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Edited by James Kingsland

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INTRODUCTION: SCIENTISTS AND POLITICIANS UNITED

Dr Ian Gibson MP

If, as the saying goes, "opposites attract", then science and politics should make comfortable bedfellows. This, we know, is not the case.

The fundamental problem we face is that the two groups often operate in isolation, have different objectives, use different terminology and do not have access to an effective forum that can bring them together on neutral ground. Despite the numerous worthwhile attempts to enhance cooperation, and various efforts by those working in each of the two fields to comprehend the behaviour of the other, mutual misunderstandings persist.

Politicians work in an environment that is characterised by important but constantly shifting agendas, and scientists often see them as self-interested and shadowy creatures. Scientists, meanwhile, see themselves as geniuses working for the advancement of our species and the world we live in, but are seen by others as remote and even arrogant when it comes to explaining their research, and unwilling to mix professionally with other groups in society – especially politicians.

Perhaps the most significant obstacle in the path of this union has been the way in which science is communicated. It is a sad truth that I am one of the few trained scientists actively participating in a political world that understands little of my previous profession. Many of my political colleagues are still struggling to come to terms with the fundamental role that science must play in the policy process. We cannot realistically expect politicians with backgrounds rooted in all walks of life, including the law courts, public relations and local politics, to grasp with ease the complex and painstaking science behind, for example, new cancer treatments such as the much-vaunted drug Herceptin. Nevertheless, they have the power to formulate the framework in which such discoveries operate, and so need at least to gain an appreciation for what science can achieve and its importance to society. At the same time, my old colleagues in the scientific community need to find ways in which to share their findings with the wider world outside their laboratories and research institutions, so that society can reap the benefits of their work.

Both sides need some sort of entry point to gain an understanding of the other – an entry point that on the one hand would give politicians a handle on a subject that is surrounded by the almost impenetrable jungle of scientific terminology, and on the other would demonstrate to scientists the importance of politics to the country's future direction and our everyday lives. Establishing a clearer and more precise mode of discussion between the two constituencies will be critical to improving cooperation between science and the political process.

The UK government has made some progress to this end. In fact, for all its oft-quoted incompetence in understanding or recognising the value of science, it may come as a surprise to some that the government has an immense network of scientific advisory systems. The Chief Scientific Adviser, our most influential scientist, has more than 80 staff working at the Office of Science and Innovation based at the Department of Trade and Industry. His role allows him regular access to the Prime Minister, and this has introduced a scientific perspective into the government's agenda. In addition, there are chief scientific advisers in more than half of government departments. All this is a sign of the government's willingness to encourage UK science. However, by introducing this institutionalised framework, has the communication problem between science and politics really been solved?

In Parliament, we find the science and technology committees of the two Houses and the Parliamentary Office of Science and Technology, which has the role of keeping Parliamentarians up-to-date with science and technology issues. In addition there are a number of all-party parliamentary groups that focus on science in one way or another, and the Parliamentary and Scientific Committee brings together those who are interested to explore various scientific issues. But to what extent do Parliamentarians take advantage of the opportunities that these groups offer?

Advisory measures alone have not made the government and Parliamentarians understand and appreciate the value that science can bring to so many important policy areas. This is as much the fault of scientists as politicians. For too long, scientists have viewed themselves as deserving support from the public purse but as passive players in the political world. They present their findings and feel antagonised when they are misrepresented or poorly understood. Mechanisms need to be put in place to make scientists more willing to advise those who develop policy, those who decide which policies to adopt, and finally those who implement new legislation.

To compound this problem, scientific breakthroughs are increasingly overshadowed by public misunderstanding. For instance, advances in fertility treatment are greeted with wonder by the scientific community, but aversion among those members of the public who place social, cultural and religious concerns above all else. We can perhaps understand their unease when scientists appear to spend so much time thinking about what they could do next without stopping to think about the possible implications of their work. For too many members of the public, such an approach seems irresponsible.

It is this communication breakdown that underlies the rift between the two constituencies, and the situation needs to be addressed urgently. The success of such an enterprise rests on a firm commitment from the government to support science at all levels rather than just to provide an institutionalised framework. It must encourage scientists to engage with and provide their expertise to the policy-making process.

Science in the UK faces another fundamental challenge.

> Despite increased investment from the government, this country remains an expensive place to carry out research and development, particularly when compared with the emerging giants of China and India.

While the Foreign Office and the British Council have spent millions developing public diplomacy campaigns and encouraging collaboration with these and other developing economies, when it comes to securing scientific collaborations, funds to back up the rhetoric have been absent.

As the authors of one our essays point out, the research councils responsible for the distribution of funding are far too conservative in their approach (see page 17). Research grants are awarded not to the most deserving and innovative projects, but instead to work that keeps the Treasury happy and follows hot political issues, or that fits with universities' Research Assessment Exercise objectives. Though there is no doubt that research into AIDS, avian influenza and SARS is worthwhile, directing large quantities of our resources into these areas comes at the expense of other vital and innovative work.

These arguments are, of course, reliant upon one crucial factor that is so frequently overlooked by politicians: long-term sustainability. In order to maintain our standing as a global research base, increase the overall appreciation of science in society and ensure policy makers attach greater credence to it, we must encourage a long-term approach to addressing these issues.

This must begin at the most basic level of education in our schools. Children should be taught the value and potential of science, and experience the excitement of new discoveries. Today's schoolchildren need to understand that everything from the MP3 player in their pocket to the deodorant they spray after PE lessons are the products of scientists rather than high-street electrical shops or supermarkets. The sad truth is that many children would rather pursue a career in marketing these goods than creating them. It is all too tempting to think of new cars, cosmetics or foods as being the products of advertising agencies, forgetting that it is engineers, chemists and nutrition experts who created them in the first place. Of course, science is about so much more than commercial products and new technology. At its core is the pursuit of a better understanding of ourselves and our environment. It is through such knowledge that we can tackle disease and protect the environment.

We must spread the word in schools about the rewarding and challenging jobs that can follow a science-based education, and put more effort into debunking the myth that science is a tedious chore. The city of Beijing alone produces more science graduates than the entire UK. Until this fundamental change occurs in our school system, we will continue to foster the perception that science is too challenging to be understood by the mainstream in society, and our status as a leader on the global research stage will be eroded even further. It is our responsibility as scientists and policy makers to ensure this does not happen. Equally importantly, professional scientists need to be supported through increased funding and improved career structures to enable them to stay at the forefront of their fields globally.

I am not so naive as to believe that the establishment of a think tank like Newton's Apple will bring about a scientific revolution in the corridors of power, or that legions of scientists at research establishments across these isles will suddenly find themselves actively engaged in the political process.

But my hope is that Newton's Apple will foster a better understanding of the benefits that scientists bring to the rest of society, and politicians' role in creating a fiscal and regulatory framework in which their activities can flourish.

Scientists and politicians need each other.

The bottom-up approach has long been out of favour when determining science policy – that is precisely why we are making it a central tenet of Newton's Apple. Our ideas will not only come from familiar faces in this debate, but also from professionals of all ages who understand, value and inspire the scientific advances that are the bedrock of the UK's future health and wealth. Furthermore, as a neutral forum, we hope to attract all stakeholders to debate, develop new ideas and identify common solutions.

Our launch publication, A Scientific Vision for the 21st Century, contains essays by eminent authors, some with experience of the policy-making process and others with a background of working at the coalface of science. They paint a stark picture of the problems we face, but offer remedies to deal with them. A positive theme throughout is their admiration and appreciation of science and all those involved in its advancement.

Our supporters, from the first meeting in January this year, have been magnificently critical and responsive to our needs. Our sponsors have provided us with much-needed donations to kick-start the project. And our staff has gone to great lengths to get us to this point. Without their help, support and guidance this venture would never have come to fruition, and for that I am truly grateful.

Newton's Apple is an exciting initiative with many opportunities for development – this publication marks only the beginning of a whole series of projects. From such small seeds mighty apple trees grow.

Sir Richard Sykes is Rector of Imperial College London and former Chairman of GlaxoSmithKline. He is chairman of the UK Stem Cell Foundation, on the Board of Rio Tinto plc, and the Singapore Biomedical Sciences International Advisory Council.

A WORLD-CLASS SCIENCE BASE: EMULATING UNCLE SAM

Sir Richard Sykes

Asked to give some tips on achieving a world-class science base in the UK, the obvious response is that we already have one. The more pressing challenge is how to stay in the premier league.

My own view on why that matters is not new or original. I believe that science essentially puts us on a course to a brighter future and that economic development or competitive advantage follows investment in science. This has been understood since the 19th century. Former MP and a professor at one of the forerunners to Imperial College, Lyon Playfair, recognised it in 1852 when he wrote: "It is indispensable for this country to have a scientific education in connexion with manufacturers, if we wish to outstrip the intellectual competition which now, happily for the world, prevail in all departments of industry. As surely as darkness follows the setting of the sun, so surely will England recede as a manufacturing nation, unless her industrial population become much more conversant with science than they are now."

More recently, the Nobel Laureate Robert Solow of the Massachusetts Institute of Technology put a figure to that line of argument. He estimated that 50 per cent of the economic growth in the US since the Second World War could be attributed directly to technology.

To get a measure of the challenges facing the UK's science base we must consider what is pitted against us, and it is clear that our principal competition is the US. In February this year, President George Bush used his State of the Union address to advance an impressive scientific agenda. His administration is looking to double federal funding for basic research, spending an additional $50 billion over 10 years in direct response to the economic threat from China and India.

The majority of the additional funding will go to the physical sciences, while the biomedical sciences will just about hold steady. Another $86 billion will be available in R&D tax credits. The US also intends to recruit some 100,000 additional science teachers and assistants for its schools.

These measures appear to have a large degree of bipartisan political and industrial support, and in part respond to a 2005 National Academy of Sciences report that foretold a bleak future for the US if it does not address the basics of science and engineering.

John Marburger, the President's science adviser, described the thinking behind the initiatives when speaking to the American Association for the Advancement of Science in April. He said that the principles are, first, that funding long-term, high-risk research is a federal responsibility; second, that areas of science most likely to contribute to long-term economic competitiveness should receive priority; and third, that current levels of funding for research in the physical sciences are too low in many agencies.

How should we respond to this show of force? I see a number of areas requiring attention.

We too must recognise the importance of funding basic research, which is our fundamental contribution as scientists.

The UK should also encourage approaches that span the disciplines, helping to bring a 'critical mass' of researchers together.

This is vital because these days physicists and chemists are just as important as molecular biologists on the front line of cancer research, for example.

We should also recognise that what is known as applied research relies heavily on basic science input. Consider the development of the jet engine, which relied on fundamental materials science research. That basic work was pushed forward because there was an application – a superior fighter aircraft – waiting for it.

In fairness, the current government has done a great deal to prioritise UK science. Research universities in this country have benefited from a far greater emphasis on science and technology spending in the past five years. However, a world-class science base does not mean simply better-tended universities. It must embrace the whole ecosystem.

The role of industry in exploiting universities' intellectual property is vital, and it is a mutually beneficial relationship. Businesses need research to make money and universities need money to do research. Businesses simply cannot build the kind of in-house R&D arm that a major research university has, especially where multidisciplinary work is being carried out. The great universities are the only institutions where world authorities in all relevant disciplines can come together and flourish.

Though I have not worked in a lab since the early 1980s, to industry big and small I offer one observation: PhD graduates from our research institutions are the people who are going to change your business model. They are the people who will innovate, who will do the new things that your company needs to stay ahead.

Industry should be on the lookout for their educated minds first, their technical skills second. Often the work of postdocs could more accurately be described as troubleshooting than true innovation, but the economic effect is positive. I would suggest a scheme to second a postdoc into SMEs (small and medium-sized enterprises) that have never had one.

A particularly welcome example of how innovation is being encouraged by government came in the 2004 Budget, with the removal of a tax measure that slowed innovation by taxing any investment funding won by academics. But that is a relief from a restriction. We also need more active measures. The US government – a big buyer of technologies – is obliged to place a certain number of contracts with SMEs. If our government were to follow this example the benefits would be enormous, giving technology-based start-up companies greater traction in the marketplace.

We face big challenges in the global market but it is important to remember that the UK remains an attractive place to do business and carry out the science that underpins it. To maintain this position we must compete vigorously for international students. The US in particular is making great efforts to attract the best young people from countries like India, China, Malaysia and Singapore.

We must make sure that these talented people know we want them here. One way to achieve this, recently introduced at Imperial, is to repay them the cost of obtaining their UK visa – at £85 per student a relatively low-cost but nevertheless symbolic move.

I am relieved to say that the international flow of scientific talent is becoming a less overwrought topic than in the past. Too much has been made of the 'brain drain'. As the former prime minister of India Rajiv Gandhi cleverly remarked: "Better to have brain drain, than brain in the drain." Today, 'brain circulation' is nearer the mark. Many scientists and engineers who leave these shores eventually return, and in many cases they come back brighter.

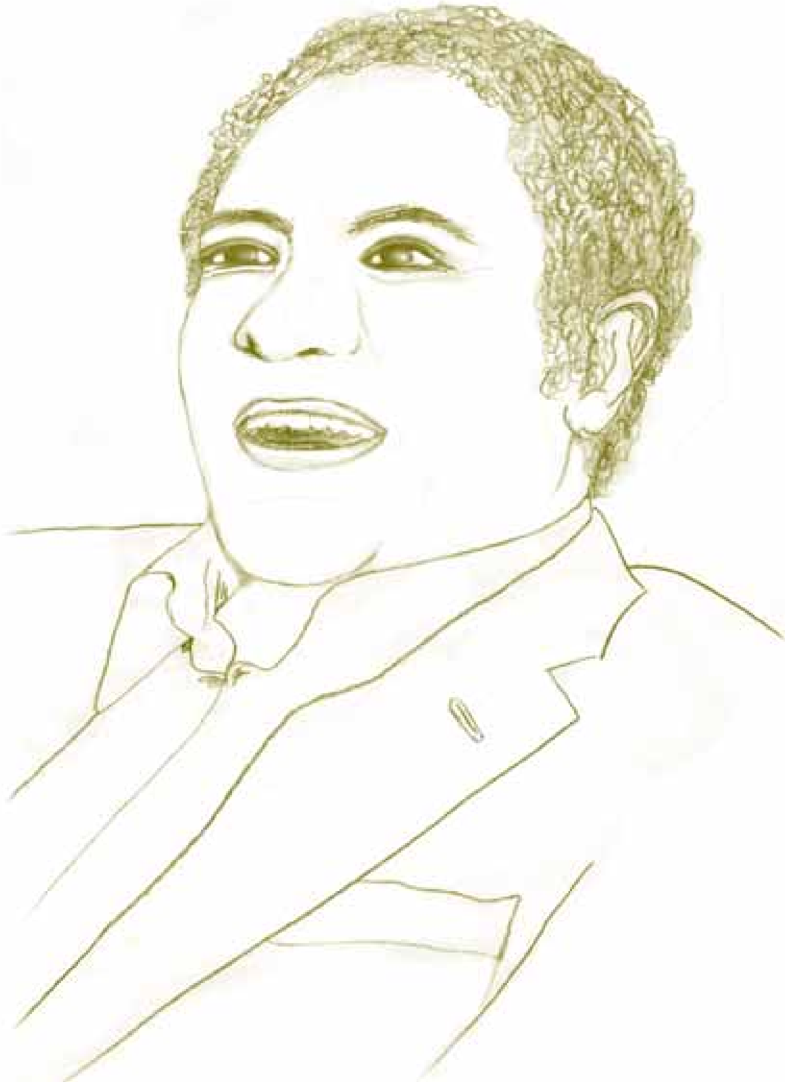
The process of nurturing the scientists of the future starts in schools, and here once again postdocs can play a role. At Imperial over the past few years we have been running a novel scheme that puts these researchers through teacher training for two years alongside their lab-based careers. They spend half their time assisting with science teaching and enrichment activities in specialist schools and studying for a PGCE (Post-Graduate Certificate in Education). They spend the other half undertaking scientific research. The scheme is funded by GlaxoSmithKline and, appropriately, is called INSPIRE.

An interim evaluation indicates that schools do indeed see the postdocs as an inspirational resource with measurable results for their pupils. Improvement in GCSE results and coursework and an increased take-up of A-level science courses have also been noted.

Schools benefit enormously from the presence of these passionate advocates for science and their knowledge of the highest levels of research. The postdocs act as role models for students and as on-hand experts for teachers. Unlike similar schemes, an INSPIRE postdoc spends many months in the same school developing relationships with students and teachers. So far, half of the postdocs have decided to make teaching science in schools their career.

But the profile of science needs to be raised not just in schools but across the board. It was striking that just a few days after the US President's announcement in February of new investments in science, Time magazine ran a cover headlined "Is America flunking science?" Its main story hankered after the formula for "a US comeback".

The high visibility afforded to science on the other side of the Atlantic is impressive, demonstrating that the subject can capture the imagination of the mainstream. Would a British-based weekly news magazine give similar prominence to such questioning of our own scientific system? Perhaps it is not only money and facilities that are enabling the US to win over the best brains. Newton's Apple should be a valuable step towards helping science take a more prominent position on the wider social, cultural and economic agenda.



GLOBAL COLLABORATION: PUTTING OUR MONEY WHERE OUR MOUTH IS

Professor Calestous Juma and Dr Monica Darnbrough

British institutions like the Royal Society pioneered the idea that scientific knowledge should be shared for the common good. Today, the pooling of knowledge to solve global problems is inextricably linked with issues of leadership and competition between nations. A new world order has emerged in which a country's influence is largely a product of its capacity to enter into global partnerships by bringing its unique expertise to bear.

In this way, countries compete to be the chosen location for research-based economic activities. Fortunately the UK has much to offer to partners in both developed and developing countries. On its own, it cannot afford all the equipment and interdisciplinary teams needed to expand the frontiers of science. So for British teams to stay at the forefront of their disciplines they need to form partnerships with the best in the world, sharing their ideas, their samples and their data, and in return gaining access to equipment, methods and know-how.

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Dr Monica Darnbrough FRS is an independent consultant; formerly Director of Bioscience Unit DTI (1998-2005).

The UK Government is starting to recognise that scientific and technological competence are instruments of international diplomacy. Its public diplomacy campaigns insist that the UK wants to be the partner of choice for excellent scientists overseas. But it has failed to find funding for the opportunities that arise.

Science is paid for by governments as a cultural activity to train scholars and to advance knowledge for its own sake, but an increasing emphasis is being put on the international dimension and on the potential economic benefits. In its thinking about the second Comprehensive Spending Review, due to report next year, the Treasury is taking a global perspective and it sees science and technology as playing an important role in the main policy priorities: globalisation; global uncertainty; public policy and service delivery; sustainable development; and tackling disadvantage. Science and technology will also contribute to the meeting of the UN's Millennium Development Goals.

In a similar vein, the Government's Science and Innovation Investment Framework 2004-2014, prepared by the Treasury, Department of Trade and Industry (DTI) and Department for Education and Skills, contains an annex that endeavours to show the economic arguments for investing in science. The benefits include attracting and keeping R&D activities in this country, as well as developing novel products and services derived from scientific and technological advances.

There are many examples of international collaboration that use scientific, technological and medical advances to address global problems. These range from the green revolution and the eradication of smallpox, to working together on nuclear radiation and on aspects of pollution and climate change. There have often been elements of enlightened self-interest in these projects, because solving problems overseas may also improve national security.

International league tables exist for most areas of work – from costs of living to sporting prowess – and science is no exception. When league tables of universities' scientific strengths are published there is considerable interest in the British media, but the tables are also scrutinised by research-based companies all over the world. British research needs to be (and be seen to be) at the leading edge if it is to remain respected by investors and the worldwide research community. Only 5 per cent of the world's research is done in the UK and that percentage will decrease as many developing countries increase their expenditure on science, training and funding greater numbers of researchers. The two greatest centres of growth are likely to be China and India.

The strength of a country's science base is also important in promoting its overall image. It helps underpin international policy negotiations and can be used as a wider tool of international diplomacy, to secure influence.

How can the UK remain at the forefront of science? Some of the research done in the UK is regarded as 'world class' or 'leading edge', but what do we mean by these terms? We take them to mean that, in many specialisms, British researchers are working at the frontiers of knowledge, exploring their fields by testing and investigating novel, imaginative hypotheses, using techniques that they and other leaders in the field consider to be the best available.

The difficulty for the UK is that the 'best' experimental approaches often demand the latest (and most expensive) measuring and imaging devices. These also often require extraordinary computing capacity.

> Partnership with other teams that are at the leading edge of research in a given field can help British scientists to develop their ideas and devise new techniques.

Most importantly, by working with international partners, scientists in the UK can access equipment that we do not have here. Of course, it is not a one-way street. British scientists often have experimental materials that their partners lack and may have perfected difficult techniques. They can provide vital test samples and know-how to partners who have the necessary kit. Both teams benefit from the collaboration.

Mutually beneficial partnerships may involve several research groups, especially in multidisciplinary fields such as systems biology, nanotechnology and climate science. They can be with teams in one other country or can involve teams in several countries. The wide international collaboration in particle physics through CERN is an example of a highly successful and long-established partnership.

Collaboration designed to help solve worldwide problems, particularly in the developing world, requires excellent science and also political support from donor and recipient governments. The Consultative Group on International Agricultural Research is a successful effort to mobilise the world's scientific knowledge for solving development problems. This network is partly based on institutions initially established by the UK around the world.

In the field of climate change, the UK played a leading role more than 20 years ago in getting the Intergovernmental Panel on Climate Change set up by the UN Environment Programme and the World Meteorological Organization. Although the IPCC does not itself conduct research, it pulls together and assesses published scientific data. This has helped to focus worldwide political attention on the issue of global climate change.

Do others want to form partnerships with the UK? Certainly they do. For example, our own experience is that in many parts of the US, researchers, heads of universities and government laboratories and regional and federal politicians are keen to collaborate with British scientists. Several states have put aside funds for joint programmes with the UK in life sciences. Unfortunately, the DTI, the Office of Science and Technology (OST) and the Foreign and Commonwealth Office (FCO) have failed to find matching funds.

Scientists in Singapore have shown their respect for British science by populating their strategic Agency for Science, Technology and Research (A*STAR) with a range of leading figures from UK academia and business. China and India are very keen to partner with the UK. All these countries are building modern facilities (in some cases from scratch) and are investing in equipment that the UK does not have.

India, Brazil and South Africa identified science and technology as a key area for international cooperation in 2003. Their trilateral commission has decided on initial collaboration on nanotechnology and the prevention and treatment of HIV/AIDS. However, there is evidence that developing countries have got tired of waiting for help from scientific leader countries.

One factor preventing UK scientists taking up valuable invitations from high-quality potential overseas partners and their governments is a lack of funding from the British government for its share of the costs. The government has stated in many policy documents that it wants the UK to be the partner of choice for scientists overseas. The FCO and the British Council have spent millions of pounds mounting public diplomacy campaigns to make researchers and governments overseas aware of the strength of UK science. But when it comes to actually carrying out the research projects, all the rhetoric is shown to be of no consequence because there are no funds available.

Recent meetings with Chinese officials and researchers elicited amazingly blunt expressions of their disappointment that the UK cannot put into action its stated aims of forming partnerships. The UK's lack of funding has driven them instead to undertake joint projects with other European partners such as France and Germany, who backed up their rhetoric with money to build facilities in China.

Public diplomacy campaigns in China, Canada and the US have worked, but the UK has whet the appetite of valuable partners only to fail to deliver practical support.

In the medium and long term, those countries who share experimental material and know-how – in exchange for access to excellent equipment and keen, well-supported research teams – will reap the economic benefits of the resulting scientific applications. Opportunities for business partnerships are likely to follow from the successful completion of research. This is certainly how France perceives its partnership with China.

Another factor preventing international collaboration is that key foreign policies do not include scientific and technological goals and are not built on joined-up, cross-department, shared objectives.

Many ministers have objectives that necessitate international action but these are not integrated into coherent, consistent, diplomatic objectives and activities.

Technological advances are raising new issues in international relations that may warrant greater involvement of technical specialists in the work of the FCO, the British Council and the Department for International Development. For example, the potential offered by satellite remote sensing to monitor the adherence of countries to international agreements and laws may well require novel organisational approaches. In addition, techniques such as DNA analysis, will be required to enforce international regulations covering biodiversity and sustainability, and the movement of genetically modified organisms and other biological materials.

So what can be done to promote and foster international collaboration? The Treasury recognises that science, engineering and technology are global activities and acknowledges that the UK should focus on the 'knowledge economy', of which R&D is an important element. The objectives set out in Science and Innovation Investment Framework 2004-2014 include recommendations to set up "a 'strategic fund' for flexible deployment by the OST against emerging priorities, for example when it is necessary to focus research effort, build national capacity (including infrastructure) or to seize opportunities from international partnership".

As the OST is merged with the Technology and Innovation Policy division (which has been responsible, with input from industry, for longer-term technology strategy thinking at the DTI) we would like to see more joined-up thinking emerge, together with substantially increased funding for international collaboration on science and technology projects.

We must unite strategic thinking about scientific areas that might benefit from international collaboration (which is the work of the government's Global Science and Innovation Forum) with knowledge of the strengths of science-based industries in the UK (the preserve of the research councils and regional development agencies' science and industry councils).

If the UK helps its scientists by funding them to join with well-matched partners overseas, in areas of science where British industry already has strengths, then we will sow the seeds not only for long-term research collaborations but also for future joint business ventures.

Finally, we believe efforts to find science-based solutions to challenges like climate change, the discovery of cleaner technologies, water resource management, and monitoring the movements of crops or people should be more closely aligned with diplomatic activities.

So for example we would like to see greater integration of the science and technology-driven actions designed to meet Millennium goals in Africa and elsewhere, which are funded by the Department for International Development and others, with broader diplomatic efforts. It might be helpful to start by focusing on scientific priorities such as biomedicine and agriculture to stimulate a rethink of overseas diplomatic policies, staffing and actions.

In the new world order of global partnership and collaboration, we cannot afford to stay standing on the sidelines.

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RESEARCH AND DEVELOPMENT: LESS HOT AIR, MORE WHITE HEAT

Dr David Lawrence

No country is a home for research and development by right. The UK's illustrious history of scientific and technological innovation may be just that – history.

My own company, Syngenta, runs the last industry-owned agricultural research centre still based here and employs around 2,500 people in the UK, 1,200 of them working in R&D. Last year we invested almost £109 million in domestic R&D, putting us in the top 10 on the Department of Trade and Industry's scoreboard of overseas investors.

We operate in a science-based sector, developing sustainable agricultural solutions to the problems of feeding a growing world population. Naturally, we need high-quality science graduates in areas like chemistry, entomology and applied plant biology. We also depend on a science-based regulatory framework for R&D, a sympathetic economic environment and public acceptance and understanding of technology.

All of these factors are linked and are threatened by the plunging public image of science in the UK. The prevailing culture of nongovernmental organisations (NGOs) is anti-science and the media seem happy to perpetuate this by regularly crying wolf with pseudoscientific scare stories. Public pressure resulting from such scares runs the risk of the UK being left behind in the most exciting new areas of research, such as nanotechnology.

So why does Syngenta still invest in R&D here? It is partly a question of heritage. The UK is an expensive place to do business, but we have experience and expertise here which could take 15 years to replace after relocating. Furthermore, the UK is still seen in Europe as a pro-science country. Perhaps most importantly, the steps already taken by the government to promote science in the UK, and the acknowledgement that R&D is a key driver of wealth creation, demonstrate some commitment toward stemming the steady loss of talented people and jobs from this country as companies do their research elsewhere.

The introduction of the R&D tax credit system, the scientific capital allowance of 100 per cent on plant and machinery, and the write-off of purchased intellectual property (IP) for tax purposes go a long way to encourage R&D in the UK. The current system is not without fault – there are problems with the practical application of the definitions of R&D and 'qualifying spend' – but the R&D credit system has been an important factor in Syngenta's decision to retain the UK as a primary location for research.

More could be done. The credit offered to large companies should be at least equal to that offered to small and medium-sized enterprises. Considering the government's wider aim of increasing tax revenues, the focus should also be on encouraging ownership of IP by offering incentives to British companies who fund research overseas. The company that bears the cost of R&D generally receives the income from the resulting IP, thus boosting tax revenues.

The government has also demonstrated its commitment to R&D-based companies through new animal rights legislation. Indeed, Tony Blair's recent criticism of the activities of animal rights extremists was a welcome assertion of the government's determination to create an environment that is conducive to bioscience research.

A more fundamental issue, though, is that the UK's passion for R&D seems to be waning. Countries such as China, India and South Korea show far more commitment to innovation and will surely reap the rewards.

It is getting harder to find enough good scientists in the UK, especially in applied sciences. The UK is closing chemistry departments, China is expanding them. The number of plant science graduates produced in the UK is now around an order of magnitude lower than that produced by Beijing alone.

To ensure the UK remains a hub for science and new technology, we need government intervention. The current R&D environment is built on the success of Harold Wilson's 'white heat of technology' revolution. But that was more than 40 years ago and we now need a similar wave of intense investment to rejuvenate and reinvigorate British science. First and foremost, we need to revisit the concept of science teaching. More needs to be done at school level to tackle the perception that science is (a) boring, (b) doesn't lead to a rewarding career and (c) is unnecessary at best and positively harmful to society at worst.

The Association of the British Pharmaceutical Industry has called for a greater concentration on vocational work, such as a science diploma developed with support from industry to enhance scientific skills and build careers. The Qualifications and Curriculum Authority could include more information about scientific careers within course content, and provide help for teachers to update their practical skills and knowledge of cutting-edge and applied research. All of these measures would help to reverse the prevalent perception among children, noted in an article earlier this year in The Daily Telegraph, that scientists are mad, secretive lab-centric boffins with wild hair who are remote from everyday concerns ('All boffins are bonkers', 9 May 2006).

It is a huge worry that applications for some degree courses in science, technology, engineering and maths (STEM subjects) have fallen steeply in recent years. The decision to rescind the closure of the University of Sussex chemistry department is to be welcomed, but many other departments across the country have not received such an 11th hour reprieve. We should support the House of Commons Science and Technology Committee's suggestion that more government bursaries be provided to study STEM subjects at undergraduate level.

While the economic value of research is appreciated, science in and of itself is not given commensurate status. Factual knowledge appears to carry no more weight than the opinion-based claims from pressure groups. As a result, science-backed risk assessment is being replaced with fad, fashion and dogma, as in the debates over GM crops and MMR vaccination to name but two.

It is not as if people were innately against innovation – where the consumer benefits are immediately obvious, as with mobile phones, the majority embrace it – but this is not the case for many industries where the public has little or no understanding of the benefits that the technology brings.

As scientists, we can undoubtedly do more to help ourselves. Professor Sir Patrick Bateson, former vice-president of the Royal Society, is right when he suggests that sometimes we need to consider more fully the impact of our public pronouncements. The public's misunderstanding of issues such as GM crops and the

MMR vaccine stem in part from mistaken research that has been published in scientific journals. Anomalous statistics are of course of interest to scientists, but we must realise that publishing them without explaining the limits of their significance to the wider world can be counterproductive.

And of course, none of us is helped by an NGO culture that seems to delight in alarming readers with opinion rather than facts. To combat stories that consist of inflated half-truths, we need to wrestle back the news agenda with informed comment and clear explanations of the benefits we offer. This fact was recognised by the House of Lords Select Committee on Science and Technology in their report Science and Society (2000), which resulted in the formation of the Science Media Centre, an organisation that helps to connect the media with genuine scientific experts for comment and interview.

Above all, we need to bring about a sea change in the public perception of science and technology in the UK. It is hard to believe now that science – rather than celebrity – was once a key part of popular culture. Not so very long ago, television schedules contained programmes such as Tomorrow's World. Now the closest many kids get to science is Doctor Who on a Saturday evening.

We must give children more opportunity to see the wonders of science, not just in theory but in action. We must explain to parents, educators and other opinion formers that an overzealous adherence to the precautionary principle is driving out the development of technologies whose benefits are huge and whose risks are tiny compared with others experienced in everyday life. If we applied the same rules to everything, we would hardly dare breathe oxygen. After all, oxygen radicals have been clearly implicated in ageing and disease, and gaseous oxygen is a serious fire hazard.

Yet although the future for R&D in the UK may appear bleak, there is hope. Given the right operating environment, the knowledge, energy and facilities of companies like Syngenta can be used to return this country to its rightful place as a world-leading innovator.

Syngenta is playing its part. We prove that the UK does not have to be an R&D backwater. Keeping innovation here is not only possible, it is vital for the British economy.

Becky Parker is Head of Physics at Simon Langton Grammar School for Boys, Canterbury. She has worked on science education policy and practice with the Institute of Physics, the Royal Society, the Association for Science Education, the Faulkes Telescope Project and the Wellcome Trust.

EDUCATION: LEARNING TO LOVE SCIENCE

Becky Parker

Why is science teaching in schools so important? A basic level of public understanding of science and an awareness of the benefits and risks associated with scientific advances are crucial. We also rely on schools to inspire young people to become the scientists of the future, entering the huge range of professions with science at their heart, including healthcare, research, environment, energy, transport, development, technical support...and education.

It is unfortunate therefore that we have a crisis in the recruitment and retention of science teachers, coupled with a failure to boost the numbers of young people taking up university courses in key subjects such as chemistry and physics. What has gone wrong?

Let's look first at the positives. Some inspirational science teaching goes on in our schools. Brilliant teachers bring science to life for hundreds of thousands of students by providing a wealth of activities to help them learn, understand and enjoy science.

Many of the materials at their disposal are of the highest quality. A number of innovative A level courses have been developed, such as Salters Horners Advanced Physics, the Institute of Physics' Advancing Physics, Salters Nuffield Advanced Biology and Salters Chemistry. Teachers and educators deserve credit, too, for the sterling curriculum development work they do that is independent of specific courses.

Excellent textbooks and DVDs are also available, and internet resources at the click of a mouse from Nature, NASA, the Institute of Physics, the Royal Society of Chemistry and Science upd8, to name just a few, providing animations, simulations and video clips galore. So, for example, teachers introducing their pupils to particle physics can now get a DVD from the Particle Physics and Astronomy Research Council showing progress on the Large Hadron Collider at CERN in Switzerland.

Whatever course you teach, resources are on hand to enhance it, with support from organisations such as the Physics Teacher Network run by the Institute of Physics.

All this would be fine if teachers had fewer classes and were not constrained by all their myriad other responsibilities.

A few years ago I met some Danish teachers at a conference at CERN who were given one hour of preparation and marking time for every hour of lessons they taught. If only teachers in Britain were so fortunate.

The main change affecting school science at the moment is the introduction in September 2006 of radically different courses for GCSE. The range of courses coming on-stream includes 'Twenty First Century Science', which the Science and Technology Select Committee welcomed in 2002 as it was being developed. Schools running pilots of the course report improved take-up of science. Many have praised the new courses for the way they stimulate interest and engagement in the subject by showing students how science affects their lives. The weight of coursework has also been lightened to allow more time for practical work.

Nevertheless, some teachers have decided to opt out of these new developments and move to the International GCSE because they prefer its less prescriptive approach. A number of top private schools are doing this. Other schools feel that the basic science content of the new GCSE courses has been lessened to make way for more practical applications, and they hope that the pupil assessment process will not veer too sharply away from testing knowledge of basic concepts. Concern that this may already be happening at Key Stage 3 was expressed in a report in The Times Educational Supplement (5 May) after the 2006 set of KS3 science tests.

Higher up the school on another positive note there are two increasingly popular AS courses that cater for a wide range of interests and look more closely at the nature of science. 'Science for Public Understanding' and 'Perspectives on Science: the History, Philosophy and Ethics of Science' is attracting students interested in wider implications and issues.

Given this wealth of resources, innovation and development at all levels of science teaching one might expect that science A level numbers would be soaring and universities overflowing with students. On the contrary, university chemistry and physics departments are under threat and recruitment into these fields is faltering.

To their credit, the Higher Education Funding Council for England is supporting the projects 'Stimulating Demand for Physics' from the Institute of Physics and 'Chemistry for our Future' from the Royal Society of Chemistry in an attempt to improve recruitment into the physical sciences.

The fact remains, however, that science and in particular the physical sciences are not flourishing in a large number of schools. There is a huge shortage of teachers. To quote the Institute of Physics: "There is a well documented shortage of specialist physics teachers in schools and colleges, particularly in the 11-16 sector, where the shortage has reached crisis levels" (Stimulating Demand for Physics, February 2006).

Is there something inherently more demanding about teaching and learning physical sciences than other subjects? Some of the concepts are abstract and counterintuitive. Fuller understanding is often only possible as you learn more and see how all the concepts fit together as a coherent whole. In physics, the more you know the simpler it all seems, because all the concepts conform to a limited number of overriding principles such as resonance, fields, and wave/particle behaviour. Earlier on in a physics course the information seems to make less sense and this can be offputting. Some pupils also struggle with the mathematical demands.

It is all the more worrying, therefore, that one third of the physics classes for under-16s are taught by a teacher without an A level in physics, according to the Council for Science and Technology report Science Teachers published in 2000.

In some cases the learning experience provided to students in these situations will be fine. Some of these teachers, however, as for any teacher working outside their specialism, will not have the tricks, stories and confidence needed to do hazardous practical work, for example. They may not have the technical support they need. They may be in a school where the turnover of staff is high and the department has a large proportion of newly qualified teachers and those on the Graduate Teacher Programme.

An increasing number of courses are being organised by the Science Learning Centres and the Institute of Physics' Physics Teacher Network to support such nonspecialists and give them experience and confidence in the classroom.

There are also financial incentives in place to encourage people back into these shortage subjects and keep them in teaching through the particularly demanding early years. People who train for a PGCE in science are entitled to a tax-free bursary of £9,000 and then a golden hello of £5,000 after completing the first-year induction period. However, all PGCE students will have to pay a fee of £3,000 from September 2006.

Other factors have played a role in the lack of expansion of student numbers in science courses. Science teaching can be incredibly demanding: imagine being responsible for a class of 30 students using 15 sets of electrical apparatus. The safe and responsible approach taken by many teachers is to restrict practical work if there is evidence of poor or irresponsible behaviour. However, the classroom diet may then become one of worksheets and other paper activities, which can become tedious for pupils.

Some students who took part in a survey conducted at the Science Museum for the Science and Technology Select Committee complained of an overload of worksheets and the emphasis on cramming to get the best possible test mark rather than to gain any fundamental understanding. As teachers we all want our students to achieve the highest grades possible. But we don't want the assessment to drive the subject into an endless set of revision guides that fill the shelves of bookshops ready for exams.

Pressure to perform well in school league tables and the lack of flexibility in assessment can mean there is not enough time for pupils to reflect on the fundamentals or pursue a particular area that excites and interests them.

It is by understanding concepts and applying these that students see the beauty and intellectual rigour of science. The strengths and insights that a science education can provide lie in understanding the fundamental processes behind how things work, and practical work is indispensable for achieving this depth of understanding. As an Ancient Chinese proverb puts it: "I hear...I forget; I see...and I remember; I do...and I understand." One can only hope that the freeing up of coursework at KS4 will improve the quality of practical work in schools.

It is often said that restrictions from ever more stringent health and safety laws limit practical work. This is true to an extent. However, I would suggest that the main constraints are the logistical and disciplinary difficulties of doing practical work with large class sizes, limited availability of resources and technician support. In Scotland, the maximum class size for practical work has been set at 20 pupils. Even so, in the Save British Science Society's 2004 survey of science teaching in Scottish schools, teachers cited the main reason for curtailing practical work as disruptive behaviour. The same must surely be true in English schools where class sizes are larger.

It is worth noting, nevertheless, that practical work need not be the be-all and end-all when it comes to inspiring young people to take up a career in science. This seems particularly true for female students. In Italy, where the curriculum is extremely theoretical with no practical work the proportion of women on university science courses stands at an impressive 50 per cent. It would be interesting to sample opinion from science graduates as to whether the provision of high-quality labs and equipment would make the prospect of science teaching more appealing.

The report from the Save British Science Society states that "a good science teacher is probably the most important aspect of anyone's science education." It notes that as more teachers retire from the profession, the effect of our failure to recruit and retain talented young science teachers will become even more acute.

Clearly, a continuous supply of talented young teachers is vital to increase the uptake of science by pupils, but other factors are also important.

Competitions, clubs, trips and other extracurricular activities all boost morale and stimulate enthusiasm for science. Yet again, however, in addition to the obvious time pressures of the curriculum, health and safety worries mean that many schools limit how much teachers can take students out of the classroom.

There is also concern that many of the new initiatives get taken up by enthusiasts while there remain schools that do not even accept offers of free educational resources from organisations such as Planet Science. To tackle this issue, the Advanced Skills Teachers scheme from the Department for Education and Skills is helping to send some of the best science teachers into schools, which benefit from their advice, support and resources.

We want our teachers to be passionate about their subject.Why then is it that continuing professional development has been so limited? As a physics teacher you could visit CERN, attend a training session run by the Faulkes Telescope Project, or shadow a scientist working for a physics-based company. A teacher might pick up such experiences over the course of their entire career, but they should be happening every year.

This kind of continuing professional development and training is typical in industry and other professions but rare in teaching.

The good news is that the National Science Learning Centre in York offered its first professional development course in November last year, and the nine regional learning centres continue to offer similar support to science teachers and technicians.

So many of the problems identified here seem to come down to freeing up teaching time and improving practical work. Perhaps Leigh City Technology College in Dartford is pointing the way: three years ago it put more person power into its laboratory in the shape of a team of technicians to help and support practical work. The number of students gaining A, B and C grades in GCSE science doubled over this period. The vice principal is convinced that the expert assistance of technicians played a major role in this improvement, and increased the popularity of the subject in the school.

Clearly, science education in Britain faces some major challenges. In particular, teacher shortages will make it difficult to increase our output of physical scientists, who are essential for the economic success and wellbeing of this country. Some of our excellent teachers and educational institutions are already rising to the challenge with innovation and imagination, but they will need all the help they can get.

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OUT-OF-CLASSROOM EXPERIENCES: LEARNING IN THE REAL WORLD

Dr Frances MacGuire

Ask any 40-something what they remember from school and they'll tell you about bad teachers and good ones, bullying and the forging of lifelong friendships, boredom and exam stress. School has it all. But if there's one thing that sticks out, it's the field trips.

Weeks and days spent in places such as the Lake District, Devon and Wales learning about glaciation, geology and ecology. Mucking about in rock pools identifying the slimiest seaweeds and the ones that pop loudest. Golden times spent out of the classroom and in the real world – a great place to learn about the natural sciences and an even better place to learn about how to get on with your classmates, teachers and the communities in which you're staying.

First-hand experience of the natural world and our cultural heritage is one of the most effective forms of education. It broadens children's outlook, it is motivating, nurtures social skills and creates a sense of place, nature, culture and history.

Real-world learning also helps to develop creativity and an inquiring mind: aptitudes that underpin a knowledge economy. Learning in the natural environment can provide inspirational experiences that will shape career choices and foster an interest in conservation science, geology, geography and biology. It also makes a welcome change for children struggling in the classroom environment. Early evaluation of a government initiative to transform secondary schools in the capital, London Challenge, suggests that out-of-classroom experiences allow excluded young people or those with learning difficulties to realise their potential and excel. Getting involved in outdoor activities also helps keep children fit and healthy.

Where schools have a policy to promote out-of-classroom learning there is clear evidence of improved access and inclusion for all, and progression in the nature of the activities from year to year and from Key Stage to Key Stage. In 2004, the Ofsted report Outdoor Education noted that: "Outdoor education continues to thrive where headteachers or individual enthusiasts provide leadership and a vision... They recognise the importance of outdoor education experiences in giving depth to the curriculum and to the development of students' personal and social development."

So you'd think that every school would have an active outdoor programme. Not so. Many providers of out-of-classroom education – nature reserves, farms, historic sites and so on – report declining numbers of visiting school groups or negative perceptions about the risks involved. Where field trips are already a curriculum requirement, such as for A level geography and geology, teachers and students are clear about the importance of out-of-classroom learning. Yet many teachers are not aware of its wider positive impacts.

Access to out-of-classroom learning varies widely between schools. When resources are tight, field trips are first up for the chop. And among teachers, confidence and experience in undertaking trips are on the wane. They cite the 'litigation culture' as a significant barrier, with high-profile accidents and subsequent court cases leaving them feeling personally exposed. The situation is so serious that the NASUWT teachers' union now recommends that its members should not take children out of the classroom. Much work will be needed to restore teachers' confidence and rebuild all the necessary skills and knowledge to arrange trips.

Further barriers include an overcrowded curriculum, the low status of out-of-classroom learning and, for some schools, the costs of visits and transport. Surveys by the Royal Society for the Protection of Birds, the National Trust and other educational providers show that economic deprivation is a major obstacle for some schools in arranging trips.

In 2003, the Real World Learning partnership was forged to address this decline in outdoor education by persuading the government to ensure that every child, as part of his or her formal education, can experience the natural world and our cultural heritage. The partnership was formed by the RSPB, the Field Studies Council, the National Trust, the Wildfowl and Wetlands Trust and the residential activities company PGL Travel. Early in 2005, they were joined by the Association for Science Education, Geographical Association, Historical Association, and Royal Geographical Society with IBG, and more recently by the Wildlife Trusts. The partnership provides safe and high-quality out-of-classroom education for more than 1.5 million children every year.

The first target of the partnership's campaign was the 2005 general election, with clear commitments being secured from the three main political parties to support outdoor education. So, for example, Labour promised in its manifesto that "to enhance our children's understanding of the environment we will give every school student the opportunity to experience out-of-classroom learning in the natural environment."

This reinforced the real progress that the Labour government had already made in protecting and opening up access to the environment and our cultural heritage. Granting free access to national museums, improving the protection and management of Sites of Special Scientific Interest and granting public access to large parts of the countryside through the Countryside and Rights of Way Act 2000 have been big steps forward.

Yet with ample evidence that many of our children feel divorced from their natural environment, it is clear that the newly created opportunities are being missed simply because of a lack of awareness that they exist and a lack of understanding about how to enjoy them.

The government can make a real difference by recognising the value of outdoor education. The Real World Learning partnership has helped to draft the Department for Education and Skills' Education Outside the Classroom Manifesto. It expects the department to provide leadership and financial support for real-world educational experiences, equip all teachers with the necessary knowledge and skills, and address their concerns about their risk-management responsibilities.

An important requirement is to ensure equality of access by providing a financial safety net for economically disadvantaged schools. This would ensure that no school that wants to provide the enrichment of out-of-classroom learning is prevented from doing so by financial restraints. The April 2006 Budget pledged over £500 million for the 'personalisation' of education. One possible use of this money was identified as "supporting access to extended activities for pupils who may otherwise not benefit".

By delivering on the other areas advocated by the partnership, the government would ensure that schools are not only aware of the opportunities to utilise this new funding, but actually have the ability to do so.

If we fail to reinstate outdoor education for all, current and future generations of children will miss out on something very special that many of their parents enjoyed. To learn about science without getting your hands dirty in the laboratory or the field is to lose its very essence – enquiry and exploration, creativity and discovery, testing, failure, cooperation and collaboration. These are also the skills vital to personal, social and business development and success.

Denying our kids access to learning opportunities outdoors threatens not just their skills development and connection to the world around them, but also their interest in science.

This is an outcome that none of us should accept.

PASSION FOR SCIENCE: A VIEW FROM THE LAB BENCH

Dr Emma East, Richard Foxton and Branwen Hide

Since the 17th century, this country has been at the forefront of science and technology. It has produced many great scientists who have shaped the world we live in through their innovations and discoveries. The importance of these achievements cannot be overstated and is reflected in the number of Nobel prizes awarded to British scientists.

To work as a young scientist in the UK today remains as exciting and rewarding as ever. Few careers offer the same intellectual stimulation and utilise such a wide range of skills. Academic science provides the chance to investigate a novel idea with the potential to discover something truly original, while making a valuable contribution to society. The opportunity to work with world-renowned scientists using state-of-the-art equipment and techniques can inspire young researchers to produce innovative work.

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Richard Foxton is a graduate of the University of Manchester. He worked for GlaxoSmithKline before starting his PhD – now close to completion – at the Institute of Neurology, University College London.

Branwen Hide is a graduate of Simon Fraser University in Canada and King's College London. She is completing her PhD at Brasenose College and the Weatherall Institute of Molecular Medicine in Oxford. She is the founder and president of Females in Engineering.

The UK government recognises that scientific endeavour is the foundation of our economic future, and in 2004 pledged a 5.8 per cent increase in its spending on science and technology by 2008.

This should raise the spending on UK science as a proportion of GDP from 1.86 per cent to 2.5 per cent, bringing it in line with other major European countries and the US. The government says it hopes to attract the highly skilled people and companies needed to turn innovation into commercial opportunity.

This initiative has been well received throughout the scientific community, and it offers more opportunities for up-and-coming young scientists. More could be done, however, to keep the most talented ones in this country. For most researchers, and in particular for young scientists, a career in academic science involves working on three-year contracts without the promise of either a permanent position or a longer-term contract to follow. While it is clear that not everyone is suited to the rigours of academic science, nor will it ever be feasible to offer all those who qualify with a PhD a tenure position, the fear is that we are losing the cream of UK talent to countries offering higher salaries and the potential for longer contracts. Between 1997 and 2005, 10 per cent of newly qualified PhDs left the UK to take up posts overseas.

What can be done to keep our most talented scientists here and maintain the UK's high standing in international science and its reputation as a place where innovation and creativity can thrive?

Due to intense competition for funding, research councils are relatively conservative in their outlook, often feeling it is essential to back research that is equally acceptable to the Treasury as it is in scientific terms. This inevitably leads to an emphasis on predictable, commercial research that is likely to yield reliable results and be published in highly cited journals. In addition, subjects that are fashionable or carry political weight, such as bird flu, SARS, MMR vaccination and so on, receive greater favour when applications are considered.

If funds are only made available to achieve attainable outcomes this will stifle creativity, with many researchers feeling there is no incentive to explore novel ideas.

But innovation is important to ensure our future economic prosperity and to create a higher quality of life through improved healthcare and a better environment.

Had this current funding structure existed 100 years ago, would UK science have been able to make the breakthroughs that we still benefit from today?

To compete strongly with other scientific nations, the funding increases promised by the government should be coupled with changes to the funding infrastructure that will better nurture our talents.

The extra money should be used to increase the standard length of grant funding from three years to five years, rather than increasing the total number of grants. One of the main drawbacks of three-year contracts is that by the end of second year, scientists have to begin looking for their next contract. They spend a large proportion of their time trying to secure further funding through an application system that is rigorous and time-consuming. This takes their focus away from the work they are actually funded to carry out, and places a lot of emphasis on short-term achievements.

Projects that involve establishing methods and techniques previously untested or unknown usually take longer to produce results than research where a lot of background validation has already been done. These long-term projects, the most challenging kinds of research, are what we have to do to keep the lead in international science. They require more commitment from funding bodies than a three-year grant.

A scheme whereby postdoctoral scientists are given a five-year post as standard, with a review of their work after three years, would make it easier for young scientists to establish themselves in their chosen specialism and location – scientifically, financially and personally.

This may initially reduce the number of grants awarded but it would favour innovative science that in the long-term would encourage greater investment from within and outside the UK.

To enable more funding for longer periods of time, alternative sources must be examined and utilised more effectively. Public-private partnerships can lead to substantial increases in science funding, exploiting existing and future intellectual property to raise significant capital for science and technology projects.

Research Councils UK has introduced a new scheme which will run until 2009 to support 200 research fellows, with the promise of a permanent position after five years. The scheme is similar to one provided by the National Institutes of Health in the US, the Pathway to Independence Award, which funds postdocs for up to five years. The expectation is that after this time a young scientist will be in a good position to win their first principal investigator grant.

There are similar fellowships in the UK, such as the Royal Society's Dorothy Hodgkin and university research fellowships which together fund around 40 new fellows annually. To make an impact on the science base of the future, a substantial investment in such schemes will be essential and further awards of this type should be created.

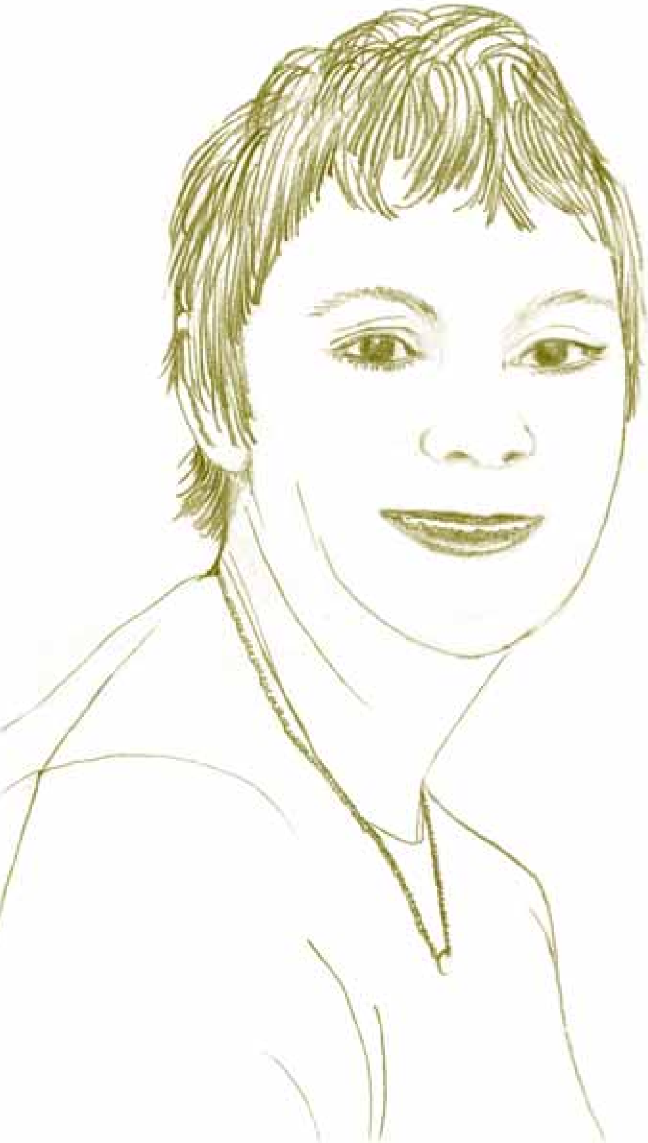
Applications should only be considered from those who are prepared to work collaboratively with other investigators from their chosen discipline, and research proposals should address outstanding unsolved problems in science in an innovative way. The host institution should also assure an established staff position at the end of the fellowship, which would put the recipient in an excellent position to win grants to further their research.

To retain highly skilled individuals in the UK, the attractiveness and security of jobs must also be improved. Grants need to become more flexible, taking into account long-term potential outcomes that will affect both the knowledge-based and product-based economies.

By concentrating on knowledge, UK science will not only retain its innovative prowess but also become the main driver for growth and employment. This is a virtuous circle because the reallocation of existing funds and the generation of new money will enable funding bodies to award more long-term grants.

In conclusion, current trends in funding policies and research strategies will not foster the development of a science base capable of producing new knowledge, understanding, ideas and products. We should be willing to take on more risky research programmes that may have uncertain outcomes but which can deliver exciting new advances. By supporting more research of a long-term nature we can deliver higher levels of innovation. In addition, a great deal more attention must be paid to addressing issues of grant flexibility for young researchers to increase the pool of innovative scientists working in the UK.

These measures will not only have a positive effect on the economy, they will also keep Britain where it belongs: at the forefront of science and technology.



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Dr Melanie Lee is Executive Vice-President R&D at UCB Pharma in Slough, Berkshire.

CANCER RESEARCH: THE CHALLENGES OF PERSONALISED MEDICINE

Professor Fran Balkwill and Dr Melanie Lee

We are entering a golden age for cancer research: fifty years of painstaking scientific detective work are finally paying off. Scientists studying the life and death of viruses, bacteria, yeast, animal and human cells have gained a deep understanding of the molecules that malfunction in malignant disease. The tools of molecular biology have accelerated this process of discovery, with the new science of bioinformatics allowing us to handle millions of pieces of data and solve questions that would previously have taken years to answer.

There is still more to learn, but the awesome speed of data accumulation already gives us enough information to make a difference in the prevention, early detection and treatment of cancer. However, from the perspective of both academic science and industry there are a number of threats to the optimal exploitation of this knowledge.

We now know that cancer is a disease where DNA damage accumulates in three different classes of gene – oncogenes, tumour suppressor genes and genes that control the integrity of the genome. Already this knowledge is leading to the discovery of new drugs that hit the malignant target while causing less collateral damage. But cancer cells are a moving target, able to mutate repeatedly and eventually outwit the most selective and effective drug. This is why much of today's medical research is focused on predicting disease susceptibility. This could lead to more risk mitigation and increase the prevalence of pre-emptive therapy, such as breast removal and reconstruction in women with a strong family history of breast cancer.

Industry is wrestling with the future of cancer therapies. In 'individualised medicine', new treatments are highly effective only if given to the right patients at the right time. This dramatically changes the economics of drug R&D, because such drugs will only be suitable for a relatively small group of patients, but each will still cost around £500 million to take from discovery through to launch. The cost burden might be eased, in part, by more targeted clinical studies. But much of the cost is driven by tight regulations governing laboratory, clinical and manufacturing procedures, and thus is independent of the size of the final market.

High efficacy is a given requirement of personalised medicine. To find the right patients, diagnostic procedures may involve genetic testing, proteomics, biomarkers, metabolomics, monitoring devices and/or surveillance. These are not primary disciplines within the biopharmaceutical industry, so partnership between industries, clinical medicine and academia will be essential.

Personalised medicine means individuals can learn of their inherited susceptibilities to disease and modify risky behaviours or take other preventative action. Clinicians will be able to give better advice on lifestyle and measure more accurately disease progression, enabling them to predict treatment response and ensure the optimum outcome. This fundamental shift, from disease-based to prospective personalised medicine, will take many years to implement. But it is an essential stepping stone for the improvement of cancer treatment.

This shift will require multi-sector collaboration. The government must investigate the economics of prevention, risk reduction and treatment compared with chronic, disease-driven therapy. Meanwhile the public must be educated to understand their risk and take responsibility where possible. Clinicians need to collaborate across specialties in order to guide lifestyle changes and treatment. In order for statisticians to build programmes for prediction and clinicians to tailor their treatments, engineers, IT industries and the diagnostic sciences must design sufficiently robust devices and monitoring systems. This rich integration across sectors should be fed by vibrant and interactive teaching in our universities.

The role of education in supporting this change cannot be overstated. The first major challenge is the difficulty in recruiting the brightest and best biomedical scientists, who will be our future principal investigators and professors. How many young people who could make a major contribution to cancer research are deterred from science as a career because they perceive it to be boring, hard or irrelevant, or because it is poorly taught at schools? How many leave science after achieving a good undergraduate or postgraduate degree because of the low salaries and/or job insecurity of academic science?

The second challenge is postgraduate and postdoctoral training in the UK. After gaining a PhD, five to six years of training is required before a scientist has the experience and ability to run their own laboratory. Some laboratories are fortunate to have a talented and committed group of postgraduates and postdoctoral fellows. However, on advertising a new position, rarely more than one or two applicants are suitably qualified, even though 50 or more may apply. Some of these will simply be unsuited to a career in biomedical science, but many have been inadequately nurtured at postgraduate level.

Third, medically qualified scientists are central to translating scientific advances into treatments, but since the mid-1990s, changes in their training combined with a very heavy workload have resulted in the loss of a whole generation of clinical investigators. New career tracks for academic clinicians, established following the Walport Report in 2005, are designed to build a cadre of multitalented doctors who are actively involved in research, but they demand superhuman commitment from those who pursue them.

The workload of a principal investigator is also heavy. Many work 12-hour days at least five days a week and rarely does a weekend go by without some deadline to be met. Added to the academic workload of supervising, publishing, teaching, keeping up with the literature, grant applications, peer review and attending scientific meetings, is the bewildering, ever-changing and often senselessly complicated bureaucracy involved in obtaining ethical permission for taking patient samples, conducting clinical trials and, worst of all, pre-clinical studies in mouse models of cancer.

Aspiring postdocs often look at their harassed bosses and think: "This is not for me." Maybe that is why so many scientifically trained graduates eschew a career in the labs for a much more highly paid job in the City.

Finally, there is the research assessment exercise (RAE) – the 'brownie points' that must be won to justify a salary from the Higher Education Funding Council for England. This has undoubtedly improved output and helped Britain retain international eminence in science, but it does increase pressure at all levels. It introduces some 'gamesmanship' that seems distant from the aspirations of science and may stifle the most creative but high-risk ideas. Instead, the RAE reinforces the status quo. The top universities retain hegemony over the research funding that is crucial to getting work published, and the emergence of new research universities is stifled.

Working in industry can be just as pressured as academia. Certainly the passion that takes scientists into work every day is just as evident. The industrial environment is more supportive, however, usually with higher standards of employee benefit and an appreciation of the talent, intellect and value to business brought by scientists and clinicians. And in addition to biologists and chemists, today's pharmaceutical businesses require experts in maths, physics, IT, statistics and engineering. Strong social skills are needed to facilitate and manage professional interactions and relationships, and this is an area where gender as well as technical ability comes into play, with women often making a valuable additional contribution.

How do all these issues affect women scientists? In some ways science can be seen as a good career for women: it is not a nine-to-five job, almost everything apart from bench work can be done online, at home, or on the move. In general, the attitudes of male colleagues are supportive and at scientific meetings in the US there is often a requirement to invite equal numbers of male and female speakers.

There are more women at the lower levels of biomedical research than there were 30 years ago. However, their presence becomes proportionally reduced as we move up the career ladder. In the top 50 biology departments in the US, women make up roughly 46 per cent of PhD students, 30 per cent of assistant professors, 25 per cent of associate professors and 15 per cent of full professors. The situation is little different in the UK where women make up 47 per cent of research students, 34 per cent of lecturers, 19 per cent of senior lecturers, but only 10 per cent of full professors.

More needs to be done in this area so that we do not lose qualified and experienced young women scientists. Part-time working or job sharing is difficult in the laboratory, but we should consider new initiatives to support women who wish to do this. For instance, part-time junior lectureships with lower RAE targets would give women some help, although it is unlikely that their part-time wage would adequately cover the cost of childcare, let alone contribute to their own living expenses.

The record of industry in enabling women to achieve the highest positions is no better. At postgraduate intake level there are equal numbers of men and women. However, the percentage of women tails off dramatically further up the job hierarchy. Figures from industry show that only 20 per cent of women reach senior management and fewer than 10 per cent make it onto the board, despite the fact that in more supportive industry environments there are mechanisms to help women through their child-bearing and raising years. These opportunities are often enthusiastically taken up, allowing women with family commitments to hold down good jobs, but the issue of the retention of women needs further consideration.

On the whole, the UK is in a strong position to exploit the advances in science that have brought us to the brink of making major life-changing progress in cancer prevention, diagnosis and treatment. This is an exciting time to work as a biomedical scientist. In addition, a more personalised, preventative approach to medical research requires many disciplines to work together in a thriving academic and clinical research environment.

However, there are serious obstacles in the way of progress. We need better salaries, improved job security and career structures for young scientists. We also need more strategies to help women sustain a career in science though their child-raising years in both academia and industry, in order to benefit from the diversity and full range of talent available.

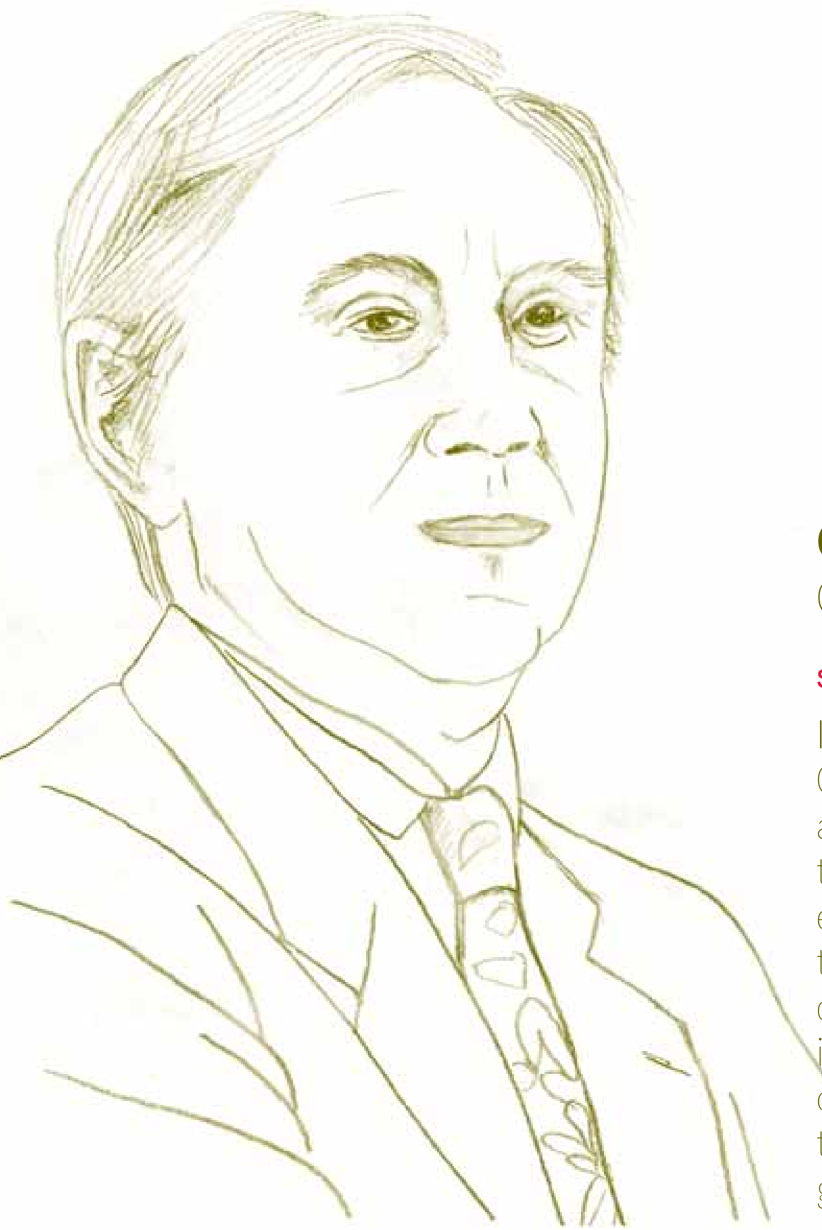
To preserve the UK's biopharmaceutical industry, healthcare economics need to embrace preventative practices and personalised medicine, and support investment in the technologies that underpin them. In breast cancer treatment, for example, breakthrough medicines like herceptin – which treats a particular genetic subtype of the disease – have struggled to win acceptance. The drug was only made available on the NHS to women with early-stage breast cancer with the help of high-profile court cases and a public campaign.

If we could work out how to deliver novel medicines like these to those who will benefit most, we would set the UK on the path to a future of great promise for the prevention and effective treatment of cancer and other severe diseases.

The public campaign so hard for these new medicines, and with appropriate education they should accept that high-efficacy treatments come with a high price tag attached. At the same time, the public must be educated to take more responsibility for their health risks and to live disease-mitigating lifestyles.

The biopharmaceutical industry must learn to collaborate more closely with the public – from schoolchildren to patient groups – with the government, economists and regulatory authorities. The European Agency for the Evaluation of Medicinal Products and the UK's Medicines and Healthcare products Regulatory Agency (MHRA) are making strides to understand the changing economics of the biopharmaceutical industry. This dialogue must continue.

We all need to have our eyes opened to the cost of our hospitals, GPs and infrastructure as well as our medicines. We must play a part in the management of our own health to avoid a heavy chronic disease burden depleting the health budget and taking funds away from the treatment of severe, life-threatening disease. A change in the attitude of society to science and scientists would also be welcome. But above all else, we need to instil in young people a sense of the excitement of collaborative scientific investigation and an understanding of the benefits it can bring.



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CLIMATE CHANGE: GOOD SCIENCE, BAD POLICY?

Sir Crispin Tickell

In 2005, the British Government's Chief Scientific Adviser Sir David King announced that climate change was the biggest threat we faced, bigger even than terrorism. In March 2006, the Prime Minister said that "in terms of the long-term future, there is no issue that is more important than climate change". He added that in tackling it we had to act quickly and go beyond the Kyoto Protocol of 1997.

From the days of Margaret Thatcher's premiership onwards, Britain has given leadership on this issue. After the G8 summit meeting at Gleneagles in July 2005 and during the British presidency, the participants – including US President George Bush – published a declaration.

Here is the key sentence: "Climate change is a serious and long-term challenge that has the potential to affect every part of the globe. We know that increased need for and use of energy from fossil fuels, and other human activities, contribute in large part to increases in greenhouse gases associated with the warming of our Earth's surface. While uncertainties remain in our understanding of climate science, we know enough to act now to put ourselves on a path to slow, and, as the science justifies, stop and then reverse the growth of greenhouse gases."

All this sounds like a prescription for urgent political action. In fact it falls more into the category of clearing the ground for such action. There are some parallels with the process that began with the discovery by the British Antarctic Survey of damage to the ozone layer that protects the Earth from certain wavelengths of ultraviolet light. Eventually this led, not without difficulty and with opposition from vested interests, to international collaboration. These in turn led to the banning of such chemicals and a slow and patchy recovery of the ozone layer.

Of course the problems raised by climate change are much greater than those of ozone depletion. But both processes demonstrate the difficulty of crossing the long and rickety bridge between the results of scientific research and their eventual applications in policy.

There is a fundamental problem arising from the different natures of science and politics. One distinctive characteristic of science is that there are always varying degrees of uncertainty, expressed in terms of probabilities.

Second, there is the tendency of some scientists to lock themselves into specialities and thus miss the big picture. Third, there are difficulties in converting the vocabulary of science into the vocabulary of politics. Finally, there are the problems of thinking in terms of the unfamiliar, and of how to cope with phoney science such as creationism or intelligent design.

As for policy-making, few politicians have scientific backgrounds or understand scientific issues. They usually think on a short timescale within an electoral cycle. They want black-and-white answers, not shades of probability. They also find it difficult to arouse public interest, and as a result can all too easily misrepresent scientific findings and become involved in emotional side issues. Indeed, the levers of our current system of governance are often operated by people who find science alien.

Meanwhile, the science underlying climate change has become steadily clearer and more precise, particularly in its modelling of our likely future. Here the British scientific effort has been outstanding, and the Met Office's Hadley Centre for Climate Prediction and Research is probably the best in the world. The same goes for calculations of some of the likely impacts by the Tyndall Centre for Climate Change Research and the UK Climate Impacts Programme.

In general terms, climate change relates primarily to the build-up of greenhouse gases in the atmosphere, now at their highest levels for 650,000 years. We are heading back to the condition of a much warmer world some 120,000 years ago when the relationship between land and sea was very different. To understand what is happening, and current arguments about it, we have to distinguish between natural change and human-driven change.

The only invariable aspect of climate change is its variability, with big fluctuations in both the distant and recent past. There are clear tipping points when conditions have changed – sometimes rapidly, sometimes slowly – from one climatic regime to another. Key indicators of these tipping points now under anxious study include the state of the Amazonian rainforest; the direction of ocean currents, particularly in the North Atlantic; the release of methane from beneath the tundra and ocean bed; and the state of the Arctic and Antarctic ice sheets, both now melting unusually fast.

During the present warm period, beginning over 10,000 years ago, we can distinguish the effects of human-driven change. This may have begun as long as 8,000 years ago when our ancestors first cleared the forests and began agriculture on a major scale. But the process was greatly accelerated by the Industrial Revolution in Britain some 250 years ago. The volume of carbon in the atmosphere was around 190 parts per million (ppm) during glacial periods in the Earth's past, it rose to around 285 ppm during warm periods, and it is now more than 380 ppm and is rising by about 2 ppm a year.

Whatever our current carbon emissions, the delayed effect of warming of the oceans suggests that more warming is to come. And there is an unhealthy paradox. The more we clear up industrial pollution in the atmosphere – letting through more sunlight – the more we could increase warming at the Earth's surface.

To some extent, the global results are already evident. Weather is changing everywhere with some redistribution of rainfall, drought, heat and cold, and more extreme events such as hurricane intensity in the Caribbean and Pacific. Obviously this affects the ecosystems of which we are a part, with influences ranging from plants and animals to insects and microorganisms. It has an impact on the availability of fresh water, agriculture and food supplies, human health in all its aspects, and, in an increasingly urban world, the maintenance of such public services as reservoirs, sewage systems and buildings. It affects the distribution of human population, promoting the movement of refugees within and between countries. Finally, it affects business and industry, transport systems, insurance, banking and forward planning.

A myriad other environmental factors need to be taken into account when thinking about the impact of climate change. These include rates of population growth. Seventy years ago there were around 2 billion people, but now there are more like 6.5 billion and the number could rise to between 8 and 9 billion before the end of this century. There is already extensive land degradation through deforestation and over-cultivation; depletion of mineral and other resources; and accumulation of wastes. Pollution of both fresh and salt water is evident worldwide. There is a marked reduction in the diversity of living organisms. And there are new risks arising from developments in science and technology, whether in the nuclear or chemical fields, or in nanotechnology and elsewhere.

Obviously changes on this scale require a new approach. Indeed, the ground is already being cleared for eventual action. We have the Framework Convention on Climate Change of 1992; we have the Kyoto Protocol of 1997 and work in progress on its successor after 2012; and we have the successive reports of the Intergovernmental Panel on Climate Change, whose Fourth Assessment is due in 2007. For the future it is clearly essential to bring in the rest of the world if greenhouse gas emissions are to be curbed in any significant way.

No one knows the climatic effects of – say – a doubling of the usual warming rate seen in previous warm periods, with the carbon content of the atmosphere increased from 280 ppm to 560 ppm. But these effects could be devastating, particularly for countries in equatorial regions. In all this the industrial countries have to accept primary responsibility for what is happening. This means not only helping other countries, but also setting a good example in their domestic policies.

Some governments have taken action, albeit slowly and reluctantly. In practical terms this requires a fundamental switch away from fossil fuels towards new energy technologies and policies. In Britain, the process is under way with mixed results so far on carbon emissions. The US Administration is talking about reducing the country's addiction to oil and investing in alternative energy sources, but has done nothing to curb current emission rates. By contrast many individual US states are taking action on their own.

In Europe, some countries have done better than others, but there has been progress under the Carbon Emissions Trading Scheme and more realistic arrangements will be made in the future. In China, new efforts have been made to reduce dependence on native coal, to switch to nuclear power and search for renewable technologies.

But no action is likely to match the scale of the problem without a deep change in attitudes. This is particularly important in the field of economics. Conventional economics, with its measuring of costs and discounting the future, together with its emphasis on economic growth and GNP/GDP, is inadequate and misleading. A number of institutions are working to establish better systems, but the message has yet to be generally heard. The costs of changing to a low-carbon economy have been much exaggerated, particularly in the United States.

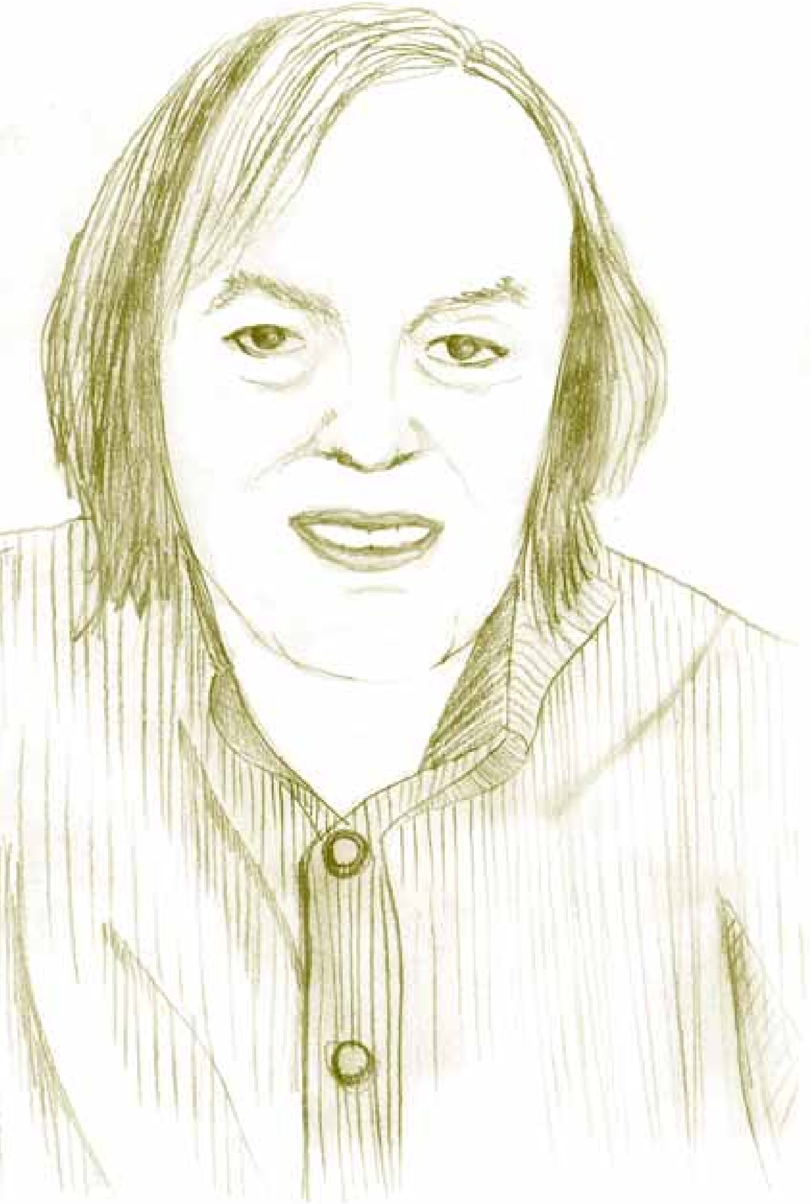
All this carries implications for the current emphasis on consumerism, which should be replaced with something based on human welfare. We need to aim for a society that is sustainable in the long term rather than one that is geared to the short-term financial gain of individuals, communities or nations.

Britain has a long and honourable record of leading across the bridge from science into politics. It was Margaret Thatcher who put climate change and other environmental issues on the agenda of the G7 meeting in London in 1984. It was her speech to the Royal Society in 1988 that laid out the problem in general terms, underlining that we were not so much owners of the Earth as brief tenants with major maintenance responsibilities. It was she who in 1989 gave the first speech on climate change by a head of state to the UN General Assembly, and she was one of only four heads of state to attend the Second World Climate Conference in Geneva in 1990. The priority she established for climate change has been maintained in varying measure by the two prime ministers who have succeeded her.

Changing our way of thinking is always difficult and sometimes painful. At present we suffer from a kind of intellectual sclerosis.

There has to be a demonstration at all levels of what can and should be done. Government departments, the research councils, the Royal Society, the Royal Institution, Parliamentary committees and the whole apparatus of non-governmental organisations, universities, local and regional authorities, business and industry have major responsibilities in persuading public opinion of the significance of climate change. In doing so they have to bring out the interconnectedness that underlies the whole issue, and which is the prerequisite for action.

We delay at our peril.



Colin Pillinger is Professor of Planetary Sciences at the Open University and was lead scientist for the Beagle 2 mission.

SPACE:
THE GREATER THE OBSTACLE, THE GREATER THE GLORY

Professor Colin Pillinger

Edward Leigh, the chairman of the parliamentary Public Accounts Committee inquiry into the loss of the Mars lander Beagle 2, thanked me in his summing-up for inspiring the nation, even if it cost £45 million.

I counted that as a victory, since during the proceedings he had rebuked me: “You should have been 95 per cent certain it was going to work if you were spending public money.” I was shocked and retorted: “It would have been done already if it was that easy, and if it was that easy it would not have been exploration. We would not have inspired anyone.”

But maybe the Establishment is changing its spots. The government recently suggested that its Home Office civil servants take more risks. Officials at the British National Space Centre and the Department of Trade and Industry certainly did take risks with Beagle 2. The question is, should they take such risks again?

When Beagle 2 attempted its landing on Christmas Day 2003, 66 per cent of all missions to Mars had ended in tears. Many more missions did not even get off the drawing board before those championing them gave up.

Before NASA’s Mars Exploration Rover mission landed a few days into 2004, the agency’s success rate was not even 50 per cent: only three spacecraft had achieved their goal out of the previous eight attempts. To succeed with its rovers Spirit and Opportunity, NASA learned some hard lessons from those failures, as indeed NASA always does. And that’s the point about failure: it is the essential ingredient of learning.

Read any book about a successful entrepreneur and you will find quotes such as: "Success is 99 per cent failure." This one is attributed to Soichiro Honda, founder of the Japanese car giant. When entrepreneurs like Bill Gates, Stelios Haji-Ioannou and Richard Branson started out they probably counted themselves lucky to achieve a 10 per cent success rate for their business ideas.

Scientists should be more comfortable with risk. The renowned 19th century chemist Sir Humphry Davy said: "The most important of my discoveries have been suggested by my failures." In scientific experiments you often learn far more from things you did not anticipate, and experiments are the fount of new knowledge.

My best example of a totally unexpected result became the raison d'être for Beagle 2. One day in 1984, a student in my lab heated the Martian meteorite Nakhla to see if it contained trapped carbon dioxide gas from the planet's atmosphere. When heated, the meteorite certainly emitted CO2 but at all the wrong temperatures. Rather than releasing trapped gas from the planet's atmosphere, we had discovered that this sample of Martian rock contained carbonate minerals.

Petrologists had been looking at Martian meteorites for 150 years and no one had noticed carbonates, which are evidence that water once trickled through the rock. They all thought heating was a daft way to look for carbonates. Nevertheless, our 'mistake' led to the finding of organic matter and in turn to the discovery of what might be fossilised life forms.

The suggestion that there might be life on Mars rekindled public interest in the Red Planet following a long hiatus that started when the Viking missions effectively wrote it off as desolate, depressing and sterile. Twenty years after Viking, when President Bill Clinton stood on the White House lawn in 1996 and announced the discovery of putative Martian fossils, CNN ran with the story for 1 hour 40 minutes without a commercial break and the infant World Wide Web crashed.

Without the initial stimulus of trying to confirm the UK's Martian meteorite results and seeking further evidence of past life on Mars, Beagle 2 would never have existed. Neither would the mass spectrometer group at the Open University be working on miniature mass spectrometers for early medical diagnosis, funded by the Wellcome Trust as a spinoff from the Beagle 2 mission.

Clearly Beagle 2 did not live up to expectations, but we profited from the experience by learning from our mistakes. NASA always gets back on the metaphorical horse before it loses its nerve – but it does so while trying to work out how it fell off in the first place.

The Beagle 2 team did just that. Having been through all the design figures and the tests it had done, the team concluded that there was no reason to suppose equipment failure was responsible for the loss. However, we came up with a long list of lessons that needed to be learned: things we could do better if we were in control of our own destiny. Beagle 2 has been described as an add-on 'instrument' to the main Mars Express mission of the European Space Agency (ESA), a situation that contributed to the failure. It is difficult enough landing on Mars without having someone else decide the priorities.

As it turned out we could not get back on the horse after this mishap: unfortunately for us someone decided to take it elsewhere.

Nevertheless, no other enquiry looked for the lessons to be learned in more detail than ourselves. The general consensus was that we did not have enough money to make the mission work. This is incorrect. The problem was that we did not have the funding at a sufficiently early stage to mitigate any risks.

In a couple of months' time, cameras aboard NASA's Mars Reconnaissance Orbiter will attempt to discern whether our best guess of where Beagle 2 might be is correct. If it can be shown that the remains of the spacecraft are in a tiny crater at the centre of the target landing region, then we will know just how close we came to success.

Confirmation of Beagle 2's final resting place would give answers to questions such as whether it was descending towards the surface slightly too fast, as a result of the unexpected thinness of the atmosphere. Or did a freak accident such as a sidewise impact with the crater wall put paid to the mission? Most importantly it would give us an idea of what worked and what did not, saving time and money for the future.

Regardless of whether or not the lander is found, the UK should try again. One of the successes of Beagle 2 was that it motivated the government to provide new money for the British space programme – specifically, money to join ESA's Aurora programme. However, the problem with Aurora is that there is only one approved mission: ExoMars.

Since it was adopted in 2003, ExoMars slipped from a 2009 launch to a 2011 launch, and thence to a 2013 launch. The later start date entails a two-year flight time, so it will now be 2015 before the craft lands. In addition, the 2013 launch and longer flight time have meant the scientific payload has been reduced to allow more fuel to be carried.

In its present form there is no provision for a data relay with ExoMars, which means the mission is dependent on NASA for returning the science. If ESA has to build its own orbiter then, yes, it can take some more science, but that will cost more money, more time, and will necessitate a bigger Ariane V rocket to launch it.

Before we know where we are it will be 2018 before the craft lands. By then, NASA will have sent spacecraft to Mars in 2007, 2009, 2011, 2013 and 2016 to address questions about life. You cannot discover life twice. And what happens if this single ExoMars mission fails?

Even more frustrating, by 2015 an opportunity to inspire the younger generation of this country to pursue careers in science and technology – the reason Beagle 2 got the money it did – will have been forfeited.

We have been told there were plenty of children who got up before 6am on Christmas morning 2003, to ask not "Where are my presents?" but "What happened to Beagle 2?"

By 2015 every one, five years old and above, will have passed through school and left without being exposed to the inspirational spectacle of the UK at the forefront of the search for life on Mars. There will, of course, be other space missions, but nothing has quite the same appeal as the Red Planet.

What Britain needs is a Mars mission to bridge the gap between Beagle 2 and ExoMars. I do not accept that we cannot afford it. We are the sixth richest nation in the world but only the 17th in terms of space expenditure. We invest annually around £200 million of government money in space, but the UK space industry as a whole contributes £4.8 billion to our GDP. Surely that's a good return.

Why not then put in £500 million, creating more jobs and greater profits and all the spin-offs that go with a space mission. Never forget that the cost of the hardware that goes into space is negligible compared with spending on all the expertise that stays on the ground, which is never at risk. But to recover the value of what has been achieved, even from a mission condemned as a failure, you have to use it somewhere else, not jettison it.

At the Farnborough International Air Show this year, Lord Sainsbury signed a concordat with the Algerian Space Agency. Yes, you read that correctly. The Algerian Space Agency. Why doesn't Britain have its own space agency? Such an agency would need a budget big enough to buy into programmes like ESA's Aurora, with enough left over to collaborate with other agencies: NASA, Russia and those emerging in the Far East.

And to really make a difference, why not fund a pioneering programme involving smaller, faster, cheaper, better missions? We might lose a couple early on, but later successes would bring huge rewards on a short timescale. As Lord Sainsbury said after Beagle 2: "We shouldn't only do low-risk projects."

Here's a final piece of advice to risk takers: you have not really failed until you give up. I have not given up. In the words of the 18th century philosopher David Hume: "The greater the obstacle, the greater the glory in overcoming it."

TALKING TO THE PUBLIC: LESSONS SCIENTISTS NEED TO LEARN

Professor Derek Burke and Professor Michael Elves

Who can blame the public for being so ambivalent about science? The marvels of modern medicine are received with gratitude and the discoveries of particle physicists with awe, but the unexpected side-effects of drugs are met with horror and the prospect of more nuclear power stations with misgivings.

With so many different issues being discussed by so many people with different agendas, it is little wonder the public do not know whom to trust. And information comes in so many forms, in scientific papers, public lectures, newspaper articles, websites, podcasts and blogs.

Research by the pollsters MORI in 2003 showed that most people do trust scientists, but that those working for industry and government are trusted less than those working in universities or for charities.

Professor Derek Burke chaired the Advisory Committee on Novel Foods and Processes, 1988-1997, and was Vice-Chancellor of the University of East Anglia, 1987-1995. He was a member of the Nuffield Council on Bioethics Working Party on Genetically Modified Crops, a specialist adviser to the House of Commons Select Committee on Science and Technology, and a member of the EU-US Consultative Forum on Biotechnology.

Professor Michael Elves is a former Director of Scientific and Educational Affairs at Glaxo Wellcome. He was a specialist adviser to the House of Commons Select Committee on Science and Technology between 1997 and 2005.

The authors would like to thank Frances MacGuire of the RSPB for her help researching this article.

When the public is weighing up whether to trust scientists, it makes judgments about their competence, credentials, experience and honesty, and also where their funding comes from.

But people are concerned too about how science will affect them, their families and communities. So when they have little or no input into decisions about something that they believe will affect their lives, such as the siting of a hazardous waste incinerator or a mobile phone mast, no one should be surprised if there is opposition and distrust. And if people feel that they are being used as guinea pigs, or think that the environment is being used carelessly, they will no longer accept 'expert views' without question.

Scientists find this sort of opposition hard to handle. They are used to disagreeing passionately among themselves, for new science is rarely as cut-and-dried as the media make it out to be. But they are comfortable with being 'critical realists' – realists because they believe that the universe can be understood by reason and empiricism, and critical because they realise that their descriptions of the world are never exhaustive and will always fall short of complete objectivity. So scientific conclusions are provisional, and can be reviewed or even substantially changed if a new piece of evidence or insight emerges.

The public and policymakers want certainty. Scientists may be comfortable with the gradual accumulation of knowledge, punctuated by occasional setbacks and breakthroughs, but the public confuses this lack of definitive conclusions with unreliability, which can lead to a lack of confidence in what scientists are saying. Meanwhile, policy makers may be under pressure to make quick decisions and do not have time to wait for more information.

While some areas of science enjoy almost universal public support, others have become much more controversial in recent years.

Take immunisation. For decades the use of vaccines was generally accepted as an effective tool for the control of serious infectious diseases. The success of the smallpox immunisation campaign was widely acclaimed, for example. But in some quarters, immunisation is now treated with caution and even mistrust.

So when an alternative viewpoint to that of the mainstream scientific community – about the risks and benefits of the measles, mumps and rubella (MMR) triple vaccine – was widely aired by the media, some parents believed they faced a dilemma. Should they accept the established view or take heed of a note of warning? For many the decision involved climbing a steep learning curve to understand herd immunity, the risks of anaphylactic shock and the pros and cons of single vaccines versus MMR.

But while parents struggled with this new-found responsibility, the risk that a serious public health problem would re-emerge increased, with significant rises in cases of measles in some areas as the level of immunity in the population declined.

When scientists are caught up in a media storm of this sort, they tend to retire baffled and frustrated, not understanding why what they have done for the genuine good of the community has been rejected. The result is that the public is left to resolve conflicting messages without their help.

Over the years, we have seen various attempts to bridge this gap between the scientific community and the general public. First there was a campaign to promote the 'public understanding of science', an approach that now seems patronising with the scientists trying to explain, in the simplest terms they could muster, why they were right and the public was wrong.

This was superseded by 'dialogue', using public opinion surveys, citizens' juries, focus groups and so on. The assumption was that by bringing together scientists and representatives of the public, reasonable men and women would arrive at a consensus solution that their peers would accept and the politicians could then adopt. But with many voices representing deep-seated differences this too has floundered.

There are several reasons why the work of scientists remains inaccessible to many members of the public. Chief among these are communication difficulties. Scientific jargon, although convenient for scientists communicating among themselves, is often impenetrable to the general public, and attempts to explain complicated ideas often emerge as patronising simplifications. But there is another problem, which is that scientists and the public weigh up risks in different ways.

Scientists like to imagine they are driven by pure reason. They are certainly constrained by evidence, but they carry into these debates a series of unspoken values of their own, for example that new technologies can nearly always be used for the common good, that they can be controlled, and that nation states will obey any international regulations. There is also a belief that small risks, even if they carry serious consequences, can be set aside.

But science operates in the real world of competition and conflict, human error and imperfect understanding. In this world, scientists' assumptions don't always hold true. Scientific understanding evolves and so too must scientists. They have a responsibility to recognise the limits of their work, and how it will be used and portrayed by politicians and policymakers.

Scientists believe that uncertainties can be resolved primarily by observation and experimentation leading to the accumulation of evidence. But how reliable is the evidence that scientific enquiry yields?

It is striking that science does eventually reach a consensus on disputed issues, which is not the usual rule in human endeavour. What is more, the answers obtained from quite different lines of inquiry are consistent rather than contradictory. In medicine, for example, evidence from physiology, biochemistry, genetics and clinical observation can be drawn together to give a single consistent picture. It might be argued that there are other explanations for this consistency, such as social pressures within the scientific community, but it is hard to believe that so many different persons, in so many different cultures and at so many different times, should produce data that are ultimately consistent.

Scientists assess the impact of developments or discoveries on the basis of risk, which is usually defined as hazard multiplied by the probability of that hazard occurring. The public, however, reaches its conclusions in a different way.

The most important factor for non-scientists is whether they trust those who have assessed a new technology and whether they feel they have had an opportunity to influence the outcome.

They are less used to dealing with uncertain conclusions and their concerns are fuelled by the current obsession with detailed ‘risk management’ for almost all activities outside the home.

The public’s reaction to risk can manifest in emotions such as outrage, dread and stigmatisation. Outrage at the activities of some big drug companies and medical researchers’ use of animal experimentation; dread at the prospect of a nuclear power station explosion; and stigmatisation of technologies such as food irradiation.

Surprisingly, the risks that the experts think will cause problems are usually not the ones that actually upset people. This may be because the public often measures risk as hazard plus outrage. So scientists will never be able to predict how the public will react to new risks by only consulting other scientists and technologists. They have to learn the lesson that the public’s perception of the risks posed by a new technology is as important as any technical assessment.

Coupled with this declining public faith in the reliability of scientific evidence and growing tendency to question it has come a greatly increased emphasis on consumers’ ‘right to choose’. Whether a choice is seen by others as rational or irrational is irrelevant – that choice must be respected. This can slide into a dangerous attitude about scientific evidence, namely that people have the right to accept or reject it according to their personal whim. According to this way of thinking, evidence carries the same weight as opinion. By contrast, at its best science is not an article of faith but is based on evidence that can be corroborated by others.

The media remain among the most powerful influencers of public opinion. Some scientists still naively think that the media exist simply to explain their findings and are upset when their discoveries are criticised or inaccurately presented. But the media does not exist as a ‘voice for science’. Print and broadcast journalists are influenced by many other players including government, industry and single-issue pressure groups, and their own pay-masters which are becoming increasingly important in forming attitudes. So to rely on the media to sell a message is usually to rely on a blunt tool over which one has little control.

Another persistent misconception among scientists is that they are communicating with a single ‘public’, when in fact communication specialists recognise that there is no such thing. The latter tailor their message to a range of audiences and use different approaches depending on the audience. To ensure their message comes across and to anticipate counter-arguments and opinions, scientists need to be just as savvy.

The take-home message? Don’t pretend your work is simple and don’t promise too much. Tailor your message to the particular audience and recognise that nowadays, when new technologies are being considered, the public can no longer be treated as passive recipients of the fruits of your endeavours.

Ben Goldacre is a medical doctor and writes the "Bad Science" column for The Guardian.

MEDIA SCARES:
WHERE ARE ALL THE SCIENCE JOURNALISTS?

Dr Ben Goldacre

You could spend your whole life talking to the media about scientific and medical research, and yet never meet a single one of the incompetent and nefarious journalists who were driving the MMR vaccination "scandal" for so long. If there is one insight which could improve communication between scientists, journalists, and the public, it is the simple observation that science journalists do not cover major science news stories.

During the crucial two days after the GM 'Frankenstein Foods' story broke in February 1999, for example, not a single one of the news articles, opinion pieces or editorials on the subject was written by a science journalist. Only 17 per cent of all the feature articles were written by science journalists.

Similarly, a survey in 2003 by the Economic and Social Research Council during the crucial period of the MMR crisis found that only 20 per cent of stories about the measles, mumps and rubella vaccine were written by specialist correspondents. Parents found themselves in the strange position of receiving advice on complex issues of immunology and epidemiology from lifestyle columnists.

The sidelining of specialist journalists, when science becomes front-page news, and the fact that they are not even used as a resource at these times, has predictable consequences. First, the scientific content of stories – the actual experimental evidence – is brushed over and replaced with didactic statements from authority figures on either side of the debate. This contributes to a pervasive sense that scientific advice is somehow arbitrary, and predicated upon a social role – the 'expert' – rather than on transparent and readily understandable empirical evidence.

Worse than this, the case against the MMR vaccine consisted of emotive appeals from parents, a lionised 'maverick' scientist ("a handsome, glossy-haired hero to families of autistic children", according to The Daily Telegraph), and Tony Blair's refusal to say whether his baby had received the vaccine. This last factor was shown in survey data to be the single most well-recalled fact about the story of the supposed link between MMR and autism.

A reasonable member of the public, primed with such a compelling battery of human narrative, would be perfectly entitled to regard any expert who claimed MMR was safe as thoughtless and dismissive, especially if that claim came without any apparent supporting evidence.

The solution is clear on one level: make the science part of the story, and have it written by specialist journalists.

There is nothing particularly complicated about the scientific evidence on either side of the MMR safety debate. As a one-sentence example, it is a central tenet of the anti-MMR lobby that the vaccine is responsible for the increasing incidence of autism, but in the mid-1990s Japan stopped giving MMR entirely, and yet rates of autism have continued to rise there. And yet, constructing the preceding sentence was in no sense a challenge to my "science communication skills". How else can we explain the conspicuous absence of such information, even now, from routine MMR coverage?

Non-specialist journalists may be unaware of background data, and there may be scope for more good briefings here. But there is a more fundamental problem about how information is critiqued. Journalists are used to listening with a critical ear to briefings from press officers, politicians, PR executives, salespeople, lobbyists, celebrities and gossipmongers, and we don't like to be seen as passive mouthpieces for other people's briefings. Consequently journalists often show considerable scepticism.

This is where the sidelining of specialist journalists is so damaging. They have the knowledge to critically appraise a piece of scientific evidence. But instead, while they are left writing "scientists have found the formula for the perfect boiled egg", their more glamorous colleagues cover MMR and GM. These generalists critique scientific evidence in the only way they know how: by questioning the character and vested interests of the source, rather than appraising the science.

(It's worth noting that the anti-MMR lobby are said to target generalist journalists where possible.)

There are other more subtle indices of how little insight media commentators have into the basic processes of science. Newspapers often refer to original academic research as being "published in the journal New Scientist", a popular science magazine that merely reports on such work.

There is also a conspicuous over-reliance by newspapers on scientific research that has not been published at all. This is true of almost all of the more recent headline stories on new MMR research. One regularly quoted source, Dr Arthur Krigsman, has been making widely reported claims for new scientific evidence on MMR since 2002, without publishing his work in an academic journal. Similarly, the unpublished 'GM Potato' claims of Dr Arpad Pusztai created Frankenstein Food headlines for a whole year before the research was finally published, and could be read and meaningfully assessed.

Sometimes it is hard to ignore the possibility that the media may deliberately exploit the technical complexity of an issue to create headlines. It transpired this year, for example, that every single tabloid story about an "undercover MRSA swab scandal" had got its results from one man, with no microbiology training or knowledge, a non-accredited mail-order PhD from an American correspondence course, and a laboratory consisting of kitchen fittings in a garden shed.

His results could not be replicated by other labs and the newspapers were told he and his methods were unreliable. He mispronounced the names of common bacteria. Yet the tabloid press described him as "Britain's leading medical microbiologist". When he finally gave over his MRSA samples for proper forensic analysis, the inevitable false positives were finally exposed, although not by the tabloids.

Another background issue here is the media's tendency to make medical and scientific stories fit the simple dramatic narratives of "miracle cure" and "hidden threat", which were viable models until relatively recently. Between 1935 and 1975, almost everything we associate with modern medicine was discovered: antibiotics; dialysis; transplants; intensive care units; CT scanners; heart surgery; almost every major class of drug, and more. As well as the miracle cures, science was finding the hidden killers that the media still pine for. In the 1950s, for example, and to everybody's genuine surprise, smoking turned out to cause 97 per cent of all lung cancers. These are now widely regarded as the halcyon days of medicine. By contrast, medical science now moves at a slower pace, in subtle refinements. There has been a huge reduction in premature deaths since 1975, but it has come about through an accumulation of marginal gains, which do not grab headlines.

Similarly, there has been an acceleration in complexity. Fifty years ago you could sketch out how an AM radio worked on the back of a napkin, using a basic school-level knowledge of science. You could fix your own car and understand the science behind most of the everyday technology you encountered, but this is no longer the case. Technology has become more difficult to understand and explain, and everyday gadgets have taken on a "black-box" complexity that can feel both sinister and intellectually undermining.

This has created further problems. As someone with an interest in science who buys newspapers and watches TV, what disappoints me most is not the foolish errors in media coverage of science, but how little science there is for me. I'm not an expert in all forms of science – nobody is – but I'm interested in reading about most of it. While the media and the 'engagement' lobby are trying desperately to seduce a disinterested public, the eager audience – the people with an interest in science, and some background knowledge, who could act as spokespeople for science in the pub – are neglected.

In fact, I would argue for a "Viral Model" of promoting science in society, focused on giving challenging and informative material to people who already have a modest background and interest in some form of science, and who can understand this information, and advocate for it in whatever their community might be. You could be wrong about MMR in an almost infinite number of different and varied ways, and people are best disabused of their ignorance in a tailored one-to-one discussion.

There is a popular idea amongst those ignorant of science that somehow "scientists", perhaps meaning "anyone who did a degree that wasn't in the humanities", must know the entire canon of all the science in the world. This is of course not the case, but those with a science background will retain a good chance of understanding complex material, as well as an interest and passion for it.

The extent to which science coverage is dumbed down becomes clearer when we compare it with the finance pages, the sports pages, and the literary supplements, where arcane knowledge and complexity are worn as badges of honour. It is hard not to see this as a reflection of the demographic of the kind of people who work in the media. And meanwhile the word 'biophoton' can appear in newspapers – but only when used incorrectly – on the alternative health pages.

Most attempts to make science popular by presenting everything as "news" or a "breakthrough" strike me, at any rate, as trite and undermining. The newspapers' recurring favourite is "scientists have found the formula for". Recently the newspapers have covered the formulae for the perfect way to eat ice cream (A x Tp x Tm/Ft x At + V x LT x Sp x W/Tt = 3d20), the perfect TV sitcom (C = 3d[(R x D) + V] x F/A + S), the perfect boiled egg, love, the perfect joke, and the most depressing day of the year ([W + (D - d)] x TQM x NA). These are stories without any content, and a popular way to reinforce a parody of science as the preserve of irrelevant, detached boffins.

In the same bag we might place stories about (unpublished) research claiming that watching Richard and Judy can improve your IQ more than exercise or caffeine: a science story that was thought worthy of an editorial in The Independent on Sunday, no less.

And while this material grabs the headlines, we are in danger of daydreaming through some of the most important technology-driven cultural and political changes for a generation.

In a knowledge economy, issues surrounding intellectual property rights are key, and yet in 2001 the European Union Copyright Directive – potentially a land grab on a par with the Enclosure Act – passed through largely unscrutinised by the popular media. Likewise the open-source software movement is making huge contributions to the way we collaborate and use computers, with significant ramifications especially for the developing world, but in the midst of a mainstream media blackout. Similarly, the linkage of personal information between different databases is a far greater threat to privacy and liberty than ID cards, but is a more complex and less tangible issue, and so it is consequently ignored.

This is all a function of the lack of 'geek' fluency in media circles. Problems that are so complex and deeply entrenched have no simple solution, but there is so much that scientists and journalists could do to improve communication, at very little personal cost.

Scientists and doctors, for example, can take care to be clear about the status and significance of their work when talking to journalists. Are the results preliminary? Have they been replicated? Have they been published? Do they differ from previous studies? Can you generalise, say, from your sample population to the general population, or from your animal model to humans? Are there other valid interpretations of your results? Have you been clear on what the data actually show, as opposed to your own speculation and interpretation? And so on.

It is naive to imagine that such basic guidelines will be heeded by the irresponsible characters on the fringes who produce so much media coverage. However, they do represent best practice, and so they are always worth reiterating: they deserve to be incorporated into codes of practice from professional bodies and research funding bodies.

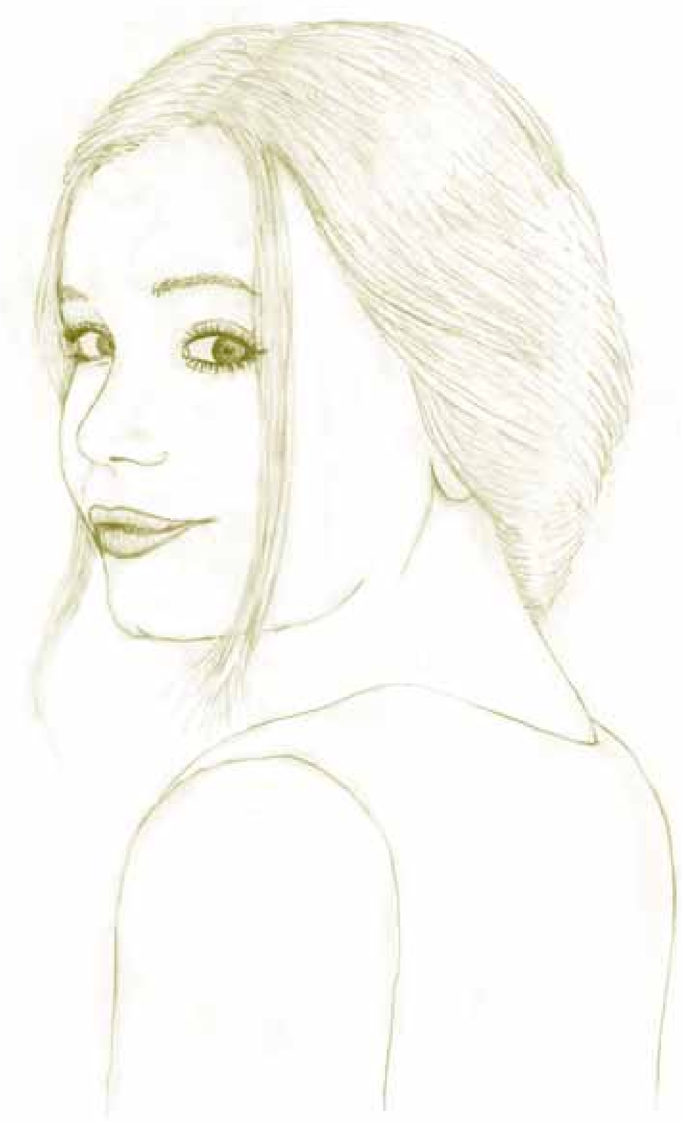
Scientists and doctors would also be well advised to take some even simpler steps: to think through the possible implications of their work, inform interested parties before publication, and seek advice from colleagues and press officers. This advice and more is all covered in the Royal Society's excellent Guidelines on Science and Health Communication, published in 2001.

Journals, too, can take a lead, since they often produce the promotional material for research. Risk communication is a key area here, and although it is tempting to present risk increases, and indeed benefits, using the largest single number available (the "relative risk increase") it is also useful to give the "natural frequency". This figure has context built-in and is more intuitively understandable: it is the difference between ibuprofen causing "a 24 per cent increase in heart attacks" (the relative risk increase) and "one extra heart attack in every 1,005 people taking it".

Similarly useful guidelines have been produced for journalists by several sources (including the Royal Society, the Social Issues Research Council, and the Royal Institution) over several years but these remain essentially ignored. They represent what any specialist science journalist would consider to be the most basic skills of their profession, such as checking the trustworthiness of sources, the validity of the research methods, the status of publication, and the credibility of any conclusions drawn.

The key problem for the public misunderstanding of science is that these science journalists are ignored, and sidelined, when they are needed the most.

And the single most important thing we can do to change this is simply to notice, and point it out, at every available opportunity.



Mia Nybrant is Director of Newton's Apple.

A VISION

Mia Nybrant

Four core objectives for Newton's Apple

With this collection of essays, Newton's Apple set out to identify a scientific vision for the 21st century. People from widely different fields of expertise, age groups and perspectives were invited to contribute, but they share a passion for science and a belief in the central role that it can play in society. Some of the challenges they highlight are very specific, such as the funding of PhD programmes, climate change, individualised medicine and the nature of science journalism. However, they all have broadly four themes in common:

• **Young minds needed.** More young people must be encouraged to take up science education to ensure that the UK's science base thrives in the future.

• **Funding and careers.** The funding and careers structures supporting the UK's science base need urgent reform if they are to continue contributing to the nation's wealth and maintain its competitive edge.

• **Science fact not fiction.** Non-scientists who communicate science to society, primarily through the media, require a greater appreciation of its methodology and limitations. This is essential if they are to avoid promotion of "phoney" science which can lead to scare stories and if the public is to "buy in" fully to scientific and technological developments.

• **Long-term action.** Scientists of all age-groups at the cutting-edge of their fields, need to have access and provide input to cross-disciplinary collaborative efforts in addressing the challenges we face, especially in the fields of medicine, the environment, infrastructure, food and energy supply.

Young minds needed

To ensure that the UK's science base, both academic and industrial, continues to thrive, there must be a concerted drive to encourage more young people to take up science. The proportion of children choosing to study scientific subjects is declining. There is a shortage of well-qualified science teachers, particularly in the physical sciences. Teachers often face excessively large classes and the classroom environment is often inadequate, particularly in terms of provision for laboratory work and lack of out-of-classroom experiences.

All these factors converge at a time when science has become one of the cornerstones of the global knowledge economy. Parents, politicians, schools (through out-of-school classes and clubs) and the media must inspire young people to take up science. Skilled science teachers should be remunerated fairly and be provided with a working environment in which they can inspire their pupils.

Funding and careers

Careers in the sciences must be made more financially rewarding and secure, putting them on a par with other options available to school and college leavers. An urgent review of the funding system and careers structures in the sciences, engineering and technology must take place:

• Research councils and other funding bodies need to support more blue-skies research and not only projects that have commercial potential or that support government policy aims.

• The length of grant-funded research projects (often three years) should be increased to enable scientists to achieve their goals and not spend so much of their time preparing for the next grant application.

• Incentives and programmes are required to foster collaboration between academia and industry, and between researchers across disciplinary and national borders.

• The regulatory framework for R&D has to be such that companies are attracted to invest in the UK's economy and employ its people.

Science fact not fiction

The benefits of science, engineering and technology must not get lost, misrepresented or misinterpreted in the ever-increasing flow of information. With the internet, 24-hour news channels and an increasingly competitive market between all forms of media, there is a danger that dramatic headlines become more important than providing an accurate picture of what is really happening in the world of science.

At Westminster, meanwhile, politicians are risk-adverse and prone to adopt short-term strategies. They may also find it difficult to communicate scientific findings to the public and explain why certain kinds of evidence but not others have been taken into account in policy formation. They often lack the knowledge and tools to do so. With so many different intermediaries and competing interests, ensuring that science is communicated accurately at all times may seem an impossible task, but the problem cannot be ignored.

A number of key questions must be addressed:

• How can we get across the message that there is no such thing as absolute freedom from risk, and indeed that acceptance of a limited amount of risk is essential in all human endeavour?

• How can we promote a greater appreciation of science and the scientific method among policy makers and politicians?

• How can journalists and other communicators effectively drive home the fact that science is an essential activity for economic growth, the environment and general health, not an isolated, fringe activity?

• How can we make people understand that science is incapable of answering questions with 100 per cent certainty, but that it is the most accurate tool we have?

• And how can effective, high-profile public awareness campaigns on aspects of science like vaccination, diet and the energy mix, be developed that reach their target audiences and make a real change in people's attitudes?

Long-term action

If the UK is to continue to contribute to worldwide efforts to tackle the major challenges of the 21st century, including global warming, epidemic diseases and poverty, scientists of all age-groups who are at the cutting-edge of their fields need to be provided access to the various efforts that Government, Parliament, learned societies, economists, investors, industry, multilateral and non-governmental organisations are carrying out to identify longer-term approaches to analysing these issues.

Each of these groups has a major responsibility to recognise and embrace what science can contribute. It is only natural that they should have different priorities, different short and long-term perspectives, and different ways of working and communicating. However, without the input of science into such an analysis and effective collaboration, nothing of substance will come to fruition.

To this end, Newton's Apple hopes to provide a neutral forum where these groups can come together to try to identify some of the solutions for the 21st century and beyond.

newton's apple

A new relationship between Science, Society and Politics

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