fst journal

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THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

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An unusual hurricane season

The catastrophic hurricane season this year - Katrina, Rita, Wilma - has raised questions about how to forecast both the frequency and intensity of hurricanes and the related storm surges. The insurance industry has properly to price the risk of damage to homes and businesses in the hurricane-prone states in the USA. To do this an estimate of the likely number and intensity of hurricanes that will cross the coast needs to be made. From the intensity estimates and the likely track, loss estimates can be made from vulnerability curves for a wide range of building construction types. The insurer not only wants to know the loss for a given address but more importantly, because of reinsurance arrangements, the aggregated loss expected for a given storm.

The exceptional hurricane season of 2005 has severely tested the models used by the industry and will lead to new research questions. Over the summer Kerry Emmanuel, Professor of Meteorology at the Massachusetts Institute of Technology, published in *Nature*[1] an analysis of the increasing destructive force of tropical cyclones over the past 30 years: he argued that the increase in intensity is correlated with the observed increase in sea surface temperature (SST). Not everyone agrees but the paper has stimulated an interesting debate on how such correlations should be tested and the confidence limits on such tests.

Elsewhere efforts have been made to improve the coupled atmospheric and ocean models to use physical understanding of the processes in the atmosphere and in oceans to improve hurricane forecasts (for example the work of the Hadley Centre[2] on the unexpected hurricane observed off the coast of Brazil – Hurricane Catarina). ❒

[1]*Nature* Vol. 436, No. 4 August 2005 p686-688

[2]www.metoffice.com/sec2/sec2cyclone/catarina.html

President of the Royal Society

A member of the Council of the Foundation for Science and Technology will take up office as President of the Royal Society on 1 December. Lord Rees of Ludlow, better known to many as Astronomer Royal Sir Martin Rees, succeeds Lord May of Oxford. His term of office will last for five years. ❒

Avian flu case in UK

It was widely reported in the UK press in late October that a parrot imported from Surinam had died of Highly Pathogenic Avian Influenza (HPAI) H5N1, having acquired it from other birds in a quarantine facility in Essex.

The report[1] of the National Emergency Epidemiology Group into the incident has now been published by the Department for Environment, Food and Rural Affairs (Defra) and this casts doubt on that interpretation of the evidence.

The main findings of the report are:

- within the species documented as coming from Taiwan only the Mesia birds were infected with H5N1 and 53 out of 101 birds had died;
- infection with H5N1 was transmitted between the Mesias, but there is no evidence of transmission to other species in the facility including the sentinel birds.

The original identification of HPAI H5N1 on 21 October was made from a pool of tissues derived from a Pionus Parrot (Surinam) and a Mesia (Taiwan). It has not been possible to say whether the virus isolated came from the parrot tissue or the Mesia tissue or both, says the report. However, in the light of the other evidence, the balance of probabilities is that the source was the Mesia sample. The H5N1 strain is most closely associated with a virus isolated from ducks in China early this year. This is consistent with Defra's working hypothesis of 23 October that the likeliest origin of the infection was the birds from Taiwan.

The facility had not been used since 9 March 2005. On 16 September a consignment of 148 parrots (Caiques, Pionus, Macaws and Amazons) arrived from Surinam. On 28 September a consignment of 186 birds (Mynahs, Mesias and Laughing Thrushes) documented as coming from Taiwan entered the facility. The 30-day quarantine period restarted with the arrival of the birds from Taiwan.

Chief Veterinary Officer at Defra Debby Reynolds said: "This report contains significant epidemiological findings and helps to further our understanding of Highly Pathogenic Avian Influenza. In particular the apparent lack of transmission of H5N1 between species in the facility will be of interest to the international community." ❒

[1]www.defra.gov.uk/animalh/diseases/notifiable/disease/ai/pdf/ai-epidemrep111105.pdf

Google Scholar

Google, the web search facility, now has an academic offshoot. Google Scholar enables searches to be carried out across many disciplines and sources: from peer-reviewed papers, theses and abstracts to articles and books. Sources include academic publishers, professional societies and universities. ❒

http://scholar.google.com

Plugging the UK energy gap

Maintaining the UK's standard of living while energy becomes scarcer and more expensive will require fundamental changes in the way we produce and use energy, according to a report launched at the Geological Society in London in November.

How to Plug the Energy Gap was written by the executive director of the UK Energy Research Centre, John Loughhead. It represents a distillation of the conclusions from a two day conference held in October at which 150 delegates, with expertise from across the whole field of energy, discussed the issues facing the UK. The meeting was sponsored by the Royal Society of Chemistry, the Institute of Physics, the IEE and the Institution of Civil Engineers.

The report aims "to provide the Government with a coherent, feasible solution to the acknowledged problem of the UK's looming energy gap". It concludes that the market alone will not deliver the goals of energy policy and argues that "clear means to encourage the necessary changes are essential".

It says that fossil fuels will remain the most important energy source for the coming 50 years, despite a growing role for renewable energy. "Clean systems", including carbon capture and storage, should be pursued urgently it says.

With regard to nuclear power, the report says that fission energy is a proven and reliable technology that "will inevitably have a key role in a future clean energy mix". The main source of uncertainty about the economic viability of the technology lies in the continuing uncertainty about the costs of disposing of nuclear waste and decommissioning nuclear plants – "both being uncertain chiefly because there remains uncertainty in Government policy" says the report.

Energy demand reduction measures will be as important as generation technologies, it says, requiring both technological and behavioural changes. Existing technology for energy efficiency is not yet fully exploited and remedying this situation is as important as new technology development. ❒

www.geolsoc.org.uk

On 11 May 2005 the foundation held a dinner/discussion at the Royal Society to clarify the policy of public support for the science base.

Towards 2.5 per cent of GDP on R&D

Keith O'Nions

Sir Keith O'Nions has been Director-General of Research Councils since the beginning of 2004. He is an earth scientist and has held academic posts at Columbia, Cambridge and Oxford (as head of the Department of Earth Sciences). He was chief scientific adviser to the Ministry of Defence from January 2000 to July 2004. He was elected a Fellow of the Royal Society in 1983 and knighted in 1999.

Government science policy has two objectives. The first is to sustain a world-class science base in Britain: the international competitiveness of UK science is a key goal. The second is the exploitation of the science base using science for the public good and for economic benefit.

Earlier this year, we allocated some £10 billion to building the science base. The total has been growing at about 8 per cent a year in real terms during the course of the current Spending Review. The largest element of the increased resources goes into sustaining the infrastructure. My sense is that most people feel that this is an appropriate investment.

We are now moving towards recovery of the full economic costs of research carried out at academic institutions. This year will be a test of the system, and we shall have our fingers crossed. Our goal is to move towards full-cost recovery while avoiding a highly bureaucratic approach. The sums of money involved are already quite substantial; 80 per cent of research costs will be paid from September, and will amount to £200 million in 2007-08.

Meanwhile, the infrastructure fund will remain at £500 million a year for the remainder of this spending review (that is why there are so many cranes around universities nowadays). There will be a further £250 million for new facilities and projects. These new funds take up a large proportion of the new money and will also have to feature large in the next Spending Review. You cannot suddenly stop these things.

How well does Britain perform in international comparisons? By now, there is a great deal of analysis of the relative performance of UK science and engineering. Without going into detail, there are many, many areas in which we are second only to the United States. But there are also some areas of engineering, some fields of mathematics and some quantitative areas of the social sciences where the comparisons are not nearly as flattering.

The question naturally arises of whether we could make good such perceived deficiencies. The research councils have paid particular attention to this question. But this will be a long term process.

The Medical Research Council has hugely re-oriented its priorities towards research supporting translation and clinical research, and with the help of £25 million from central funds now has a budget of £140 million a year in this area.

There has been a similar development in the field of energy. The Engineering and Physical Research Council (EPSRC) has now assumed the leading role in the development of future energy options. With an extra £25 million, the council will survey everything from photovoltaics to nuclear fusion. The budget may not be enough for the long term in my view and I believe the issue will re-appear in the next spending review.

The allocations to the research councils should not be regarded as indications of winners and losers. Circumstances affect them differently. Research councils carrying out a substantial proportion of the research they support in their own institutes will, by definition, already be meeting the full economic costs incurred. Councils such as EPSRC, which is very much a grant-based organisation, will be affected more noticeably.

I now turn to the second of the two objectives of the 10-year framework – improved exploitation of the science base, especially for economic benefit. I begin with the target in the 10-year framework document to spend 2.5 per cent of GDP on R&D ten years from now. The role of the business sector is evidently relevant to the process of fruitful innovation. In some fields, notably in pharmaceuticals and information technology, R&D accounts for a substantial proportion of companies' turnover. Elsewhere (as, for example, in the financial services sector), R&D may be only a small proportion of turnover, but for good business reasons. Our concern, now and for the years ahead, is that we should use what resources there are to stimulate the process of innovation.

We already have a number of tools at our disposal. One is the relatively new system of R&D tax credits: if all companies claimed what they are due, that would amount to half a billion pounds a year. There are also public funds for the support of knowledge transfer and innovation. For example, there is the Higher Education Innovation Fund (HEIF), which will have a budget of about £120 million a year at the end of the Spending Review. Much of that will be

UK	1.90
science base	0.35
other Government departments R&D	0.31
private sector	1.24
France	2.20
Germany	2.51
USA	2.67

Table 1. The ratio of R&D to GDP.

shared among academic institutions on a formula basis, but over the allocations period about £50 million will be awarded competitively in the hope of backing a small number of adventurous projects. I should also refer to the Public Sector Research Establishment (PSRE), which will have £20 million a year to spend on projects linked with this agenda. In addition, there is the New Technology Strategy Board within the Department of Trade and Industry, which will have £160 million a year to spend at the end of this spending review. That is a new board chaired by Graham Spittle of IBM; among other things, it is formulating a technology strategy in support of the innovation agenda.

Taken together, the cost of these activities is relatively small compared with the funds going into the science base. There are obviously questions of whether we are on the right track and whether we should increase the funds we now spend on them.

I conclude with a few remarks on the relatively poor performance of the UK in R&D. After all, 1.9 per cent of GDP seems miserly compared with the 2.7 per cent of GDP spent in the United States. What can be the explanation? I have already referred to the high proportion of sales revenues spent on R&D in the pharmaceutical sector. That appears to be the case in all technically advanced countries: R&D is typically more than 10 per cent of turnover. Much the same is true in electronics and information technology. In other sectors of modern economies – banking, for example – spending on R&D may be relatively much smaller everywhere.

So different sectors of an economy may be characterised by research of different intensities. The research intensity of a particular sector of industry will be similar from one country to another, but there will routinely be marked differences between the size of each industrial sector in national economies. The consequence is that when the research spending of industrial sectors is aggregated for comparable countries, the proportions of GDP spent on R&D in each of them will depend on the relative importance of the different sectors. Specifically, part of the reason why the UK spends less on R&D than the US is that, although information technology is equally research-intensive in both countries, information technology is a smaller part of the economy in Britain than in the United States.

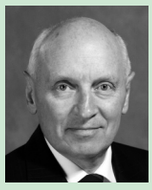
So our 1.9 per cent is more a reflection of the make-up of our economy than it is of under-spending or under-investment in a particular sector. That is a first approximation to the truth.

The various sectors of a modern economy can also be categorised by the value they add to the overall economy (technically, value added is the value of total sales minus the cost of bought-in goods and services, and is a good approximation to 'wealth creation'). In Britain, banking and financial services come top of the list, oil and gas come next, followed by support services, telecommunications and pharmaceuticals. The last of these is the first industrial sector in the list where the research intensity exceeds 2 per cent.

I have not directly addressed the question of the link between research and useful innovation. Part of my purpose has been to suggest that the connection is complex and not well understood. It goes without saying that, for the British economy as a whole, what matters is that wealth creation should satisfy the ambitions of its people. I emphasise again that we are still feeling our way in the management of our efforts in this field. ❐

The costs and the priorities

David Wallace



Professor Sir David Wallace CBE FRS DL is vice-chancellor of Loughborough University. He is treasurer and vice-president of the Royal Society, immediate past president of the Institute of Physics and a fellow of the Royal Academy of Engineering. He is also chair of the UK e-Science Steering Committee. He was knighted in 2004 for services to UK science, technology and engineering.

I am going to talk from the perspective of higher education, and give very much a personal view. The first point I want to make relates to selectivity: in the UK, research funding is already highly selective. This is already well known but I want to illustrate it by referring to the ratios of funding which are used for grades 3A, 4, 5 and 5* by HEFCE. If you are in a Grade 5 department, you roughly get 2.7 times that for Grade 4; and 5* brings 3.4 times that amount. The funding model has actually been changed for 2005-6 and these ratios are now 1:3:3.75. This degree of selectivity is far higher than could be justified by funding only individuals who do research, in RAE terms, of 'international excellence', with no funding at all for individuals of 'national excellence'. That is my first point.

Second, let me discuss TRAC (Transparent Approach to Costing), the forerunner to full economic costs. It led us to identify the full infrastructure costs of our work in universities and to allocate those across teaching, research and other areas. It also added costs, some sensible; for example, you have to depreciate your assets at current values, not at historical costs.

The result is that everybody runs at a loss if full overall economic cost is calculated according to these rules. It is unclear to me whether this will actually become part of our Statement of Recommended Practice in the future; I am not convinced that it should, because not all costs included seem reasonable

discussion

Individual enthusiasm. A number of participants argued that while it was vital to recognise the UK's enviable record of scientific success, it should be noted that this had come through the ability of individual scientists to pursue their own interests. To constrain them within set procedures and processes, and to demand results in areas that might not lie within their own priorities, risked losing the enthusiasm and drive that had led to past successes.

to me. However, if it does, then certainly all universities that do research will be in deficit. Estimates of academic time spent on teaching, research, etc, are open to interpretation and this has resulted in a bit of bureaucracy for academics. The data gathered, though, was important not least because it was partly behind the Government's willingness to put more money into infrastructure and sustainability.

Some details from Loughborough University may be of interest; it is typical of data I have seen from other research-intensive universities. According to our TRAC data, our UK/EU student costs are broadly in line with income, and the surplus from international students is invested in the staff and facilities they expect when they come to us. We lose money on publicly funded research and a little bit less on non-publicly funded research. We make a surplus from our other activities. However, under TRAC accounting, instead of having a surplus of around 3 per cent on our annual accounts we would have a loss of 5 per cent.

Third, I turn to full economic costs (FEC). The requirement here is to cost *individual grants* fully according to the principles that lie behind the TRAC accounting scheme, *including* the Principal Investigator (PI) salary. From September 2005, successful research council applications will receive 80 per cent of FEC, a significant increase on the current figure now. It is important to stress that you receive only 80 per cent of direct costs such as a Research Associate salary. There are obviously concerns about whether other public and non-public research funders will recognise and award FEC – the EU is a particular concern here. It is a great relief that the monitoring of the time of the PI will be at the university level, and not, as originally appeared, at the level of the individual grant.

There are interesting implications for funding councils as well as research councils. If you are in a project-rich area with lots of research council funding and you have good Principal Investigators, their salaries are fully costed in the research council grant. In areas like mathematics, academics do not have access to the same level of additional research council funding and so what is going to happen? A funding disparity will emerge between project-rich areas like much of science and engineering compared with project-poor areas in, for example, the economic and social sciences. Over the next few years, the research and funding councils will have to decide whether or not they respond.

A funding disparity will emerge between project-rich areas like much of science and engineering compared with project-poor areas.

Fourth, looking at 'strategic subjects' I believe that the changes introduced in recent years by the Higher Education Funding Council for England (HEFCE) have not helped the situation. The first was in 2003-4 when HEFCE changed the teaching funding model: at Loughborough we lost £1 million as a result. It hit predominantly the pre-92 universities, which have most of the 'hard' science research base. In 2004-5, the ratio of teaching funds for laboratory and non-laboratory subjects has decreased from 2:1 to 1.7:1. And in 2005-6, Quality-related Research (QR) funding (HEFCE were very helpful in giving us the data) for non-laboratory subjects has gone up by 17 per cent and for the mid-laboratory subjects by 14 per cent. Yet for laboratory subjects such as engineering, physics and the like, the increase is only 8 per cent (and for chemistry it is -1%); there has been a relative shift out of laboratory subjects.

Each of these changes was only at the c. 4% level, and they were arrived at rationally by HEFCE, but they all add to the challenges that a university vice-chancellor and a university council face in supporting the sciences.

There are also a number of other agendas, e.g. 2008 RAE, the 10 Year Framework, regional agendas and so forth. I think that the key word for the future should surely be 'impact'. It could be the academic impact on peers and their take-up of ideas or it could be industrial impact, or in terms of the regional agenda the impact for the region. I think that, because of the extra money, there will be no getting away from the pressure to demonstrate impact over the next three or four years. Provided the Government continues to accept a wide definition of the term, this should not necessarily be a threat to basic science.

Finally, as the new fee regime comes on board, I hope that HEFCE – as minority funders even of teaching – will recognise that we have a million and a half stakeholders out there who will be pressing, rightly, that we deliver quality and innovation: after all, they will be paying for tuition and taking on debts to cover it. The ability of HEFCE to match teaching income to costs for specific subjects will be reduced, and so also should its burden for quality assurance. All this will place an increasing demand on universities to allocate resources and invest in ways which are not simply driven by financial parameters, ironically at a time when we understand our income and costs better than ever before. ❐

discussion

HEFCE and the research councils. Speakers raised the question about the relationship of the research councils and the Higher Education Funding Council for England (HEFCE). It seemed sometimes that the formula allocations from HEFCE ran counter to the priorities that the research councils were developing in funding projects. However, the point was also made that the dual support system had been set up in order to give individual institutions the ability to use their block grant in the way they wished: to suggest that HEFCE should align its funding to research council grants would be to undermine the principle of institutional autonomy.

Asking the right questions

Mark Walport

Dr Mark Walport FMedSci is director of The Wellcome Trust. He was professor of medicine and head of the Division of Medicine at Imperial College of Science, Technology and Medicine, London. His clinical and research interests focus on immunology and the genetics of rheumatic diseases. He won the Roche Rheumatology Prize in 1991 and the Graham Bull Prize in Clinical Science (Royal College of Physicians) in 1996.

Science needs to be managed flexibly, supported by policy that provides the right drivers to foster the process of discovery and nurture the individuals and teams involved with it. The difficult questions for funding agencies, whether public or private, are:

- how to distribute money in the best way to support research?
- how and whether to set research priorities?
- how to pick the best scientists?
- how to know whether, through the above, they are making a difference?

Unlike today, where the governments of the leading economic powers aspire to support basic and applied scientific research from the public purse, prior to the twentieth century research was mostly funded privately or by industry.

Vannevar Bush, the visionary engineer and scientific administrator who directed the USA's wartime Office of Scientific Research and Development, was a key contributor to the evolution of research funding. He presented a report to President Roosevelt entitled *Science The Endless Frontier* in which he outlined the means of supporting scientific research after the end of the war. In it he noted that progress in the "war against disease depends on the flow of new scientific knowledge. New products, new industries and more jobs require continuous additions to knowledge of the laws of nature, and the application of that knowledge to practical purposes. This essential, new knowledge can be obtained only through basic scientific research."

Today, similar rhetoric can be found in the UK's 10-year Science and Innovation Investment Framework, which reaffirms Vannevar Bush's principle of funding excellent basic research and encouraging knowledge transfer.

But who drives the process of discovery and who asks the research questions? A key tension for all funding agencies is between the bottom-up and the top-down approaches to the support of research.

Joshua Lederberg, an American geneticist and microbiologist who received a Nobel prize in 1958 for his work on bacterial genetics, presented a prescription for funding agencies in 1991: "…simply put, the best way to administer a creative research environment is to find people of great talent and reasonable ambition – whatever their specific disciplines – and leave them to their own devices." This approach has great merit and is the prescription used for a large fraction of the funding that is provided by the Wellcome Trust.

In the UK, science has always had a strong strategic component. One of the principal objectives of the Royal Greenwich Observatory, London, which was established in 1675 by King Charles II, was to solve the problem of determining longitude at sea for the benefit of naval and commercial fleets.

The top-down approach provides the scientific community with money to tackle specific scientific problems. However, there are two problems with this approach. The first is 'unripe time' – that is, working on a problem when the necessary toolkit is not available. President Nixon's War on Cancer, which was initiated in 1971, was a limited success because the molecular tools were not widely available to tackle the problem at that time. The second problem is the danger of funding second-rate science because of restrictions on use entailed by ring-fenced funds.

The bottom-up approach to funding is exemplified by the Nobel Prize-winning Paul Nurse. He was trying to understand his observations of dividing yeast cells and set himself the challenge of tackling what he felt was a tractable problem: this has now helped us understand some fundamental cell biology. It is extremely important that we preserve this kind of curiosity-driven, bottom-up investigation

discussion

Peer review. Peer review was attacked as being responsible for much delay, and a hindrance to radical thinking. But it was a method that was tried and trusted; scientists and researchers would be very unwilling to see it dropped in favour of what might be a quicker, but would certainly be a more arbitrary, method of assessment. But it should be used carefully, and with the aim of promoting projects, not rejecting them.

of science.

However, there is an attractive middle ground between the bottom-up and top-down approaches. This may be particularly useful when there are areas of research that, using the language of the pharmaceutical industry, can be classified as 'unmet need'.

The Grand Challenges in Global Health programme, funded by the Bill and Melinda Gates Foundation with financial contributions from the National Institutes of Health, the Wellcome Trust and the Canadian Institutes of Health Research, is an example of an excellent approach to stimulating scientific activity in areas of unmet need. The world's scientific community was asked to identify the important questions and the roadblocks to solving critical health problems in the developing world. Fourteen 'grand challenges' were distilled from the responses by an expert committee. These challenges formed the basis of an invitation to the world's scientific community to propose first-class approaches that would provide solutions and health benefits.

As Sydney Brenner argues, identifying good science involves identifying scientists who have important questions to answer coupled with sound experimental approaches. Maintaining this kind of flexibility in the discovery process is imperative and is perhaps sometimes forgotten by funding agencies. Key questions for funding agencies to ask would seem to be: "Are you a good scientist?" "What have you actually discovered?" "Who have you trained?"

Maybe we should also actually read an applicant's two or three best papers, rather than just the titles of the journals in which they are published. Then we need to know the researcher's question, why it is important, how they will approach it and what resources are needed.

How should one train and support young scientists? Key is to ensure that the brightest youngsters are trained in the best laboratories. There is an important duty of care for all of those involved in the training of scientists to act as role models and provide mentorship to their research trainees. History shows that one great scientist begets another. Personal fellowship schemes are a very powerful way of supporting young scientists on a path to their own independent scientific careers.

There are, of course, limits to planning science; science after all sets its own priorities. You cannot predict discoveries or anticipate what may come from new knowledge. It is therefore important to support a balance of the best ideas and best people – and we have to provide flexible mechanisms for doing so. We also cannot completely ignore the issue of unmet need. If a problem does not confront scientists then they are not going to work on it – so it is sometimes important to bring opportunities to their attention. For example, there is a mismatch between the burden of much parasitic infectious disease and the location of state of the art laboratories in the developed world. But equally, there is no shortage of fascinating and important science that can be pursued on diseases such as malaria, trypanosomiasis and leishmaniasis.

discussion

The management dimension. More funding was essential, and should not be swallowed up by an over-managerial culture. Ministers were accountable to parliament and the public and so they needed to have some measures, or outputs, which they could use to justify expenditure. The danger lay in setting management targets which took no account of professional realities or the uncertainty about the outcome from any research project.

Having given out a grant, how can we measure its success? This is vital if we are to persuade politicians and the public that research is a fundamental activity worthy of sustainable support.

A great deal rests on persuading the politicians. In 1966, Project Hindsight (funded by the US Department of Defense) looked at the science behind 20 military weapons, including the Polaris and Minuteman nuclear warheads. The report concluded that the contribution of university research had been minimal, that mission-orientated science was the most successful and that the lag between discovery and application was shortest when scientists worked in an area targeted by a sponsor.

The flaws in this argument are fairly obvious. While developing a missile or a gun is not likely, in the short term, to have been influenced by what happens in university laboratories, it would be surprising if the nuclear warheads had not been significantly influenced by a great deal of rather basic physics research that had gone before. To say that university research had not been important, though it may not have been the desired outcome of that research, was not true.

This exposition of the importance of mission-orientated research infuriated many in the scientific community and led to a bibliometric analysis by Comroe and Dripps. They published a paper in *Science* in 1976 which showed that 10 major clinical advances in cardiovascular medicine could be traced back to roots in basic science. This conclusion became a powerful advocacy tool for increasing basic science budgets in the USA.

Historical case studies are a powerful method for evaluating the impact of scientific research – and show that a long view is essential. The Wellcome Trust supports a series of 'witness seminars'. Developed and run by Dr Tilly Tansey at University College London, these collate the oral histories of the participants who were involved in major discoveries. One example is that of obstetric ultrasound; if you look at clinical papers on this subject, you will not find basic research cited. The history, though, was that Ian Donald, an obstetrician working in Glasgow in the early 1950s, had been interested in naval research on sonar detection during the war. He thought this could be applied to human situations. The result was a remarkable collaboration with the people that supplied Glasgow shipyards with equipment to scan metal welds and detect defects. An ultrasound machine used in shipyards was translated into an extremely useful clinical advance, but this would never have become clear from any kind of bibliometric analysis.

So, we have to be sure that we are measuring metrics that are sensible and provide the right drivers by avoiding perverse incentives. We need a mixture of managerial measures (the input, the activities, the output), but we must not neglect the case studies and other qualitative measures. What really matters is what has actually been discovered, whether this is important new knowledge and whether training has been provided to the scientists of the next generation.

In summary, the important questions for us to answer when developing the science policies of the future are:

- what are the correct drivers for the research environment that we want to foster?
- do current management approaches stifle creative scientific research?
- how do we best capture the outcomes of research?
- finally, and I think most importantly, how do we continue to persuade politicians and the public that fundamental research really matters?

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The Government's response to the Tomlinson Report has divided educationalists. The issues raised were considered at a dinner/discussion on 25 May 2005.

The Government response to Tomlinson

Julie Bramman

Julie Bramman is head of curriculum at the Department for Education and Skills, a role that includes responsibility for all 14 subjects in the National Curriculum for primary and secondary schools. It also includes cross-cutting curricular themes such as sustainable development, culture and creativity, as well as learning outside the classroom. She has a leading role in implementing the Government's 14-19 White Paper.

First I would like to sketch out the Government's vision for secondary education: I will focus on our response to Mike Tomlinson's report, as set out in the 14-19 White Paper that we published in February.

We are, of course, aware of the criticism that the Government has not fully embraced the recommendations of the Tomlinson report. We have decided to retain the existing GCSE and A-level qualifications system, rather than adopt an over-arching diploma for both vocational and academic routes. It is important to build on what is good within the current education system rather than replace it wholesale. GCSE and A-levels are high-quality, internationally recognised qualifications and – perhaps most importantly – they are universally understood by young people, parents, employers and universities. We consider the real challenge is bringing the same levels of quality, coherence and understanding to what has been described as the 'alphabet soup' of vocational qualifications.

The development of the new diploma system will provide a real opportunity to break down the academic and vocational divide. This requires a fundamental change in cultural attitudes, which by its nature will take time: it can only be done if everyone fully supports and recognises these qualifications.

Apart from retaining GCSEs and A-levels, we have used the Working Group's analysis of the system and adopted many of its major recommendations. The reforms are based around these key principles: securing the basics; stretching every young person to their full potential; offering a high-quality vocational route; re-motivating disengaged learners; and preparing all young people for the world of work.

What do these broad principles mean in practice? Employers have consistently raised concerns about the basic skills of young people, focusing predominantly on communication and maths but also including wider skills such as team working. That is why we will ensure that every young person must leave school competent in English and mathematics. We intend to define what it means to be functional in English, maths and also information and communication technologies (ICT). To ensure that the curriculum imparts these skills and that qualifications judge their mastery, it will not be possible to achieve a Grade C or above at GCSE without having mastered the basics.

It is vital that we stretch and challenge young people so that they can realise their full potential. Some students need a greater degree of stretch and challenge in their studies; this is why the new diploma and A-levels will offer gifted students the option to answer more challenging questions. We will also allow schools to offer higher education modules, where the pupils are ready for this level of study.

It is a top priority to secure vocational pathways for the young. Traditional academic qualifications have served the needs of many students successfully, yet there are a number of students with different needs who would benefit from a greater variety of teaching and learning approaches. For these young people there will be 14 diplomas covering the main occupational sectors.

We are working with key stakeholders, including employers and Sector Skills Councils, to ensure that the diplomas have suitable content. There will then be a phased delivery of diplomas, with the first four in ICT, engineering, health and social care, while the creative and media diplomas will be introduced in 2008. All 14 will be available by 2015.

It is important to re-motivate young people who drop out of the system. Proposals in the White Paper will allow students access to a much wider range of environments and types of learning. The new package of qualifications and other changes to the system will result in a clearer framework of progression pathways so that, through to the age of 19 and beyond, students will have real choice and a range of options available to them. This will provide a framework to ensure that all young people will be prepared for the world of work.

Now I would like to consider the implications for science. The Tomlinson report was fairly silent on the issue of science, and that contrasts with the White

Paper where it is given prominence throughout. Our first priority is to ensure that young people have the knowledge to enable them to make informed choices about their education at the age of 14. We therefore see reforming the curriculum for 11-14 year olds, which is Key Stage 3, as vital. It is important that the excitement, relevance, and crucial importance of science is clearly infused throughout the Key Stage 3 science curriculum, rather than it being just a long list of facts that need to be learnt.

There will be a new programme of study at Key Stage 4. From 2006, all students will still have to learn science, but the current substantial programme of study will be replaced by a smaller statutory core, suitable for all students. However, it is expected that the majority of students will devote the same proportion of their studies to science as they do now, taking courses that lead to the equivalent of a double award GCSE. We have gone further, creating an entitlement for KS4 pupils to study a course in science equivalent to two GCSEs.

The new programme of study will include a common core — to achieve a single award GCSE, students will have to study some additional science. To achieve a double award, two alternative progression routes will be provided through the study of Additional Science GCSE. Students can take a course to develop a broad understanding of science. This provides preparation for the more advanced study required for careers in engineering and medicine, with the emphasis on explaining and theorising. Or they take the second route, focusing on developing practical scientific capability, which will engage students in the world in which science is applied – occupations such as healthcare, agriculture, manufacturing and communications.

By extending the successful Key Stage 3 strategy to cover the whole of the secondary phase, we anticipate that the existing success, especially the improvements in teaching and learning and attainment that have been possible at Key Stage 3, will be replicated at Key Stage 4.

It is also important to consider the impact of the wider education system, and how other successful programmes and initiatives can feed back into the system more generally, raising standards and expectations for all. The Specialist School System, for example, is the cornerstone of the Five Year Strategy published last summer: these schools have a vital role in helping to improve the student's experience of science. Almost two out of five current Specialist Schools specialise in science or technology, and we know that Specialist Schools are improving at a faster rate than non-specialists at Key Stages 3 and 4.

Other issues that we need to consider include the differences in representation and attainment between the genders, in ethnic minorities and across socio-economic groups. The Department for Education and Skills and the Department for Trade and Industry are collaborating to develop solutions to the problem of poor uptake of physics among girls, for instance. The Science Learning Centres network, jointly funded by the Wellcome Trust and the Department for Education and Science, will have a key role in offering training and professional development opportunities for teachers of science in the wider workforce.

All these measures and more are targeted at improving the levels of attainment at 16, but there is also the post-16 dimension to consider. There has been a dramatic decline in the number of students studying science subjects at A-level and beyond. Even when students do pursue scientific study, a large number pursue careers in other sectors. This decline is dangerous, not only because it means that as a country we will not have a labour force sufficiently skilled to take the economy forward, but also because it is a problem that is self-perpetuating.

I have outlined a number of initiatives and commitments that we have made in a variety of strategy documents. It is of course important to bear in mind that all these elements are ultimately pieces of a multi-dimensional jigsaw which will ensure that we have a sufficiently knowledgeable and skilled workforce to take the economy through, and beyond, the twenty-first century. ❐

www.dfes.gov.uk/14-19/documents/Final%20Report.pdf

The view from the chalk face

Pauline Cox

Pauline Cox is head teacher at The Tiffin Girls' School, Kingston upon Thames. She studied geography at Birmingham University before working overseas in Warsaw and at Legon University in Accra. She was head of geography at Waldegrave Girls' School in Richmond and then spent seven years as deputy head at Cranford Community College in Hounslow. Mrs Cox was a member of the council of London South Learning and Skills Council from 2002 to 2004 and is Secondary Heads' Association representative for Kingston.

I have been invited to put the head teachers' view of the Tomlinson-Kelly debate surrounding the education of 14-19 year olds. It is a brave person who attempts to represent the diversity of views of the 3,500 secondary head teachers in the country – not forgetting all the colleges and further education establishments also charged with educating 16-19 year olds. But this is what the debate sounds like and feels like from the 'chalk face' in a high-achieving selective girls' school with a large and successful sixth form of 277, with most girls going on to university. We are a mathematics and computing specialist school – one of the first in the country.

The Tomlinson Report was eagerly awaited. Few in the education world have Mike Tomlinson's wealth of experience and breadth of vision and even fewer have his diplomatic skills. Tomlinson achieved something rare in education: broad agreement. Its main proposal – for an overarching diploma to unite the vocational and academic pathways – was coherent, relevant and revolutionary and reflected a genuine consensus view about the future for 14-19 education.

The academic and vocational divide in education dates back to at least the 1944 *Education Act*, and there is general agreement that the perceived inferior nature of vocational education is a problem that a knowledge economy in the twenty-first century cannot afford. The Tomlinson report was a sound basis for tackling the problem, but its timing was unfortunate. Spring 2005 brought a new Secretary of State for Education and an election. In responding to the report, the incoming minister Ruth Kelly threw out the baby and the bathwater. She jettisoned the proposal for an overarching diploma and in retaining the *status quo* with A-levels and GCSEs she has perpetuated the academic/vocational fault line that runs right through education. Tomlinson's vision appeared to be Kelly's nightmare.

So what challenges were Tomlinson and

Kelly trying to address? About half of 16-year-olds attain five good GCSE passes; it is the other half that presents the problem. At the age of 16, many young people become disengaged from education and disappear from the system. Our educational success rate and staying-on rates after 16 compare badly to our economic competitors. Kelly is aiming to increase the participation rate for 16-18 year olds from 75% to 90% in 10 years and to do this we need high quality vocational education.

Kelly identified four major objectives to address the problem of education and skills for 14-19 year olds: functional maths and English; tackling low staying-on rates after 16; better vocational courses; and stretching all young people and engaging the disaffected. This last is possibly the biggest challenge of all. But Kelly has cherry-picked Tomlinson – and she left out the best cherry in the bunch, the overarching diploma unifying vocational and academic education.

Head teachers were disappointed by the rejection of Tomlinson – but are now faced with the challenge of delivering Kelly. That will be made harder by a perennial problem: education policy makers usually underestimate the facilities and resource implications associated with any form of change. Teaching any 14-19 year old needs good buildings and modern equipment, and this is particularly true of the specialist facilities needed for vocational courses. The 14 vocational diplomas outlined in the Government White Paper will need good industry-standard facilities. Capital investment will be vital, yet most head teachers struggle to access capital funding.

GCSEs and A-levels are cheaper to teach than vocational skills, as they require little in the way of specialist facilities; yet the qualifications themselves are held in higher esteem than vocational qualifications. And this is the basic problem surrounding the delivery of vocational courses for schools and colleges.

Both schools and colleges face desperate shortages of qualified teachers. The teachers we have are getting older and we also face a rapid turnover of young staff. Colleges face particular difficulty: college lecturers receive about 8% less than teachers – and they are the main teachers of vocational courses. Again we have this academic and vocational divide which extends also to funding: schools receive more per student than colleges – and even then it is a financial struggle for us.

Above all, for teachers we need on-going professional development – both in the methodology of teaching and also in updating subject knowledge, especially in science and technology. Introducing new courses and qualifications requires training and planning. Both are too easily brushed over.

discussion

A sense of déjà vu? It was pointed out that the Hamlyn Commission, 12 years ago, had come to similar conclusions about the need for an overarching diploma and this too had been rejected. It was argued that there were good political and practical reasons for this double rejection in just over 10 years. The views of parents and employers had to be given due weight: there was clear evidence that these groups were strongly attached to the current GCSE and A-level structure and were suspicious of fundamental change. Ministers had to weigh expert opinion against the views of voters and take a decision which, in their view, would be acceptable and in the public interest.

Kelly is proposing changes that will impact on teaching in every one of the seven year groups in secondary schools. This means rewriting every scheme of work and many lesson plans. This needs extensive teacher time and planning time.

We have too many exams at secondary level. With Tomlinson we had hoped to see a reduction in testing. Over-testing affects learner motivation, produces bureaucracy, loss of teaching time and above all costs money. At least the 14 specialised diplomas will help to simplify the alphabet soup of vocational qualifications, some 3,500 in total, with 123 awarding bodies. However, they have to be recognised by university admission tutors, parents and employers.

But whatever happens we must have exam syllabuses, specimen exam papers and textbooks before we start to teach. We need a lead time of one or two years for any exam change. We must avoid the debacle of the last A-level changes of Curriculum 2000, when we were teaching sixth formers with no syllabuses and no clue as to where we were going for far too long.

Kelly is promising us the chance to stretch more able pupils. Harder questions at Advanced Extension Award level are to be welcomed. Unless we introduce greater differentiation at the top grades, the UCAS system could fragment with more and more universities setting their own entrance exams. At A-level, Kelly proposes that universities will be given the pupils' grades from each module paper. An A*, A** system might be easier to implement.

How do we organise the delivery of 14-19 education and skills? To provide a wide choice of A-levels, or the new specialised diplomas, requires large schools and colleges. A sixth form size of 250 is considered the minimum for offering at least 22 subjects at A-level. In my local authority with 10 secondary schools, six have non-viable sixth forms on these statistics.

Yet parents like school sixth forms. They like the structure, discipline and small size of these schools. In an attempt to be viable, school sixth forms create consortia, as do schools with colleges. But if both providers are poor then the consortium provision is also poor. Travel time for students, as well as pastoral care and guidance, become issues. The wide range of 14-19 provision around the country shows the complexity of providing education for this age group. The introduction of the Learning and Skills Councils with responsibility for 16-19 education has not brought any degree of rationalisation, as some might have hoped.

One of the biggest issues which will not go away is: how do you run a coherent, planned 14-19 curriculum where schools are only 11-16 institutions? Collaboration of any sort takes time and effort. These are not commodities too often available in our stretched education system.

It is too easy in this debate about structures, funding and qualifications to lose sight of the students and parents that the system is supposed to serve. With no overarching diploma, the academic/vocational divide will continue. Parents and pupils want the higher status GCSEs and A-level route, however inappropriate for their ability and aptitude. Good advice and guidance is vital here and has been lacking in the past. Many employers still talk about O-levels: how will they ever cope with specialised diplomas?

Where do we go from here? We have to implement Kelly. Yet by the time children starting school today leave school in seven years time, how many secretaries of state will there have been, how many more education acts and how many more changes of policy?

I am not advocating *no change*. But constant change is disruptive and detracts from the main business of schools – educating children. Elements of Kelly are to be welcomed. However, they do not fully address the problems they set out to solve. Tomlinson would have been the choice of most of education. Above all we cannot implement change without resources, teachers and buildings. If you are at school at a time of rapid educational change, then you are a guinea pig for untried and untested ideas. And we must remember that every child has only one education – and every child matters. ❐

Good science teaching matters

Bob May

The Lord May of Oxford OM AC Kt FRS is the former President of The Royal Society. Lord May holds a professorship jointly in the Department of Zoology, University of Oxford and Imperial College, London, although he started his career as an applied mathematician and theoretical physicist in Australia and the US. Between 1995 and 2000 he was chief scientific adviser to the UK Government and head of the Office of Science and Technology. He became a member of the UK House of Lords in 2001.

I have a lot of sympathy with what the other two speakers have had to say about drawing too sharp a distinction between academic and vocational qualifications. Nonetheless, against that background, I am going to focus my discussion in a rather different direction and talk about teaching just science and mathematics for 14-19-year-olds.

The genesis of this talk is a Teachers' Award made by the Secretary of State for Education in the Commonwealth of Australia. He wrote to Australians all over the world for anecdotes about teachers and three of them gave him stories about the same person, which seemed to him rather remarkable. The award was a tribute to a rather remarkable person. He was my chemistry teacher and takes much of the credit for enthusing me about science.

My own school in Sydney was a state grammar school. There were no league tables in those days, but it was the state grammar schools that stood out in any lists of exam achievement: since then, as here, it was felt that these schools were elitist and most of them have gone. Today if you look at those league tables, they are dominated by the private schools that used to be the places that you sent your kids to if they could not make it to the grammar school – parallels with Britain perhaps?

The chemistry teacher who taught at that school, taught eight current Fellows of the Royal Society; he also coached a track team that won the state schools championships in 28 out of the 32 years he coached them. He did not teach to a syllabus. Some people loved him, some people hated him. In our final year, as 16 or 17 year olds, he taught us that the important thing was to learn how to learn for yourself. The Honours course was taught by writing essays on topics of your selection and checking them against the older repertoire of past students – which by my time was quite a few. The burden of marking exams he managed (because he was a creatively lazy person) by handing the exam papers back to the class to grade each other's – a brilliant pedagogic device and also one that involved considerable learning skills in relation to life.

What I learnt in school more than anything else was not a set of facts from a syllabus: I learnt to question the conventional wisdom – to ask what are the relevant facts and then disregard what you have been told and try to think it through for yourself. And so my talk is not going to survey the current landscape of syllabuses and changes in the syllabuses because I think that there are some issues that transcend the details.

How does this relate to education today in Britain? Let us just look at the facts. The trend in this country for A-level entries between 1991 and 2004 was upwards overall. In some science subjects though, it is very different. Biology entrants increased slightly by 12 per cent but there were decreases in physics (by 34 per cent), chemistry (16 per cent) and mathematics (22 per cent).

Is this because of the general perception that it is harder to get top A-level grades in maths, physics, chemistry and languages that in some 'softer' subjects? A study by a group in Durham supports the perception that these subjects are harder. They took groups of students who had roughly equal performance at GCSE level, and looked at the grades they got in A-levels. From a list of 60 subjects, the five that were significantly most difficult to attain top grades were chemistry, physics, Latin, French and mathematics. The five least difficult were design and technology, graphical communication, communication studies, art and photography. What these have in common is that their assessment is more subjective than objective.

This presents parent and student with a tricky choice: tackle substantial subjects that are worth mastering, but risk getting low grades; or go for subjects where high grades

discussion

The importance of the teacher. There was general agreement that the crucial factor in successful teaching was the expertise and personality of the teacher, rather than the detailed requirements of the syllabus. Indeed, some argued that the syllabus was almost irrelevant to the teaching process and that perhaps assessment should also be left to the teachers who knew their pupils. However, others pointed out that no Government could accept a situation in which there was no external evaluation of success and a measure of accountability. This did not mean that league tables were the right answer (it was generally felt that they were not) but one could not ignore the desire of parents and employers to know which schools were objectively judged to be successful.

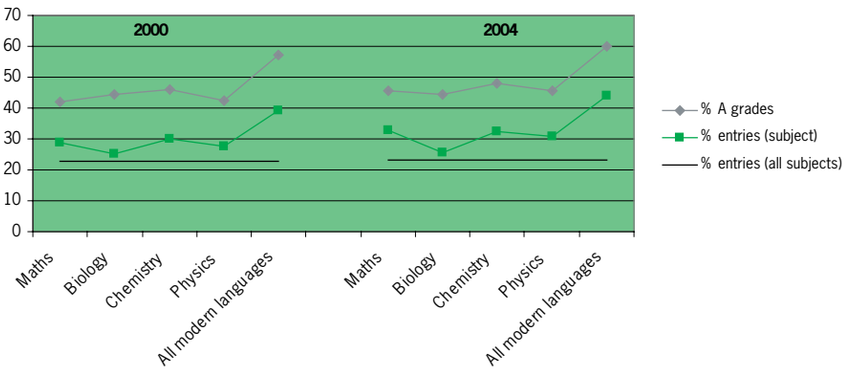


Figure 1. Independent schools A-level entries and A grades as a proportion of all school entries. (Source: ISC, March 2005).

Least difficult subjects	Most difficult subjects
Design and technology	Chemistry
Graphical communication	Physics
Communication Studies	Latin
Art	French
Photography	Mathematics

Table 1. Relative difficulty of the five most difficult subjects and five least difficult subjects at A-level. (Source: CEM, Durham).

are there for the taking.

Another interesting set of figures is the proportion of A-level entries and top A-level grades obtained by the independent schools (defined as private schools that charge for their services). The independent sector represented 23 per cent of all A-level entries in the years 2000 and 2004. But in 2004, they represented 33 per cent of the entries in mathematics, 31 per cent in physics, 32 per cent in chemistry and 45 per cent in all modern languages. If you look at the percentage of the top grades, they represented in maths, physics, chemistry and all modern languages, 46, 46 48 and 60 per cent respectively. This contrasts dramatically with, say, social studies: here they represented just 13 per cent of the A-level entries and 27 per cent of the top grades. One thing these figures tell us – something I consider socially unfortunate – is that the declining cadre of people who are going to be the basis of the knowledge economy are coming, out of all proportion to the number of students, from the independent schools. All power to the independent schools for having the resources.

In my view, children are guided away from maths and science not simply because they are graded tougher, not simply the fact that it is harder to get good teachers, not simply that the laboratory work is expensive and can be ill-afforded in under-funded state schools. As well as all this, there is the perception that careers open to chemists and physicists are not well paid.

There are some figures on the issue of pay that prove otherwise. A study by Price Waterhouse Coopers, commissioned by the Royal Society of Chemistry and the Institute of Physics, shows the 'working life additional earnings' by degree subject studied at university, compared to those who left school with two A-levels. Not surprisingly, medicine and law are at the top of the league table, but they are closely followed by engineering, physics and chemistry. Towards the bottom of the list are English and history.

Another way of looking at a graduate's achievements is to see how much income tax they pay during their working life. Law and management are at the top of the table, but the engineers, chemists, physicists, and those who studied in European languages are next in line. They are vital to the economy and the Exchequer is doing pretty well out of them. The Government would do well to recognise that fact. Yet although the Department for Trade and Industry and the Treasury have launched a 10-year plan for science that recognises the need to sow the seed corn, the DfES is not investing sufficient funds to provide the qualified people we need in these areas.

If we are to achieve excellence in science we must stop creating perverse incentives for students and universities to move away from scientific subjects. The obsession with grades, regardless of the usefulness of the subject, is one. And the high cost of laboratory-based subjects is another: this should be taken into consideration in departmental and institutional budgets.

As things stand, a vice-chancellor will spot the subjects that cost more to teach and are relatively less well-funded than others, and will be strongly tempted to close the chemistry department, even though there are well-qualified students ready and able to go there. This happened at Exeter and, for undergraduate studies, at Swansea. An accountant's calculation has cost us dear, depriving us of the next generation of scientists and teachers.

To sum up, we face the task of creating an educational system that respects the differential costs in teaching. My personal experience makes me think we should rely less on a tightly drawn syllabus, and more on the sort of teaching that gave me an understanding of science and its methods, and an appreciation of its relevance to a full and rewarding life. That is what Lennie Bassett taught me. ❐

discussion

Academic and vocational courses. There was a general welcome for the 14 subject specific vocational syllabuses: however, concern was expressed about their slow introduction and there were also doubts about their suitability for those who did not wish – or were not able – to pursue academic courses. There was a wide difference between technicians able to cope with, develop and understand IT systems, and a bricklayer for example. Different types of further education courses, apprenticeships and training needed to be built into the systems, it was argued. Did FE colleges really understand what the different needs were? There were far too few apprenticeships, and the financial incentives to companies to provide them were inadequate – particularly as a trained apprentice was likely to be poached by a rival firm. It was important that FE courses should be designed so that those who had not been successful in academic work, or had failed to find work they liked, could have a second chance.

Has the UK been successful in creating a vibrant biotechnology industry – and what of the future? These issues were discussed at the Foundation's meeting on 8 June 2005.

From science base to market place

Doug Yarrow

Doug Yarrow is director, corporate science group, Biotechnology and Biological Sciences Research Council (BBSRC). He is responsible for programmes in knowledge transfer and innovation, industrial interactions, international relations, public affairs, interaction with stakeholders and policy development. Dr Yarrow was formerly with the Science and Engineering Research Council, where he served as director of biotechnology.

The UK possesses a bioscience research base of international quality. It is important that UK plc benefits from this research base and BBSRC has put in place mechanisms to encourage commercialisation and promote collaboration with industry.

We are making significant investments in important emerging areas such as stem cell research, brain science and e-science; the BBSRC is also investing some £50 million in systems biology over the next three years. In addition, stipends for postgraduate training have been increased: we currently support 2,000 PhD students and many of them go on to use their skills in industry.

BBSRC participates in a number of partnership schemes with industry, including the Link Scheme, the new DTI Collaborative Research and Development Scheme, Industrial Partnership Awards and CASE awards for postgraduate training. We encourage networking between the science base and industry through a number of mechanisms – Faraday Partnerships, Knowledge Transfer Partnerships and a new Industry Interchange Programme.

How can ideas with potential commercial significance be recognised, protected and exploited? We see this process as a ladder up which the concept progresses stage by stage, and where we provide support and assistance at various stages to help reduce barriers to commercialisation. An example of the first stage is the Young Entrepreneurs Scheme, begun 10 years ago. The aim is to increase the commercial awareness of postgraduate and postdoctoral bioscientists. Working in teams of five, they propose a hypothetical business idea and, during the course of a week, with mentors on hand, develop that idea into a business plan. At the end of the week, they have to present that plan, in a 20-minute slot, to a team of venture capitalists who act as judges. The students feel this scheme adds a dimension to their experience that is not part of conventional PhD training.

More recently we became concerned about a gap in funding: although research grants were available on the basis of scientific quality, there was no funding to help demonstrate the commercial potential of scientific work. So, in 2004, we launched the Follow-on Fund, which provides relatively modest sums – up to £60,000 – to enable grant-holders to continue their work, perhaps employing a technician, with a view to demonstrating its commercial potential. This year we are putting £1 million into this fund.

Enterprise Fellowships, run in conjunction with the Royal Society of Edinburgh, allow academic scientists to spend a year exploring the commercial potential of their work. They have mentors and receive business school training.

The Business Plan Competition, launched in 1999, helps scientists to ascertain whether they have an exploitable idea that could form the basis of a spin-out company. Out of over 100 ideas submitted to us in that first year, we selected 16 for detailed mentoring by accountancy and legal firms plus experienced entrepreneurs who helped them develop robust business plans. Our first two competitions, run in conjunction with the Medical Research Council, resulted in 33 teams going through mentoring. A survey conducted just over a year ago found that 10 of them still exist and have raised significant risk capital.

The next stage on the ladder is to obtain seed money. This issue has recently been addressed by the University Challenge initiative, with universities gaining access to seed funding of up to £250,000. In addition, the BBSRC has become a partner in the Rainbow Fund offering seed funding to its institutes. Once seed money has been secured, the next step is to find a base. Biotechnology incubators provide a nurturing environment and many universities have them. The BBSRC runs incubators at Babraham, John Innes and at Roslin. Babraham is one of the most successful biotechnology incubators in the UK, with 20 companies under its wing. Finally, at the top of this ladder we have the Small Business Research Initiative, which to date has awarded 33 contracts totalling £7 million.

There are many examples of BBSRC-funded scientists drawing on one or more of these schemes to speed the transfer of ideas to the marketplace. For example, Tim Hart, a graduate of the Young Entrepreneurs Scheme, moved on to form his own environmental biotechnology company, Cybersense Bio Systems. Tim felt that his participation in the scheme was so important that he has become one of its sponsors. Kevin Stott, who I believe is

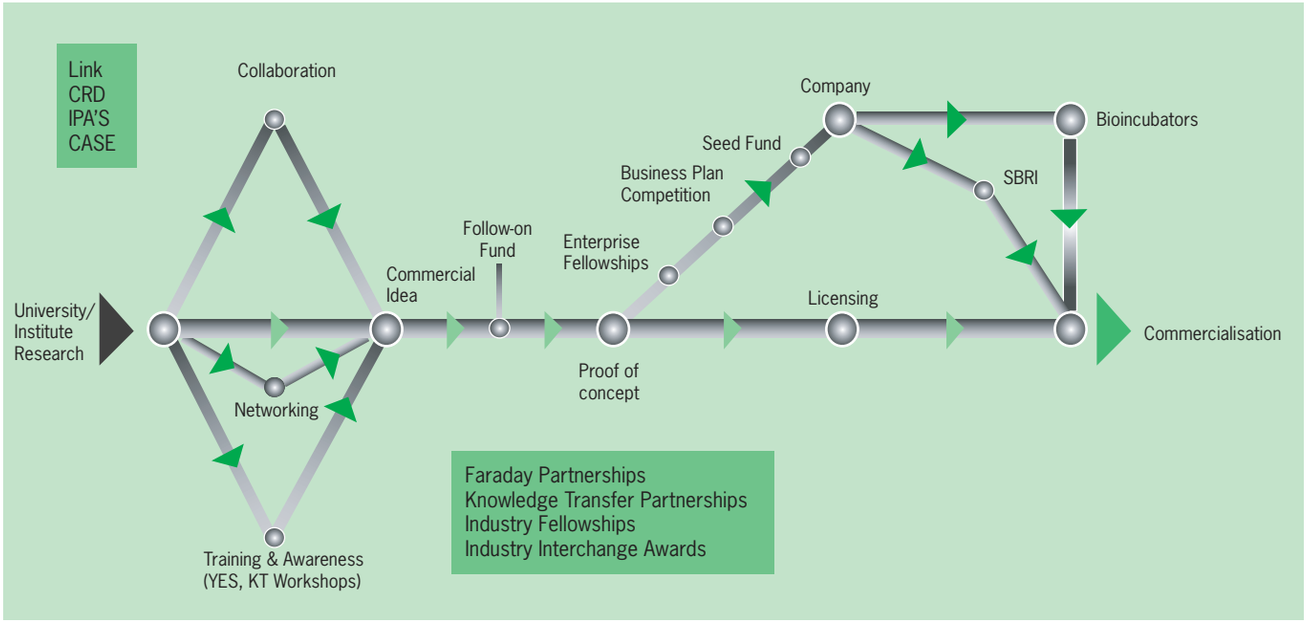


Figure 1. From science base to market place.

in the audience tonight, was at Cambridge when he entered the Young Entrepreneurs scheme with an idea for inhibitors of protein folding. In 2001, he raised risk capital and floated his company, Synexis, now located in the Babraham bioincubator. The next example is Martin Wickham at our Institute of Food Research who, while participating in YES, explored the commercial potential of an *in-vitro* model of human digestion. He gained follow-on funding for that idea and we have recently given him an enterprise fellowship to pursue it further. There are other examples too numerous to cite here.

How well does scientific research address the needs of industry? The BBSRC is developing a technology strategy using a number of criteria to identify relevant areas. The BBSRC BioScience for Industry panel is leading on this and we have established a range of technology priorities.

I will finish by describing progress in implementing two of the technology priorities. Integrative mammalian biology is an area where there is a pressing need for enhanced activity in research and training. With industry, the Medical Research Council (MRC) and the higher education funding councils we have raised over £11 million and are currently soliciting bids to establish three or four research and training centres. In bioprocessing, we have established a club in which 20 companies are providing £1 million towards a £10 million initiative to support high quality research of relevance to industry. We also plan to collaborate with DTI in pursuing other technology priorities.

In the UK, we have an excellent bioscience research base. We are working hard to ensure that we exploit it effectively and that bioscience research addresses the needs of industry – and I think we are getting there. ❐

A view from the City

Martin Wales

Martin Wales is senior analyst, European biotechnology/medical technology, Equity Research at UBS. He is responsible for coverage of biotechnology and medical technology stocks in Europe. Dr Wales has been at UBS since 2000, having previously worked as a healthcare analyst at HSBC and Greig Middleton. Prior to entering the City, he worked in the biotechnology sector at Celltech.

What is biotechnology from a fund manager's perspective? The original US biotechnology industry developed around the idea of biologics, particularly recombinant proteins, and was very successful – some of the biggest biotechnology companies in the world today, such as Genentech and Amgen, are based on that technology. Indeed, if you were to ask a US general fund manager what a biotechnology company is, he or she would probably tell you that it is a profitable, fully integrated protein drug company. By contrast, if you ask this question of their UK counterparts, the cleverer ones might tell you that they are cash-burning development-stage research companies – a somewhat different answer!

There is no defined biotechnology sector in the UK, however. Many companies in the healthcare sector could be described as biotechnology companies. Indeed, most would say that there are around 20 – or, if you include AIM companies, about 32 – such companies in the UK, with a collective market capitalisation in the order of £2 billion. This sounds impressive, until one remembers that the UK healthcare sector represents £125 billion in capitalisation and that is only 10–15% of the overall UK market. Its relatively small size allows UK generalist fund managers to ignore the biotechnology sector; in addition, its companies are hard to understand and the standard valuation approaches – price earnings multiples – are not always applicable.

The first UK biotechnology companies were listed in the early 1990s and the sector has grown in terms of the number of

companies, their market capitalisation and size relative to the market, over the course of the past 13 years. However, its liquidity, by which I mean the number of shares that are traded, is relatively low. One could be pessimistic and see the UK as a mere dot in the world biotechnology sector, but I prefer to be optimistic: given the strength of the research base here, we have the opportunity to become a much more important part of this sector.

We are exceptionally good at discovering and developing technologies; where things tend to break down – or where the market thinks things tend to break down – is in the development process. Fund managers recognise that there are pockets of excellent research in the UK, but the general perception is that the industry has largely failed to develop commercially significant drugs. Within Europe only about one-quarter of the drugs developed by the biotechnology sector in phase III clinical trials reach the market. The only exception to this is the very successful drug *Humira,* developed in the UK and used to treat rheumatoid arthritis.

Timescales are an important factor in the City and there is an obvious disparity between the many years it takes to develop a drug and the relatively short time limits – typically around a year – that we, as sales-side analysts and stockbrokers, must work to.

Disclosure is another problem. The fund management community recognises that biotechnology is a relatively high-risk area in which to invest, but there is a feeling that the information available is more limited than many would like. This problem affects three main areas: clinical trials, discussions with drug regulatory authorities, and licensing and marketing deals.

First, there needs to be as much full disclosure about successful and unsuccessful clinical trials as possible. Although we do recognise that commercial pressures may inhibit disclosure in some cases, many feel that more could be done in this regard. Second, although the content of discussions with drug regulatory authorities is a sensitive area, again, investors feel the need to know what is going on. Financial regulators need to engage drug regulators directly. Third, UK companies are currently under no obligation to disclose details of licensing and marketing deals. Although commercial sensitivity is often given as the reason, details of such deals in the US are freely available on the Securities and Exchange Commission (SEC) website.

These issues all come to bear when we talk of raising money. Drug development is a costly process. I have already mentioned the issue of timescales. Investors are sensible and understand that this is a high-risk sector. They acknowledge that it is a case of 'buyer beware', but this should be on the basis of information disclosure that is as full as possible. They are not convinced – and nor am I – that we are getting that yet. If investors cannot make money from IPOs (initial public offerings), they will not invest and, certainly recently, IPOs have not made money for a lot of people, in particular their investors. On a more positive note, the AIM market (alternative investment market) has proved to be a vehicle for some fundraising.

I will end by raising a few questions rather than drawing any formal conclusions. Given the quality of our research, why have we not been more successful in the UK at clinical drug development and commercialisation? Can the differing time scales of institutions, investors and companies be reconciled? It is hard to expect venture capitalists to take the burden, given that their funds are generally invested for a long period anyway. Is there anything that can be done in terms of some kind of financial incentive, a tax break perhaps, to encourage venture capitalists or even public funding bodies to become more involved? Can we improve information disclosure? I think that we can and we must.

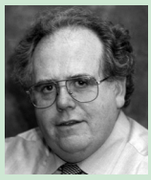
I have not touched on the role of 'big pharmas' in biotechnology in the UK. This may seem odd, given that we have two of the world's largest pharmaceutical companies here in the UK, but investors in this sector look globally and it is up to the UK sector to be competitive. The only other point to make is that, with the exception of vaccines, the UK 'big pharmas' have not been overly successful at developing biologics. I wonder whether this has had an impact on the knowledge base underpinning the development of biotechnology companies in the UK.

Would paying more for drugs to meet real clinical needs benefit the UK sector? In the US, innovative biologics to treat genuine unmet needs are very well priced; perhaps that has been a factor in the success of the US sector.

Finally, I should point out that the UK sector has been very effective at mergers and acquisitions. That may be an area in which we have got it right, both in terms of companies merging and acquiring technologies to re-invent themselves, and also knowing the right time to exit – in some cases to foreign investors. ❑

A glass half full or half empty?

David Chiswell



David Chiswell is chair of the BioIndustry Association. He worked as a research scientist in the UK and the US and at Amersham before co-founding Cambridge Antibody Technology in 1990, and was its chief executive officer from 1996 to 2002. Dr Chiswell also holds positions as chairman of Arrow Therapeutics Ltd and non-executive director at Arakis Ltd.

One of the major political landmarks affecting biotechnology in the past few years was the report of the Bioscience, Innovation and Growth Team[1], which examined the current state of the biotechnology industry in the UK and the barriers preventing it from growing. The report included a 'strapline' to the effect that the UK possesses a good base for a biotechnology industry but that its future growth will depend on the actions we take now.

There are many different areas and subdivisions within the healthcare sector, and the UK has been very successful in some of these. Among service suppliers, Amersham, my old company, has been extremely successful. In Europe, Lonza has done well. In the speciality pharmaceutical world, where companies look for niche markets, Shire has been an international success. In the vital innovation-led field of drug development, however, we have been less successful. That is the sector I want to focus on.

One important difference between these sub-sectors lies in their financing requirements. A company can grow as a service supplier or a speciality pharmaceutical producer without immense amounts of capital. However, the only way to grow as an innovative drug developer is to have access to large amounts of capital – and that is where we are failing.

Market capitalisation of the top 10 profitable biotechnology companies range between $10 and $85 billion (exemplified

by Genentech and Medimmune). These are very substantial companies which on average raised $700m before they became profitable. Nearly all of them were founded in the 1980s. Clearly, this is an industry that needs a long time scale and a large amount of capital.

Although the push in this sector is provided by research, the pull is in the health markets. Who will pay for the products, assuming they are developed effectively? The US spends more money per head on healthcare than we do and I think that will always be the case. They have the world's biggest market and only one regulatory authority. In Europe, we have 26 markets and two regulatory authorities. It is the US health market that drives investment in European companies that are developing drugs; if the American people stopped paying for innovative drugs, the European industry would suffer. Although the European pharmaceutical market is large and there is genuine political desire to invest in research and development in some countries, we labour under regulations that hinder growth. There is no European patent,patient access to drugs is delayed and almost every regulation that comes out of Europe is an obstacle rather than an aid to competitiveness. At least partially as a result, for example, *Herceptin,* a monoclonal antibody used to treat breast cancer, was approved in the US two years before it became available in Europe.

Another factor is investment in R&D by companies. At every level, US biotech companies spend more on R&D than their European counterparts. A two-year-old US company spends almost as much as a European company that is six to 10 years old.

In terms of fundraising, the amount of money raised by European companies in public equity markets is insignificant compared to US firms. Investment stock prices yielded a compound annual growth rate of 10% between 1990 and 2003 in the US; in Europe, there was a compound annual loss of 10%. One of the reasons people do not invest money now in European companies is that these investors have not made enough money in the past.

The US, then, has the biggest health market, a critical mass of established profitable companies, a deep talent pool (particularly in management), generous research funding and the most developed public capital markets in the world. So what can we do here in the UK? The US will always outstrip us in public research funding, but we must continue to exert pressure in this area and ensure that funding is focused on the good centres. European framework funding, which is quite a significant amount of money, is absolutely useless for companies – it is spread so thinly with so many restrictions. At Cambridge Antibody Technology, we stopped applying for it in 1993 because it was not worth our time.

We need to raise the status of science as a career and improve pay for researchers. We must also accept the fact that improvements in health care have to be paid for, whether it is by the Government, the taxpayers or the patients themselves. Indeed, patient involvement may be a key to improving the whole system. The US Food and Drug Administration acknowledges the benefit to patients of more rapid approval in drug regulation. It was forced to adopt this view, at least partly, by the AIDs activists in the 1980s, who in effect said of AZT, "We are the patients. This drug works. We want this drug. Give it to us." We have never had that in Europe. We should be angered by the fact that we are expected to accept second-class citizen status when it comes to access to drugs. We should move rapidly to a single European approval – not 26 or 27 market approvals; just one. And we need a fast-track system for drugs that are going to make a profound difference; not for those that will make minor differences, but the ones that can change the way people are treated.

In the area of corporate development, we need a single market for European stocks; there are not enough specialist fund managers in the UK or any single European country. We could also take action to remove other impediments to fundraising. Inflexible shareholder pre-emption rights is an issue that the BioIndustry Association have been focusing on for the past couple of years, and we are now seeing some progress in this area. Competing with US companies for licensing products or getting the best deals is made much easier when there is a large amount of cash showing on the balance sheet and European investors should acknowledge this.

UK biotechnology can be viewed as a glass that is half full or one that is half empty. I take the first view: the glass is half full, but it will not fill up by itself. We need to create the right environment first. ❐

1. Report available at: **www.dti.gov.uk/bio-igt/bigt-report.html**

Barriers to early growth

Andy Richards

Andy Richards describes himself as a serial biotechnology entrepreneur and business angel. He is a director of Vectura plc, Arakis, Biowisdom, Daniolabs, Theradeas, Cancer Research Technology Ltd and Babraham Bioscience Technologies Ltd. Dr Richards is also a founder member of the Cambridge Angels, a founder investor in Library House, a member of the Council of the University of East Anglia and an adviser to several major venture capital funds.

I am what is called a 'business angel', I start up and invest my own money in early stage ventures and from that vantage point I am able to see at first hand the barriers faced by the biotechnology industry. As the final speaker I will try to cover barriers that the first speakers have not identified. However, I do not want to give you the impression that I am pessimistic about the future of this sector – I am not.

There is one barrier in particular that I would like to discuss: and that relates to the regulatory environment. The entire

discussion

Animal rights activists. Animal rights extremism was identified as an obstacle both to investment and to recruitment in the biological sciences. One participant thought it was a major disincentive to companies considering biotechnology, even as suppliers or customers, because of the personal risk to individuals. Another explained he had been able to reverse the views of pupils at a community school on the issue of animal experimentation in medical research: engaging young people in the debate was important. The debate over GM crops was described as an object lesson in how not to engage the public.

biotechnology industry is built on the twin pillars of the regulation of patents and the regulation of approvals for medical products – these are obstacles that make the business vastly expensive. However, once a company has cleared these two critical obstacles, it has an attractive exclusive period in which to maintain its position.

The barrier in the UK is not the regulations themselves, but the relatively unsophisticated approach to these taken by start-up companies. When I speak with professors or entrepreneurs with ideas for bold start-ups, I find that their science is great, they have been to all the symposia about finance, they have an idea of business plans, and they have consulted their accountants. What they do not have – and it is their biggest weakness – is an understanding of the regulatory requirements for their product, and this contrasts with equivalent activities in the US. This is a further example of an often-stated generalisation that when we start up companies in the UK we tend to back 'science projects' whereas in the US they back 'businesses'.

Drug regulation is not necessarily a barrier to success; it can be a source of opportunity as well. We often see a surge in company fortunes when a relevant regulatory window opens up. This is especially so in the US, where there is a keen awareness of regulatory trends and changes are exploited rather than bemoaned.

As an investor there are many areas that I would not enter because of the regulatory position. Stem cell research is one example. I would not back a stem cell company: this is not because of the science nor regulations governing the science, nor the size of the opportunity, but because of the uncertain regulatory environment for developing and registering a commercial product. Give me uncertain science any day, over an uncertain regulatory environment.

At the moment, the regulatory window has opened for personalised medicine. The breast cancer drug Herceptin, for which patients can be selected, has completely changed the game. Suddenly the regulatory authorities are allowing selection of patient groups. This is a sizeable opportunity that the US biotechnology companies are piling into. Do we have anyone here specialising in that area? No. We need to improve our understanding and use of regulation as driver and opportunity. We have underplayed it and we are not educating our entrepreneurs of its importance.

The next barriers to discusss are those resulting from discontinuities in the financial continuum. The biotechnology industry needs to be able to raise substantial amounts of capital, based on success; when we achieve success, we should then invest further, rather than ducking out by having to license early. The amounts of capital required are very large, so the financing continuum is absolutely critical to the growth of the industry. Two discontinuities in finance that I would like to mention are large-scale IPOs (initial public offerings) and early-stage seed funds. These two are linked – if companies are not being successful with IPOs, then there is obviously higher risk and likely lower return for early-stage seed money since for investors – at some point – there will be a need to make an exit.

Early-stage funding is in particular crisis at the moment – both for companies that are trying to raise traditional venture money and for venture capital companies looking to invest. The 'seed funding tap' may have been turned off for a number of reasons and one of these is the advent of complex preferential share structures. That may sound like something dreadfully technical, but its impact is profound. It arose during the dot.com boom when prices were inflated; people said, "We'll invest in projects on the up-side but we're going to protect the down-side." They brought in complex anti-dilution ratchets and liquidation preferences. These meant that, although they were investing a pound, they expected to get their pound out before anyone else received a share – and not just their pound but often two, three, or even four pounds before the shares in a company were divided up. The result has been that no one knows how much anyone owns and everyone spends their time arguing, not about the size of the overall cake but about what their portion of the cake is. Early-stage venture capital companies and business angels are now saying that they will only invest in companies that are not going to use traditional venture capital financing routes. This is a major problem and one of the reasons everything is going to AIM (alternative investment market), where all the shares are equivalent. Some venture-backed companies have investor bases so poorly aligned that they are paralysed from moving forward.

What is the cure? I am not saying that preferred share structures need to be banned in any way. I do not think we should regulate this; it is important that there is flexibility in financing structures, but I do think it is an issue that needs to be recognised and debated, and that investors need to think about negative impacts before imposing such schemes.

In the area of IPOs, there is a peculiar anomaly that in the US only large companies can issue an IPO, whereas in the UK only small companies can do so. However, I am less sympathetic in regard to this problem. Companies need to set themselves up with options other than IPOs. People need to think much more commercially and become involved in other ways of running their companies, whether organising big joint ventures or setting up trade sales and mergers earlier. We in the UK have not been good at doing that, although recent events suggest this is changing. The crux of the matter is that we have to encourage our companies to change, and that is the final point I wish to make. If you look at successful companies, you will see that all of them have changed. When Amgen initially floated, its important products were chicken growth hormone and indigo for dyeing denim jeans. That company has changed since then! Millennium is another spectacular example of change. It was a genomics company that morphed rapidly into a drug discovery company, then into a cancer development company and finally into a cancer sales company. At each stage, it dropped almost everything it had been doing before.

We tend to take a cynical view of change in the UK. We need to adopt a positive attitude in order to convince the investment industry that change in businesses – whether it is adding new products or altering a company's science base, or moving from a licensing model to an 'own sales model' – is good, not bad. If we do that, we will help companies to evolve and grow and will have a vibrantly successful UK biotechnology sector. ❐

discussion

A new model for biotech? There was criticism of the received model of a biotechnology company that has to survive on its own, relying on venture capital followed by an initial public offering. It was argued that it would be more useful to pursue links between new and established companies. Innovations happen in both large and small companies, and the latter need to start doing deals with the former. One speaker took the view that there is an outdated model in the UK in which biotechnology companies produce tools for the pharmaceutical industry. In the US, biotechnology companies have built businesses by selling their own products.

The threat of a flu pandemic killing millions of people worldwide – and many thousands in the UK – is at the top of the political agenda. The preparedness of this country in the face of this challenge was discussed at the Foundation's meeting on 22 June 2005.

The frontline is in community care

Ilora Finlay

Professor the Baroness Finlay of Llandaff was a member of the House of Lords Science and Technology Select Committee inquiry into fighting infections. She is vice-dean of the School of Medicine at Cardiff University. A professor of palliative medicine, she has worked with Marie Curie Cancer Care since 1987. She established the courses in palliative care at the University of Wales College of Medicine from which 800 senior clinicians worldwide have graduated.

One of the first things to note is that there are lessons to be learned from the past: we have had pandemic flu before. Of course, the virus changes over time but these epidemics always occur rapidly when 'herd immunity' goes down (that is when people are susceptible) and vaccination comes later. However, the diagnosis and treatment – if there is any treatment – takes place out in the community.

In the last century, there was the 1918-19 H1N1 Spanish flu (long before influenza A virus was discovered). Then there was the Asian flu pandemic and the Hong Kong flu, the re-emergence of H1N1, and the last epidemic in 1989. There were 'excess deaths' – almost 30,000 even in 1989. Where were the sufferers cared for? Well, they were mostly looked after in the community with a, relatively, very small number of hospital admissions. So preparedness in the hospital sector might be slightly misguided unless primary care is really geared up.

What are we going to do with this wake up call? What happens when people get flu? Well, whatever the type, you have a temperature, your muscles ache, you have upper respiratory tract symptoms and you feel completely wiped out. That only lasts a few days and happens quite rapidly. Then people go on to get the chest symptoms and ongoing post-flu symptoms.

Just what do people do when they go down with this cluster of symptoms? They go to their GP (perhaps in this day and age, they phone NHS Direct). If they are really worried, they may go to the hospital casualty department. These are the front line places where people will present themselves.

People are in the community. If you are going to give treatment in the community, it should be by people who are used to working in this environment. The key resource here is the NHS and particularly primary care.

How do we actually know what is going on? First of all, you have to confirm that there really is a problem; again, we are back to primary care and surveillance. You have to identify the new virus, usually using PCR (polymerase chain reaction). Now, to get samples from, say, Aberystwyth analysed, they come to Cardiff and you need at least 24 hours. The result would be sent out through the Public Health Instant Response Teams by fax or circular email: this notifies everybody in the team and also goes out to primary care. This cascade mechanism actually works pretty well but the information has to be very clear.

In 1986, a surveillance scheme was started in Wales with a volunteer sample of 30 practices, covering 6 per cent of the population. This involved weekly, paper-based reporting and weekly feedback via a newssheet. It has not changed since then because it works. It is very simple, paper-based reporting, with a secretary phoning the practice manager; it is still not computerised. The reason it works is because there is a personal relationship between the participants. In the House of Lords report on fighting infection[1] we spoke about electronic data but if you lose the human touch, you lose the ability to motivate people to keep on reporting, however boring it is. Due to the week-on-week reporting, although 25 per cent of the population was probably infected in 1989, the effect was spread out, it did not hit everyone at the same time.

Neuraminidase inhibitors may be an effective treatment but they have to be administered in the first 48 hours of contracting flu. A decision has to be taken about who will get them, because we have not got enough for everybody in the country. Then there are issues about whether people should be isolated and how you maintain civil order. We all go to mega-supermarkets where we stand next to each other, so gone are the days of communities being relatively isolated. One also has to think about key personnel such as teachers and health care staff, police and ambulance drivers: how are they supplied with neuraminidase inhibitors?

With regard to community care, we need really clear instructions, through NHS Direct, the GPs and A&E, about who gets the drugs and who does not, where people are to go and what is to be done. Then, when people die, how do we handle the deaths? This, remember, is going to kill people who were not expected to die.

Then there is the next issue, of body storage and cremation. The pandemic will probably happen in the winter, so the weather will be cold. This will make it

easier for body storage but we do need to think about the disposal of bodies as well.

So, basically, we need to get the information out to those in the front line who know what is happening, we need to ensure that primary care knows that targets are suspended in the middle of an epidemic (GPs will stop earning money unless they are told 'abandon your targets, we are now in a flu epidemic') – but I am not sure that that all this is written down anywhere. Hospitals, too, may want to clear beds, allow for staff sickness, readjust their ratios of staff to patients, and so on.

There is also the question of the media, who in this day and age pick things up before we even know about it. Keeping a dialogue going with this group is absolutely crucial.

A pandemic will occur everywhere, it will have to be managed and there will not be a vaccine in the early stages. Key resources need to be mobilised effectively and available treatments need to be distributed. Disruption will occur but, historically, we have not seen wholesale dislocation in such situations. No amount of preventive activity will stop this event happening and I am afraid that the constant questions to ministers, and from ministers, are probably futile. They may in fact result in us taking our eye off the ball. ❐

1 House of Lords (2003) *Fighting Infection*. Available at: **www.publications.parliament.uk/pa/ld200203/ldselect/ldsctech/138/138.pdf**

An incredibly virulent disease

Jeremy Farrar

Jeremy Farrar OBE is director of the Oxford University Centre for Clinical Research Unit in Ho Chi Minh City, Vietnam, a centre funded by the Wellcome Trust. Dr Farrar is a Wellcome Trust senior clinical research fellow and avian flu is one of his particular research interests. He was awarded an OBE in the New Year's Honours List for services to infectious diseases and tropical medicines.

There are a lot of numbers and letters talked about in relation to influenza but there are really three crucial elements – the first is that this is a RNA virus like HIV and the problem with RNA viruses is that they are not very good at going from one generation to the next. Every time they divide they make mistakes, they have a very high mutation frequency and that is very important as they change over time.

The other two most important elements are on the surface of the virus – haemoglutinen and neuro-amides, and these are numbered H1 to H15 and N1 to N9 respectively. That is how we get H5N1. These strains vary from year to year and that is the problem: an H1N1 vaccine will not protect you against an H5N1 virus which is why we have to keep producing new ones each year.

The most frightening previous epidemic was, I think, the 1918 or so-called Spanish flu, although it probably originated in the US. As the virus underwent tiny changes, it re-assorted with other viruses. In 1918, some very minor changes in an avian flu strain changed and became a very virulent human flu: the figure of 20-50 million people dying is probably an under-estimate.

In terms of responding, you also have to appreciate how phenomenally quickly this will happen if it does occur. There is a tremendously rapid rise in excess mortality and then, equally a very rapid fall off: in 1918 the whole outbreak started, went through its peak and stopped within about 3-4 months. That outbreak, which was different to normal flu, killed young, fit, healthy individuals; normally we think of flu as affecting the very young or the very old, but pandemic strains seem, for reasons that are unclear, to affect young, fit, healthy people.

I am going to change tack now and look at Vietnam which represents rural Asia. Asia is home to about 40% of the world's population; Vietnam has a population of about 80 million, China is 1.2 billion, India is about 1.1 billion. Ho Chi Minh City currently has a population of about eight million, but by 2020 it will be 20 million and for Ho Chi Minh City you can read Guangzhou, Beijing, Shanghai, Delhi and all of the other major urban conurbations. The population of humans compared to poultry in these environments is about 1 to 10, so there are about 80 million chickens in Ho Chi Minh City and some 800 million chickens in Vietnam – China is about the same ratio. We live much closer in Vietnam to our chickens than you might do here and this mass urbanisation in Asia, allied to these very close living conditions, makes it no coincidence that, in the recent past, we have seen epidemics caused by Nipah and we have seen SARS and now we have seen H5N1 developing. I think that, as we look forward over the next 20 years, this is going to happen with increasing frequency.

To talk of this as the flu that might cause you to miss a day of work is a misnomer. This is incredibly virulent; patients would go from being able to sit up and eat breakfast at 8 am to being dead by 8pm. I have never actually experienced anything quite so virulent in respiratory infections in my

discussion

Stopping the spread of disease. It was suggested that, in the event of an outbreak, ministers would be under pressure to 'close the UK'. Although some countries had escaped Asian flu in 1957, academic research suggested that anything short of a total ban on international travel would have made little difference. It still seemed likely that just restricting international or even domestic travel in a future outbreak might merely spread the mortality over a longer period without significantly reducing the total number of deaths.

career. I would also say that H5N1 is completely resistant to amantidine, both in petri dishes and also *in vivo*, in patients.

One of the most frightening examples was a young child, admitted to our hospital, with essentially a very mild form of H5N1. He was stable over the first three days and, crucially, was requiring no oxygen. At this point in time, he had what we call a 'wild type' virus, in other words it was sensitive to oseltamivir. By Day 4 of oseltamivir, a resistant mutation had occurred – a single base mutation, that means just the change of a single amino-acid in the protein. The child now had a resistant virus, and associated with this was a rapid progression of the disease: the child tragically died three days later. A small number of children with 'normal human flu' and taking oseltamivir develop resistant mutations and when you expand that to a population, it is at least possible that H5N1 could be resistant to oseltamivir by the time it hit London.

The strategy of stockpiling oseltamivir is, I think, absolutely the right thing to do. However, if we base our whole public health strategy on a drug where the virus can become totally resistant with a single mutation, then we are putting too many eggs in one basket. Many virologists will say that the resistant mutation actually confers a biological disadvantage; in other words, that virus is not very fit and will die out naturally. Yet that seems not to be true for H5N1 which as the above tragic case shows can be both resistant and nasty..

Is this media hype or a real threat? Well, in order to get a pandemic, we need three things; the emergence of an antigenically new virus against which we have no protection– we clearly have that. We need to have transmission of that virus to humans– clearly we have that as the deaths in Asia have shown. Thirdly, we have to have efficient spread of the strain between humans; this is the bit that we are missing at the moment. There have been no cases of efficient transmission of the virus between humans and clearly the virus would need to acquire or develop that ability for a pandemic to occur. I would like to mention pigs, though; pigs carry the receptor for both avian flu and human flu and are a perfect factory for making a recombinant virus. Of course in many parts of the world pigs and poultry live very closely together.

Some 150,000 people get on an aeroplane every day in Asia and fly to Europe or North America. Unlike SARS, in the early stages of flu when you are at your most infectious and your viral load is highest, you are asymptomatic; this means that screening at airports for high temperatures will not turn away your most infectious individuals.

We desperately need new diagnostics, we desperately need clinical studies to understand this disease from an epidemiology perspective and learn how to treat it, we desperately need new drugs and we need to understand how to use the current drugs better. We need to know what might happen if you gave these drugs to everybody to prevent disease (this may well happen as a panic measure) and we need to understand what may happen to the virus when we undertake a mass vaccination programme in poultry. Then, we need to put in place long-term research strategies so that, 20 years from now, we actually have an influenza vaccine that covers all strains and removes this as a global threat.

Are we better prepared in 2005 compared to 1918? I suspect not: we rely on a drug to which a single mutation can confer complete resistance; we do not have a vaccine that can be produced in anything like enough doses quickly enough; and we still rely on a remarkably inefficient process for making a vaccine which requires development of the vaccine in eggs – this is something out of the Dark Ages. We also have the much greater movement of people around the world, and the development of huge urban conurbations particularly in Asia which serve as the perfect environment for the virus to adapt and develop the ability to pass between human beings. ❐

The vital importance of communication

David Harper

David Harper CBE is director of health protection, international health and scientific development at the Department of Health. Dr Harper is also the Department's chief scientist. While head of the Department's environmental hazard's branch, he was responsible for issues such as radiation, toxicology and air pollution as well as, since the 9/11 attack, emergency preparedness.

We need to be very clear about what a pandemic of influenza may mean. People say to me "well, seasonal flu, we deal with it all of the time" and pandemic influenza is sometimes, incorrectly, compared. Pandemic influenza is likely to be a very different type of disease: past pandemics tell us that we should expect more severe disease, with greater mortality, including in population groups that we would not normally expect to be hard hit by seasonal flu. We might expect a future pandemic to follow the same pattern and we need to keep these differences in mind.

The current avian influenza situation in South East Asia is focussing attention on the possibility of a potentially pandemic virus emerging from this source, and the UK is continuing to set up its preparedness planning. On 1 March this year, the UK Health Department launched an extensively revised pandemic influenza contingency plan. Part of our preparedness involves communicating what we are doing.

Our first pandemic plan was published in the late '90s. The revision updates what we know about pandemic influenza and measures for its control, sets out our plans and at the same time provides a source document of current information. A pandemic will of course, by definition, have global impact.

The UN organisation with responsibility in this area is the World Health Organisation and we are working closely with them and with the EU. We are also working internationally in a group called the Global Health Security Action Group; this was set up by the Health Secretaries of the G7 countries, plus Mexico, very shortly after 11 September 2001 to look primarily at threats from terrorism, particularly using biological, chemical and radioactive weapons. This works well and is quite unique, in my experience, as it is directly responsible to ministers, it has a mandate from ministers, and it delivers. The group became involved with SARS in 2003, and, is now looking at pandemic influenza. The UK is co-chairing the influenza initiative with the United States (supported by Canada and the other countries). The WHO are involved in the Group and so is the European Commission.

The UK Influenza Pandemic Contingency Plan sets out responses for internationally agreed escalating states of

Pandemic influenza. Five alert levels	
0	No cases anywhere in the world
1	Cases only outside the UK
2	New virus isolated in the UK
3	Outbreak(s) in the UK
4	Widespread activity across the UK

Levels of Alert in the UK Influenza Pandemic Contingency Plan

pandemic alert. At the moment, we are at the earliest pre-pandemic alert level, with cases of a new influenza virus (H5N1) only outside the UK, and with no sustained person-to-person spread.

Crucially, the UK Plan identifies who does what: clarity of roles is key to management of any crisis. The Plan, together with separate operational guidance specifically for health service planners, is designed to help organisations develop their own operational plans.

Our plan needs to be a dynamic, living document to be of greatest use and we fully intend to update it regularly to take account of scientific and other developments, and the feedback we get.

Given the many unknowns, for planning purposes, we have made a number of basic assumptions, for example on attack and transmission rates. We have the benefit of a great deal of independent expertise in this area in the UK, particularly in the field of mathematical modelling.

Experts indicate that at Week 3 following a pandemic taking hold in the UK, we would expect a very low number of deaths (0-50, across the whole of the UK). By Week 6, this is starting to increase. At Week 9, numbers are much higher, particularly around the population centres. And then, by Week 12, the pandemic is subsiding.

Modelling is also being used to assess the likely impact of reducing population movements globally and within the UK. Experts estimate that restricting movement from South East Asia to the UK and other countries would have little impact: it might buy us a short amount of time, but the total number of cases will essentially be the same and whilst we are delaying it, we are also prolonging the pandemic.

Other speakers have stressed the need for strong surveillance and alert mechanisms – it is absolutely vital we do what we can to build capacity within South East Asia in the context of avian flu. As regards countermeasures for pandemic influenza, our ideal would be to have a vaccine against the pandemic virus in time to protect the UK population. However, we do not yet have a pandemic virus. The virus in SE Asia is still a bird virus: it is infecting humans, it is highly virulent and has a very high mortality but, at the moment, it has not changed to spread from person-to-person.

We might expect, although we cannot be absolutely sure, that a virus with greater affinity for humans would carry a lower mortality.

In the meantime, antiviral drugs are an important part of our defence. The UK is one of the countries which has decided to stockpile significant quantities of the neuraminidase inhibitor, oseltamivir, against the contingency of an influenza pandemic. We have a small amount at the moment: something of the order of 100,000 treatment courses.

The good news is that ministers agreed, some while ago, to commit a substantial amount of money to buying enough oseltamivir to treat 25% of the UK population; 14.6 million treatment courses will be delivered over the next two years, starting from August. We hope to take receipt of the whole order within 18 months.

There are still uncertainties we have to address: these drugs have not previously been available in the pandemic situation and we do not know for sure how effective they will be – but the best advice we have at the moment is that they are likely to help, particularly in the time before we have a pandemic vaccine.

The challenges are, I think, fairly self-evident. We need to deal with potentially very large numbers of ill people, and probably large numbers of dead, and all the consequences of this.

Some of the messages will be complex and difficult. Good communications at all stages – with health professionals, with the public and with the media – will be key to our ultimate success. ❐

Addressing all contingencies

Bruce Mann

Bruce Mann is head of the Civil Contingencies Secretariat at the Cabinet Office. He has previously been Director of Defence Policy at the Ministry of Defence and was also Director of Defence Resources and Plans at the MoD. He was seconded to NATO headquarters during the Kosovo crisis and he was Secretary to the Butler Committee which investigated the intelligence advice given to the Government before the Iraq war.

I am going to cover what we are doing in Whitehall and beyond – but not the health sector which has already been addressed – to build preparedness for a flu pandemic were it to occur. First, though, a word about the Civil Contingencies Secretariat. This body is concerned with protecting people, their health, their safety, their economic well-being. If we are going to do that, much of the work will have to be delivered at regional and local level. I bring out those two points because they drive everything that we do.

We try to identify threats before they emerge and assess the risk (risk for us is defined as the combination of probability and impact). We pursue response plans for those risks that seem imminent and make sure that we have got the capability to deal with them. We test, test and test again and make sure there are sufficient staff who are trained to know what they are going to be doing.

In terms of the science that underpins what we do, we track about 100 risks in total on a rolling basis, potential events that would have a large scale, national level, disruptive effect were they to happen. A flu pandemic is clearly one but we cover everything from natural disasters through terrorism all the way to industrial action.

We identify a risk and then attempt to model the response to that risk should it occur. We ask what the police service would need, what the health sector would need, and what other agencies and bodies involved would need in effectively responding to the situation. On the basis of this assessment, we define relatively

simple capability requirements, whether this involves training people, buying equipment and so on.

The questions we ask ourselves each time we are confronting a risk are how are we going to manage this at central government level, in the regions, at the local level, and what do we need to do to keep the essential services running. And then we have to consider what functional capabilities are needed in terms of the effects of disease, mass casualties, mass fatalities, informing the public and so on.

In the context of a potential flu pandemic, we are being as open and honest as we can be on what it is that we think the UK is facing. The influenza pandemic plan on the Department of Health website has a great deal of information; this is probably the first time, certainly in my memory, that the Government has said, in advance, "This is what might emerge, this is what the response would look like and, indeed, this is where we couldn't respond. For example, vaccines wouldn't be available, we would have to deal with the disease in some other way."

There are certain central planning assumptions we have made: a 25 per cent clinical attack rate, and a 0.37 per cent case fatality rate which leads to the headline statistic of around 50,000 dead which the media has picked up on. However, because we do not know what is going to hit us, the number of deaths could be anywhere between 20,000 and 700,000. We have a central assumption against which we are building our plans but we are also adding the ability to scale up, and given the best case, to scale down.

Every year we assess the top risks that we think this country faces, and flu is now the top risk out of those we track, taking account of both probability and impact. We are not saying that it is going to emerge but we are treating it as if it will. That is a prudent precaution.

We have a number of non-medical work streams – these, in simple terms, are what other Government departments, the regional tier, devolved administrations and local authorities are increasingly engaged in. The key points on each are:

discussion

Central and local. Concern was expressed over a perceived 'gulf' between the central planning and modelling process on the one hand and the clinicians in primary care and other local people who would carry the main burden in any outbreak. The leaflets that were supposed to have gone to GPs did not seem to have arrived. In response it was said that the Government had already carried out four regional exercises and that this was the first time it had published so much information in advance of an emergency. It was also said that the UK had done lot behind the scenes but not all of this had been made public 'for fear of raising the temperature in the media'.

Gathering information

This is the process of gathering data, getting it verified for quality, and then sent to the HPA and Department of Health. The scientists and the modellers work on that data and say 'on the basis of these findings, we think this is what is going to happen'. From this work, recommendations can be made in terms of social interventions. These recommendations then go to Ministers, who make the final decisions.

Social interventions

Early guidance has been sent to the regional tier and to local authorities on what they should plan for. That does not mean to say that ministers will definitely cancel football matches or shut schools, but we have got to be ready, as a country, to take those actions if they become necessary. We are about to set up, with the people doing the detailed planning, a 'feedback group', which asks "have you hit any difficulties, are there things that you need better and clearer guidance from us on, are there policy issues that you want us to sort out to help you to do your local planning?"

Business continuity

We are dealing with two issues here: one is continuity for the general business community; the second is concerned with keeping the country running – power, water, food and so on.

Mass fatalities

As I said earlier, we are working to a central assumption of around 50,000 dead, on a scaleable basis.

Overseas – while we are tonight focusing principally on the UK, there may be British citizens overseas who become ill or die; there are specific groups to be considered as well like the armed forces, diplomats, and so on.

Communications

This is fundamental in two senses. First of all, we need to ensure the British public are given advice on how they might protect themselves. Secondly, we have to explain what is happening and the Government's response.

Crisis management

This would be run from COBR, the Cabinet Office Briefing Rooms. As this would be a country wide pandemic, we would operate through regional organisations to reach local services. It is, in fact, a devolved matter, and the devolved administrations would manage within their own competences but overall management would be from Whitehall.

Exercises, testing and assurance

We are carrying out exercises, both in terms of data flow and in terms of the response, at regional and national level and, increasingly, at international level, including across the European Union.

What I have described is a rational, Whitehall, process, but if there is one thing that concerns me, it is to what degree we are going to see irrationality in media reporting, in public reactions and so on. However rational we try to be inside Whitehall, we will have to take a degree of irrationality into account in our planning. ❐

discussion

Informing the public. Different views were offered on the merits of public communication. One speaker recalled that when SARS had hit the headlines, the relevant websites had been swamped and she had seen people fighting in a supermarket as they stocked up on food. In contrast, the recent interruption of diamorphine supplies had not been publicly broadcast; clinicians had been briefed on what to do while the public did not realise how low stocks were. It was suggested that the key issue was to get information to the people who needed it and communications should not be allowed to interfere with other control activities. Against this it was argued that most people would get information from the internet where information was not limited in any way.

Sir Hermann Bondi, cosmologist, relativist and public servant, died at Cambridge on 10 September at the age of 85. He was born in Vienna in 1919 and educated (as a mathematician) at Cambridge. In recent years he struggled cheerfully with the parkinsonism that afflicted him.

Sir Hermann Bondi
1919 – 2005

Bondi's experience of life in Britain began with a spell in a prison camp, in which he was interned as an enemy alien at the outbreak of the Second World War. There he met fellow-Viennese Thomas Gold, both of whom were eventually returned to Britain from a camp in Canada in the belief that their skills could contribute to the war effort. In the event, they were assigned to a radar research unit whose director was none other than Fred (later 'Sir Fred') Hoyle, another Cambridge mathematician.

Hoyle has related in his autobiography (*Home is where the wind blows*, 1996) how the result of this haphazard encounter was a kind of perpetual seminar, conducted most evenings and dealing not only with the problems of radar but also peacetime topics, astrophysics for example. To its credit, the small group did develop a practical way of telling the altitude as well as the range of unknown aircraft from a single radar echo.

When all three returned to Cambridge – Gold had to be shoe-horned in – they embarked on radical innovation. Bondi and Gold worked up their idea of the steady-state theory of the universe – infinite in space and time, but expanding while at constant density. Hoyle independently worked out the conditions that should be met by a physical mechanism for creating matter continuously (so as to keep the density constant). Famously, the theories engendered great controversy in 1957, when Cambridge radioastronomers (led by Sir Martin Ryle) claimed experimental disproof. Hoyle never acknowledged defeat, but Bondi seems to have been persuaded by the discovery of the microwave background radiation within the decade.

Bondi had other fish to fry. He became one of the small band of people equipped by their knowledge of general relativity and their skill at mathematics to make meaningful speculations about extreme gravitational circumstances – black holes, for example. By then (in 1957), Bondi had been appointed to the chair of mathematics at King's College, London.

His public service dates from the 1960s when, after acting as chairman of a series of public enquiries including the proposal to build a barrage across the Severn estuary (which the Bondi enquiry favoured), he became director-general of the European Space Research Organisation, based in Paris. This was followed by his appointment as chief scientific adviser to the Ministry of Defence in 1971. At this time he used his growing influence to push forward several good causes – science education in British schools in particular.

On the face of things, Bondi cannot have seemed a natural scientific recruit to the corridors of power – he was notoriously independent and sharp-tongued as well. Yet he seemed to thrive on these activities on the grounds that he was able to 'get things done'.

Even so, after two decades in the public service, Bondi returned to academic life, first as chief executive of the Natural Environment Research Council (1980) and then as Master of Churchill College, Cambridge (1983-90).

Public service never made him into an orthodox creature. In that spirit, he was an active member of the Pugwash organisation. He was also irreligious and served as president of the British Humanist Society for more than a decade in the 1980s.

John Maddox

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25 October 2005

Carbon Abatement Technology for Power Generation

Malcolm Wicks MP, Minister of State for Energy, Department of Trade and Industry
Nick Otter OBE, Director, Technology and External Affairs, ALSTOM Power
Dr Kjell Bendiksen, President, Institute for Energy Technology (IFE) Group, Norway
E.ON UK (Power Technology), European Carbon Exchange and Nuclear Industry Association

19 October 2005

The Lord Lloyd of Kilgerran Award Lecture

Dr Helen Lee, Reader in Medical Biotechnology and Director of Diagnostics Unit, Department of Haematology, University of Cambridge

12 July 2005

Strengthening International R&D Partnerships – is there a case for increased US/UK collaboration?

Sir Gareth Roberts FRS FREng, President, Wolfson College, Oxford
Professor Charles Vest, Former President, MIT
Sir Robin Saxby, Chairman, ARM
BAE Systems, CCLRC, PPARC, EPSRC, CMI and QinetiQ

22 June 2005

Is the UK well-prepared for an influenza epidemic?

Professor the Baroness Finlay of Llandaff
Dr Jeremy Farrar OBE, The Wellcome Trust Clinical Research Unit, Centre for Tropical Diseases, Vietnam
Dr David Harper CBE, Director of Health Protection, Department of Health
Bruce Mann, Head, Civil Contingencies Secretariat, Cabinet Office
The Wellcome Trust and the Health Protection Agency

8 June 2005

The future prospects for the biotechnology industry in the UK

Dr Doug Yarrow, Director, Corporate Science Group, Biotechnology and Biological Sciences Research Council
Dr Martin Wales, Senior Analyst, European Biotechnology/Medical Technology, Equity Research, UBS
Dr David Chiswell, Chair, BioIndustry Association (BIA)
Dr Andy Richards, Serial Biotechnology Entrepreneur and Business Angel
Association of British Pharmaceutical Industries (ABPI) and South East England Development Agency (SEEDA)

events

25 May 2005

The Education of 14-19 Year Olds

Pauline Cox, Head, Tiffin Girls' School, Kingston
Lord May of Oxford, President, The Royal Society
Julie Bramman, Head of Curriculum, Specialism and Collaboration, Department for Education and Skills

Biotechnology and Biological Sciences Research Council and The Comino Foundation

11 May 2005

Science Policy and Management

Sir Keith O'Nions FRS, DGRC, OST
Sir David Wallace CBE FRS, Vice-Chancellor, Loughborough University
Dr Mark Walport, Director, The Wellcome Trust

BAE SYSTEMS, The Council for the Central Laboratory of the Research Councils and The Natural Environment Research Council

27 April 2005

Can the UK get on, and stay on, a path to a sustainable economy?

Jonathon Porritt, Chairman, Sustainable Development Commission
Anna Coote, King's Fund
Dr Bernie Bulkin, former Chief Scientist, BP
Professor Howard Dalton FRS, Chief Scientist, Defra

Department for Environment, Food and Rural Affairs and The Natural Environment Research Council

23 March 2005

The UK Productivity Gap

Professor Vicky Pryce, Chief Economic Adviser and Director General, Economics, DTI
Professor Jonathan Haskel, Queen Mary, University of London
Professor John Van Reenen, Centre for Economic Performance, London School of Economics

The Gatsby Foundation and The Royal Commission for the Exhibition of 1851

9 March 2005

Transport Policy - How should road congestion be managed?

Graham Pendlebury, Director Road and Vehicle Safety and Standards Directorate, Department for Transport
Dr Archie Robertson CBE, Chief Executive, Highways Agency
Professor David Rhind CBE FRS FBA, Vice-Chancellor, City University
Professor Anthony May OBE, Chairman, Inquiry into Transport and Emeritus Professor, Institute for Transport Studies, University of Leeds, Royal Academy of Engineering

Department for Transport and Lloyd's Register

23 February 2005

Identity Management

Des Browne MP (represented by Katherine Courtney), Minister of State for Citizenship and Immigration, Home Office
Ian Watmore, UK Government CIO and Head, e-Government Unit, Cabinet Office
Ed Mayo, Chief Executive, National Consumer Council

Sharp Laboratories of Europe and QinetiQ

1 February 2005

Visit to Ford Dagenham Diesel Centre

Mr Roger Putnam, Director, Ford
Jacqui Smith MP, Minister of State for Industry and the Regions , DTI

1 December 2004

Science and the City

Paul Myners, Chairman, M&S
Stephen Timms MP, Financial Secretary, HM Treasury
Dr Peter Goodfellow FRS FMedSci, Senior Vice President , Discovery Research, GlaxoSmithKline

ARM, Comino Foundation, GlaxoSmithKline (GSK) and HEFCE

23 November 2004

Strategic Subjects in Higher Education

Sir Howard Newby CBE, Chief Executive, Higher Education Funding Council for England
Pam Alexander, Chief Executive, South East England Development Agency
Tom Swan OBE, Chairman, Thomas Swan & Co Ltd

Engineering and Physical Sciences Research Council (EPSRC), Royal Society of Chemistry (RSC) and South East England Development Agency (SEEDA)

10 November 2004

Science Communication - are we making progress?

Professor Colin Blakemore FRS FMedSci, Chief Executive, Medical Research Council
Professor Kathy Sykes, Collier Chair: Public Engagement in Science and Engineering, University of Bristol
Fiona Fox, Head, Science Media Centre, Royal Institution of Great Britain

Defra, Pfizer and The Wellcome Trust

28 October 2004

Energy Policy — Security of Supply

The Lord Sutherland of Houndwood KT PRSE FBA, President, Royal Society of Edinburgh
Peter Mather, Director UK and Europe, BP
Kieron McFadyen, Technical Director (Europe), Shell Exploration and Production

Scottish Enterprise, The IEE and the Institute of Physics

26 October 2004

The Lord Lloyd of Kilgerran Award Lecture

Dr Richard Durbin FRS, Head of Informatics Department and Deputy Director, The Wellcome Trust Sanger Institute

20 October 2004

Public Health — imposing choice?

Derek Wanless, Inquiry Chairman, Securing Good Health for the Whole Population
Melanie Johnson MP, Parliamentary Under-Secretary, Department of Health
Lucy Neville-Rolfe, Company Secretary, Tesco
Professor Siân Griffiths, Senior Clinical Lecturer, Department Public Health and Primary Care, Oxford University

Gatsby Charitable Foundation and the Kohn Foundation

12 October 2004

Risk Perception and Public Policy

Sir John Krebs FRS, Chairman, Food Standards Agency
Professor Ian Diamond, Chief Executive, Economic and Social Research Council
Professor Nick Pidgeon, University of East Anglia

Defra, Fishmongers' Company and Pitchell Consulting

20 July 2004

Science & innovation investment framework 2004–2014

John Kingman, Director, Enterprise and Growth Unit, HM Treasury
Sir Keith O'Nions FRS, Director General Research Councils, Office of Science and Technology, DTI
Andrew Barker, Head of European Equity Strategy & Managing Director, UBS

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