the only way we have of learning truth is by a process of openly sharing our evidence and subjecting it to rigorous peer criticism. This culture does not always sit comfortably in Government. My first experience of the problem was when a colleague told me that it was no good getting a group of scientists in to advise, because they would almost certainly argue with each other!

Similarly, the demand for certainty has to be resisted. This can mean that things which we take for granted – such as the need for external and independent peer review and the publication of research – can be problematic for our colleagues. Here there are issues of principle – of what fundamentally makes science possible – that have to be fought for. These principles are reflected in Guidelines 2000 and 2005 on the use of science in Government and the Committee pointed to their importance. There is an interesting comparison here with statistics. In the Queen's speech, the Government announced its intention to legislate to reinforce the independence of statistics. Statistics already have significant protection for their independence and publication managed through the Statistics Commission and the National Statistician.

Scientists find truth by challenge and argument, and that is why science is essentially a public activity. However, there is some scientific activity in Government that, at least for the moment, we do need to keep secret. We have to manage that need against the fact that good science comes out of open challenge. It can be too tempting not to have peer review on grounds of confidentiality, but we must find ways to make sure peer review does happen. What we must not allow is the need for secrecy to spread beyond what is necessary: if we do, then the quality of our work will be damaged. ❐

Science, truth and politics

John Gummer

The Rt Hon John Gummer MP has served as Minister of Agriculture, Fisheries, and Food and as Secretary of State for the Environment. He was the UK Environment Secretary from 1993-1997, playing a key role in Convention on Climate Change meetings. He was later awarded the Medal of Honour by the Royal Society for the Protection of Birds - the UK's largest environmental organisation. He is Chairman of Sancroft International, a corporate responsibility consulting company.

Politicians start from the disadvantage of recognising that truth is often inconvenient. Worse still, it is subject to new knowledge – it is the best that we can do at that moment in time. Out there is a public, of course, that does not recognise either of these facts. It will hold to its cherished theories, whatever the facts.

Truth is not only a matter of what is said, but also how it is heard. It not only involves saying it right, but saying it in such a way that you know it will be received right.

Politicians who imply that evidence exists for a policy when in fact it does not will find themselves in great difficulty when they do need science to be able to carry through a different policy. All politicians have received large numbers of letters from the Alzheimer's Society, telling us that we should not accept the best evidence we have on how certain drugs should be used for Alzheimer's disease. Yet the National Institute of Clinical Evidence (NICE), the organisation that is supposed to give us that advice, has not only provided just that but has looked at the issue all over again because of public disquiet.

I write to my constituents to say that I am not a scientist and I am certainly not a medic, so I can only rely on the best evidence there is. In the end it would be quite wrong of me to accept their view against the best evidence that I can have. I have to say that, because if I go with the populist view then I can never ask the public to accept the best advice that we have on other issues.

I do believe, as politicians, we have done a disservice to the nation over

discussion

Shortcomings of Parliament. Speakers had concentrated on the problems of the executive, but there were significant questions to be raised about the performance of Parliament. How many members had scientific training, or indeed, interests? Why was it that the Select Committee had difficulty in filling its ranks? Did Committees understand that they must allow sufficient time for quality evidence to be produced? Did they have sufficient and sufficiently qualified staff to produce good reports? What Parliamentarians had, for example, protested against Ruth Kelly's statement on junk foods? If the executive was sloppy about using science, was not that the fault of Parliament? Political argument, no less than scientific argument, was desirable – where it did not take place, as perhaps it had not over climate change, there was the danger that the Government was allowed to get away with insufficiently robust policies.

genetically modified organisms. I think Britain is damaged very considerably as a result. More than that, we have failed to help some of the most vulnerable nations in the world because politicians have discovered – in the moratorium – a mechanism to get out of making a decision. We should have taken the best advice available and acted upon it.

I think the same is true, too, of the way in which we often deal with smaller and less important things. Here I would like to make a point about the conclusions of the Select Committee Report. Very often, the problem is not that the evidence is not there, but that the evidence does not get to the person who is supposed to be making the decision. I remember, when I was the Minister for Agriculture, that I was on the Council of Ministers in Europe which was being asked to make a final decision about the noise of construction machinery. The person who briefed me in the DTI took for granted the truth of the industry's statement that it could not get its road mending machinery down to the decibel level required. There had been no effort to ask for any scientific evidence and so, because that was the evidence I had, I spoke on that basis and voted against it.

As is so often the case, within six months the industry managed to meet the decibel level without any difficulty whatsoever and I felt betrayed because I, on behalf of the United Kingdom, had said something which was actually untrue.

Yet sometimes the facts that you are dealing with are very, very elusive and I want to point to the very clear way in which this report has recognised that some things lie between science and what is perceived. Let me give you the example of organic food. The organic argument is scientifically nonsense. Yet the organic believers (and it is, to some extent a belief) have every right to insist that if you call your product 'organic' it actually meets particular requirements, ludicrous though they may be. It is right for Government to insist that people who want organic food can, when they buy it, be absolutely sure that it meets these requirements. That is a proper act of Government. The fact is that people who buy organic food are making a choice and they have the right to know that when they make that choice, it is a truthful one in the sense that it is meant; it does not need to be a scientifically proven one. We do have to recognise that it is not always easy to talk in terms of 'this is the science'.

I want to end by discussing what that means for Government decision-making in terms of getting the right scientific advice. I am very concerned that it is always easiest to make savings in Government by cutting scientific research. Defra is a good example, because most of Defra's expenditure is actually decided by ministers around the table in Brussels, and outwith the ability of the Treasury to control. What is left is very limited, so when the Government makes a perfectly reasonable decision that we should all cut our budgets by 8 per cent, in Defra that 8 per cent can only fall in the very narrow bit over which it has control. So you end up by cutting back on flood prevention and science and research, because there is nothing else.

Because Defra did not have the best scientific advice on the way in which computers could be used to implement the perfectly proper policy which lay behind the Rural Payments Agency, it found itself vastly overspent. Without the necessary advice, it made the wrong decisions, it found itself overspent and the Treasury then told it to find the money somewhere else. So where has it found the money but through cutting the very advice that led to the mistake in the first place – so next time it will be worse. That is the circle we have made for ourselves. Now it does seem to me that Government has to set an example for the rest of society in not cutting back on the resources which it needs to make decisions.

I think that Professor Wiles was absolutely right to draw attention to the fact that statistics are now going to be much more carefully protected from any hint of government intervention. Why only statistics - the whole business is about public trust and confidence. Let me give you one example, which will be embarrassing because it is rather different from what Phil Willis said: I think the Food Standards Agency is actually less believed today because Sir John Krebs was not followed by somebody whose scientific independence was seen to be of the same quality that he himself had.

I end with a comment on the most important thing of all: climate change. I do find it unacceptable that, in the same Queen's Speech, we are told on the one hand that we will have an independent statistics operation absolutely separate from Government and on the other that we are not to have an absolutely independent organisation to deal with the problems of climate change. If we are to deal with climate change, as we have to, we must have a scientific base that we can point to as being the best advice there is – advice that is publicly stated, without fear or favour, checked, monitored and constantly available. We politicians will not deliver unless the public has access to the best advice that can be given, and that advice is turned into proper targets and there is proper monitoring of those targets. Scientists themselves need to help us get what we need in this area.

The problem about truth is not only that it is immediately disagreeable if it undermines much long-held belief; but that it goes on being disagreeable. Politicians hope that you will forget it; that they can overcome the disagreeable nature of truth for long enough for that particular truth to disappear out of the public eye. One of the things I regret that the Committee perhaps did not consider was this: how do we ensure that scientific advice remains sufficiently public so that it does not become lost to the argument and we revert to the uninformed prejudices with which we started? There is no area where that is more important than in the battle against climate change. That battle will take a long time and it needs continuous refreshment from science, which must remain public and which must not be forgotten. ❒

Professor Sir Gareth Gwyn Roberts FRS FREng

16 May 1940 – 6 February 2007

There was an essential Welshness about Sir Gareth – he had lost neither the lilt in his voice nor the fierce love he had for his homeland. He was born in Penmaenmawr, one of twins, where he remembered a very happy home life. The family was strict Calvinistic Methodist and this early influence remained with him in his attitudes and values although he was not a regular church attender. Indeed, Wolfson College, of which he was President, is the only Oxford college not to have a chapel and he had no plan to change that, although he did introduce the silent Grace at the beginning of formal meals in Hall.

He went from the John Bright Grammar School, Llandudno, an important period in his development, to University College of North Wales, Bangor, to read physics. There he obtained a first, followed by a doctorate (and later the DSc) and a lectureship. It was in 1966 that he broke away from both Wales and academe to become a research scientist with the Xerox Corporation in Rochester, New York. This was a long distance for someone then so parochial but, although he had a number of offers from various universities, he was conscious of a need for industrial experience and a chance meeting with the Xerox Research Director – when speaking as a substitute for his PhD supervisor Richard Treadgold at an international conference – settled the immediate future. He opined that he did his best work as a scientist there, even having a theorem named after him. It was also a happy time domestically: he had two happy marriages with three children and he was then enjoying the early years of the first marriage and of fatherhood.

However, Richard Treadgold had gone to the new University of Ulster, Coleraine, and in 1968 he beckoned Gareth to join him, so Professor Roberts (as he became) took leave of absence from Xerox to establish a new department of physics where he remained as its Dean until 1976. He retained his industrial contact by spending one day each week with ICI creating a team to develop the company's interest in electronics: Sir Geoffrey Allen was his mentor. In 1976, ICI transferred his research laboratory from Runcorn to Durham at the same time as the opportunity arose to become Professor of Applied Physics and head of the Department of Electronics and Physics at the University of Durham. It seemed to be for him.

This, too, was a period of personal development and professional satisfaction. He was one of the youngest professors and led the arrangements for responding to the first University Grants Committee visit to Durham. That went well and as a result he was invited to join the UGC Equipment Committee and, later, to follow Sir John Gunn into its chair. So he was propelled, not at all unwillingly, into the public arena with subsequent appointments to some 20 national committees. He had the advantages of early administrative responsibility and the need for only four hours sleep each night, so natural and honed ability and time were particular gifts of his. Durham, as he reflected, was different from Bangor and Coleraine: his niche was the seamless interface between science and engineering, an area which fascinated him. He enjoyed also the collegiate life as a fellow of Hatfield College (later a Life-Fellow) and the sport. All his appointments required him to build and to create – perhaps, once a task had been completed he needed, like Alexander of old, new worlds to conquer. In fact he had not wanted to leave Durham but the package of Director of Research and Chief Scientist at Thorn EMI for four days each week and an Oxford visiting professorship of electronic engineering for one day (not to mention a fellowship at Brasenose College) proved irresistible so he made that move in 1985.

It was in 1986 that he was awarded the Holwick Gold Medal and Prize. One may be forgiven for thinking that this very successful industrialist and academic, with an international reputation for his research in semiconductors and molecular electronics, the author of publications and patents (some 200 at the last count), the holder of several national awards, including the Fellowship of the Royal Society (1984), later also the Fellowship of the Royal Academy of Engineering (2003), and the presenter of the Royal Institution Christmas Lectures on BBC television in 1990, might want to stay with this rewarding package and enjoy watching football, playing duplicate bridge and listening to classical music.

Not so! In 1990, he was approached, through Lord Dainton, to consider appointment as Vice Chancellor of the University of Sheffield. He accepted that appointment and looked back later on the 10 years in this post as the happiest of all his berths and one where he might be more remembered than any of the others. Perhaps this was not strange, bearing in mind his grooming for just such a position over the years. During this decade, he served as a non-executive director of the Sheffield Health Authority, a board member of the Regional Development Agency for Yorkshire and the Humber, and Chairman of the Trent Institute for Health Services Research. This period also saw a very happy second marriage and, of course, a continuation of his public life and his research. In 1997, he was knighted for his services to education.

Then came the opportunity, as he approached retirement in Sheffield, to return to Oxford, to the beautifully-situated Wolfson College, which he did in 2001. He enjoyed Oxford greatly: he remained a Fellow of Brasenose where he much appreciated its history and traditions as much as the contrast with the post-graduate and liberal environment of Wolfson. He continued with his public life (as a Board member of the Higher Education Funding Council and Chairman of its Research Committee, Chairman of the Treasury Study into the Supply of Scientists and Engineers in the UK, Chairman of the DTI/CVCP Research Careers Initiative, Chairman of the DTI Genome Valley Steering Group, Board member of the Retained Organs Commission, member of the Council for Industry and Higher Education, and non-executive Chairman of Medical Solutions plc). He had several honorary degrees, had served as President of the Institute of Physics, as Foundation President of the Science Council until 2006, and had just been appointed President of the Engineering and Technology Board.

He was a member of the Council of the Foundation for Science and Technology to whom he was a good friend. Indeed one of his last public engagements was as Guest Speaker at the Learned and Professional Societies Luncheon in October 2006 where he spoke about professional regulation, a subject and an audience close to his heart. It was shortly afterwards that he was diagnosed with cancer and he died on 6 February 2007. The Director of the Foundation then said that "Sir Gareth's contribution to the fields of engineering, science, and technology was such that it will be a continuing memorial to a great man". So many will mourn his passing but none more so than his wife, Carolyn, and his children to whom we send our deepest sympathy. ❒

Keith Lawrey

A question of identity

Archimedes

Archimedes is an experienced observer of the evolution of public policy who contributes occasional comments on the character of the debate at the Foundation's dinner discussions.

Amartya Sen, in his book *Identity and Violence*, points out the dangers of identifying groups by a single characteristic – e.g. religion, nationality or colour. People do not have a single identity – as a Muslim, or a Croat, or a black. Rather, they have many identities – they are old or young, rich or poor, vegetarian or carnivore, environmentalist or avid consumer. At various moments in their lives the identity which matters most to them will change, and the identity which others impose on them may well not be that to which they attach importance. To pick out one identity for someone, and to assume that it is the characteristic to which he or she attaches most – or sole – importance not only belies the richness of human nature, but leads to groups which can become antagonistic to other groups of different 'identities'. Misunderstanding, stereotyping, hostility – and eventually violence – follow.

I have noticed, in FST discussions, a tendency to identify people by a single characteristic – they are scientists (and therefore right) or non-scientists (and therefore wrong). I do not suggest that the gloomy consequences Sen envisages will necessarily follow, but there is a danger of over-simplifying, stereotyping and failing to communicate. The distinction itself is an oversimplification; there is a spectrum of attitudes, ranging from the scientist who is a master of his discipline and does not venture outside, at one extreme, and at the other the non-scientist who rejects any scientific evidence in favour of intuition, 'common sense' or divine inspiration. But in between are scientists who care so passionately about, say, the environment that they will pontificate on issues outside their discipline and non-scientists, equally passionate, but able to accept factual evidence put before them.

You could, for example, have a physicist and a biblical scholar, both passionate about environmental issues – e.g. they are for biodiversity and against GM crops. Neither of them may know much about biology but for each of them their 'identity' as an environmentalist is more important than their identity as a scientist or non-scientist. And it is not necessarily the case that, were a biologist to provide evidence that their fears were misplaced, it would be the biblical scholar who was found more resistant to changing his views!

What is important to both of them is their common identity as environmentalists. If we persist in seeing them as only a scientist or non-scientist (or, as the case may be, a Muslim or a Christian) we stereotype them, we increase the difficulties of communication and we miss the possibility that they can work constructively together to further a common interest. As Sen would put it, we ignore the richness of human nature and make it more difficult for societies to function cooperatively and inclusively. Sen's passionate arguments are relevant, even for the Foundation for Science and Technology. ❐

Recent lectures and dinner/discussions organised by the Foundation.

7 February 2007
Can the career path for young researchers be improved?
Professor Wendy Hall CBE FREng
Sir Graeme Davies FRSE FREng
Dr John Bothwell

17 January 2007
The Cooksey Review: a review of UK health research funding
Sir David Cooksey
Professor Colin Blakemore FRS FMedSci
Professor Sally Davies FMedSci

15 November 2006
Scientific advice, risk and evidence-based policy making
Phil Willis MP
Professor Paul Wiles CB
The Rt Hon John Gummer MP

8 November 2006
The Stern Review on the economics of climate change
Sir Nicholas Stern FBA
James Smith
Andy Harrison
Professor Sir Partha Dasgupta FBA FRS

2 November 2006
Science Education
Professor Anne Glover FRSE
Professor John Holman
Bob Kibble

25 October 2006
What are universities for?
The Lord Rees of Ludlow PRS
Professor David Eastwood
Nick Butler

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