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THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

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

New centres for manufacturing research

Four new research centres, that will develop new ways of manufacturing in the fields of electronics, laser use in production processes, medical devices and food production, have been awarded a total of £21 million by the Engineering and Physical Sciences Research Council (EPSRC) as part of a £45 million package of investments in manufacturing research by the Government.

The new Centres will involve academics from 15 universities across the UK and over 60 project partners from industry. EPSRC currently supports 12 centres across a wide range of fields, from Additive Manufacturing through Industrial Sustainability to Continuous Manufacturing and Crystallisation. These four new centres bring the total to 16. They will all be in operation by October this year.

EPSRC's Chief Executive, Professor David Delpy said: "EPSRC Centres of Innovative Manufacturing are building on previous investments we have made in the research base and combining academic innovation with industry knowledge. These new centres are in areas that are strategically important to the UK and the work there will push research boundaries and drive growth."
www.epsrc.ac.uk

Catapult appointments

New appointments have been confirmed by the Technology Strategy Board for two of the new Catapult technology and innovation centres.

The Future Cities Catapult will be chaired by former Government Chief Scientific Advisor Sir David King. Its Chief Executive will be Peter Madden who joins the Catapult team from Forum for the Future, a non-profit organisation working internationally with cities, governments and leading businesses to innovate sustainable products and services where he was Chief Executive.

Will Whitehorn has been announced as Chairman of the Transport Systems Catapult. He is best known for his role at Virgin to establish the company's original train franchise and more recently as President of Virgin Galactic where he pioneered the development and concept of commercial spaceflight. The Chief Executive is to be Steve Yianni, who joins the Catapult from Network Rail. As Technical Director he has been pivotal in delivering the 30-year rail technical strategy, which received industry-wide recognition. He also contributed to the engineering success of the Ford Motor Company and JCB with over two decades of experience in leading manufacturing organisations.
https://catapult.innovateuk.org

Government adopts Heseltine recommendations

The Government has confirmed that it is accepting in full or in part 81of Lord Heseltine's 89 recommendations to advance the process of decentralisation, unleash the potential of local economies, strengthen partnerships with industry and foster economic growth. In five cases the Government has taken a different view: its formal response sets out why. Three recommendations on the content of the Single Local Growth Fund will be addressed at the Spending Round in June 2013.

The core proposition of Lord Heseltine's report is a decentralised approach that breaks Whitehall's monopoly on resources and decision making, and empowers Local Enterprise Partnerships (LEPs) to drive forward growth in their local areas. Alongside this, Lord Heseltine makes a number of recommendations that strengthen the underpinnings of long-term growth, from changes to the way in which Whitehall supports growth, to strengthening partnerships between government and business, and business and education.

Following a commission from the Prime Minister, Lord Heseltine presented his report *No Stone Unturned* to the Chancellor and the Secretary of State for Business, Innovation and Skills on 31 October 2012. The Government's response was published on 18 March.
www.hm-treasury.gov.uk/d/PU1465_Govt_response_to_Heseltine_review.pdf
See also pages 10-14 of this issue.

Top British innovations

Alan Turing's Universal Machine has been voted the greatest British innovation of the past 100 years, in an online vote. Imagined by WWII codebreaker and mathematician in the 1930s, the Universal Machine provided the theoretical basis for all modern computing.

X-ray crystallography – which revealed the hidden atomic structure of compounds and celebrates its centenary this year – and the iconic Mini rounded out the top three greatest innovations from a shortlist of around 100.

The shortlist of innovations in the Great British Innovation Vote was compiled by the GREAT Britain campaign, the Science Museum Group, the Royal Academy of Engineering, the Royal Society, the British Science Association, the Department for Business, Innovation and Skills, and Engineering UK. Over 50,000 votes were cast.

"The vote has been an exciting battle between the tangible products of British ingenuity, such as Mallard and the World Wide Web, and innovative ideas, such as Turing's Universal Machine," commented Roger Highfield, Director of External Affairs at the Science Museum Group. "We've started an interesting public debate about innovation, particularly how creativity and technology feed into scientific discoveries."

Ionic liquid chemistry was voted as the innovation most likely to shape the 21st century.
www.topbritishinnovations.org

Building the nuclear supply chain

The importance of creating a viable nuclear supply chain to support a new fleet of power stations and deal with the maintenance and decommissioning of existing plants has been recognised in the award of new funding announced at the end of March.

The funding will support 36 projects across the UK in developing new technologies for the construction, operation and decommissioning of nuclear power plants. This brings together over 60 experienced organisations including Laing O'Rourke, Sheffield Forgemasters and EDF. They will work alongside innovative small and medium sized enterprises (SMEs) and universities.

The £18 million joint funding between the Technology Strategy Board, the Department of Energy and Climate Change (DECC), the Nuclear Decommissioning Authority (NDA) and the Engineering and Physical Sciences Research Council (EPSRC) is expected to leverage in an additional £13 million.

By 2030 it is forecast that globally there will be £930 billion investment in building new reactors and £250 billion in decommissioning those that are coming offline. The nuclear new build programme in the UK alone could generate up to 40,000 jobs at its peak, the Government estimates. The nuclear industrial strategy launched at the same time sets out the basis for a long-term partnership between Government and industry to exploit those opportunities.
www.gov.uk/government/news/31-million-injection-for-new-nuclear-technology-in-the-uk

Feeding, fuelling and healing the world

George Freeman

George Freeman is MP for Mid-Norfolk, Government Adviser on Life Sciences and Chairman of the All-Party Parliamentary Group on Science and Technology in Agriculture. Before entering Parliament in 2010 he had a 15 year career in biomedical venture capital. As Government Adviser on Life Sciences he has worked closely with the Department for Business, Innovation and Skills (BIS) and the Department for Environment and Rural Affairs (Defra) in coordinating the Government's Ag-Sci Strategy. He has spoken and written widely on the potential of UK agricultural science, technology and entrepreneurship to lead a sustainable economic recovery.

The developing world (the 'BRICs' and next 11 economies identified by Jim O'Neill at Goldman Sachs) will in the next 50 years go through what the developed world has gone through in the 300 years since the Agricultural Revolution. This explosion in global population and living standards is going to place significant strains on global resources, particularly in regards to food, medicine and fuel, the three core 'life science' markets, creating enormous new markets for UK science and innovation. I believe the UK faces an extraordinary opportunity to support and lead a new phase of global sustainable economic development. It can do this by unlocking the value of our Knowledge Economy to help create innovative technological solutions to these 'Grand Challenges' facing our generation.

As the Foresight Report set out so powerfully in 2011, future demand on resources will be influenced by complex economic and social drivers accelerated by population growth. As the report shows, by 2030 the global population could be as high as eight billion and by 2050 as high as nine billion, creating significant global resource pressure. By 2050, we will need to produce roughly twice as much food using roughly half as much land, water and energy.

By harnessing our world class science and research base in developing an innovative and entrepreneurial knowledge economy, we have an opportunity to attract major inward investment to the UK research base and fuel an ever larger cluster of entrepreneurial companies developing technological solutions and exporting them globally. We can build trade links with emerging economies and lay the foundations for a sustainable economic recovery, for them and us. We can also restore the UK's historical leadership on these global challenges and establish a strategic role in the new world order, inspiring public confidence in the Prime Minister's statement on the steps of Number 10 in May 2012 that "our best days are ahead of us".

I believe Science and Research are key to us 'winning in the global race', especially in the appliance of science to the key markets of food, medicine and fuel which underpin the fast-emerging global bio-economy. That is why I was delighted to be asked by the Prime Minister and David Willetts to become Government Adviser on Life Sciences and help develop an appropriate long term policy framework.

In 2012, the Prime Minister launched a new medical Life Sciences Strategy focussed on our biomedical sector. This year will see a similarly ambitious strategy for the Agri-Food sector. At its heart is the idea that by integrating our research base with our industrial supply chain (in this case our world class food and farming sector) and better integrating our aid and trade missions through the Department for International Development (DFID) and UK Trade & Investment (UKTI), we can attract significant investment into the UK as well as achieving export-led growth.

The UK has not had a coherent Agri-Food strategy for decades, but the imperative to unlock new models of economic growth creates a real opportunity. The new Agri-Tech Strategy is being put together by the Department for Business, Innovation & Skills (BIS), the Department for Environment, Food and Rural Affairs (Defra) and the Department for International Development (DFID), with strong support from No 10 and No 11. The aim is to set out a coherent vision in order to create a more integrated ecosystem and so promote greater collaboration between our food and farming sector and our research base.

Over the next decade we should be unlocking an increase in private-sector and global-sovereign investment in our research, focussed on the challenges that UK and world farming faces in the years ahead. We want to see the UK become the place where venture capital finds, funds and develops the latest agricultural innovations. We want our food and farming sector to draw on UK science and innovation as it seeks to produce 'more from less', in a more resilient and sustainable model of agricultural productivity. We want all of this to benefit our country by attracting additional inward investment and export through both aid and trade.

The Prime Minister is committed to using his position as Chair of the G8 to drive forward British leadership in tackling world hunger and the scourge of food insecurity. The Agri-Tech Strategy aims to set out the way we see this country growing this sector of our economy, while at the same time delivering on our commitment to the developing world. Our aid and trade missions can and must go together. Trade, especially in the basic primary markets that kick start the economic development cycle, is the best form of aid. These challenges may seem great, but through our scientific, entrepreneurial and global leadership this strategy can benefit the UK taxpayer, its consumers and our cluster of world-class researchers and entrepreneurs – as well as those in the emerging economies of tomorrow.

The challenges of economic recovery we face in our own economy, and the challenge of resilience facing the rapidly emerging developing world, are two sides of the coin of opportunity. Science and technology are the keys to unlock it. □

Scientific innovation has had a profound effect on our everyday lives and the pace of change shows no sign of lessening. But what will be the role of science in tackling the challenges facing humanity in the coming years? A meeting of the Foundation for Science and Technology on 6 February 2013 debated the issues.

Addressing the challenges of the 21st century

John Beddington

I will start with the National Risk Register (Figure 1) and consider what challenges the incoming Chief Scientific Advisor, Sir Mark Walport, might have to look forward to. The Register categorises risks in terms of their likelihood and impact. They include, among others: pandemic influenza; space weather; coastal flooding; and terrorist-related activities.

There have been six pandemics in 120 years which implies an approximate 65 per cent chance of another within the next 20 years. The variability in severity of these viruses is large, as seen in the relatively benign consequences of H1N1 swine flu, but the potential for very serious outcomes justifies placing a pandemic at the top of the risk register. This is one example of a very wide range of new diseases in animals and plants we have seen over the last few decades.

One of the most recent diseases to emerge is the Ash disease *Chalara fraxinea*, which resulted in the first COBR emergency committee meeting to deal with an issue where the timescale was a decade or more. It is quite clear that the world has changed: within a very short time, a new disease can sweep around the world. Swine flu had reached around 50 different countries within a month of its emergence.

Volcanoes might have seemed an odd inclusion on a UK Register, at least until recently. There are two different, and real, threats though. A couple of years ago, an eruption in Iceland produced large amounts of volcanic ash which closed down our airlines. It is very likely we will see something similar in the medium term – the consequences to us will very much depend on the whims of the weather at the time. However, more worrying is a major effusive eruption – it could last six or seven months at a stretch, causing chronic health problems, affect agriculture globally, and give rise to other major disruption. This is a low likelihood event in any one year but over a 20 year horizon the cumulative risks are not insignificant.

Professor Sir John Beddington CMG FRS FRSE was the Government's Chief Scientific Advisor until March. He led the provision of scientific advice to the Government during the 2009 swine flu outbreak, the 2010 volcanic ash incident and the emergency at the Fukushima nuclear power plant in 2011. Previously he was Professor of Applied Population Biology at Imperial College. He has been an advisor to the Foreign and Commonwealth Office, the Department for Environment, Food and Rural Affairs (Defra), the Ministry of Defence and the Cabinet Office.

Space weather

Another major issue on the National Risk Register is 'space weather'. The problem with space weather is that, first of all, there is absolutely nothing anyone can do to control it – the sun is a force unto itself. Sunspot activity operates on an approximately 11-year cycle and is moving towards a maximum. A reasonable 'worst-case' would be a repeat of the so-called 'Carrington Event' in the 19th Century which involved a whole mix of space weather types and severely disrupted the very limited electrical infrastructure existing at that time. Today we are of course far more dependent on such infrastructure.

As an example, an event in March 2012 was a very near miss, where there was sun spot activity followed by a coronal mass ejection.

While satellite monitoring can determine whether such an emission will hit the Earth or not, there is one further crucial piece of information concerning the possible disruption of the grid or our satellite communication systems. This is the magnetic orientation of the emission when it hits the planet. Humanity will have 17 hours notice of the emission hitting the Earth; but only 40 minutes warning of whether the polarity will cause major problems to the grid, requiring complete shutdown. With the limited information we have on such events, we have approximately a 1 per cent chance each year that we will be hit by a Carrington magnitude event of correct polarity to affect us – that is 18 per cent over 20 years.

Terrestrial weather

An important feature of the risks present on the register is that many of the events considered are climate- and weather-related. The storms, gales, low temperatures and heavy snow, inland and coastal flooding and so on – all of these are determined by the background climate and all are, therefore, likely to be

DISCUSSION

The role of social science

Social scientists are vital to dealing with problems involving public attitudes and behaviour. It is important that a Chief Social Science Advisor is part of the Chief Scientific Advisor's team. The hope was expressed that one would be appointed soon. Public attitudes can be altered through effective campaigns such as the anti-smoking and the anti-drink-driving campaigns. The methods behind these successes should be adopted more widely.

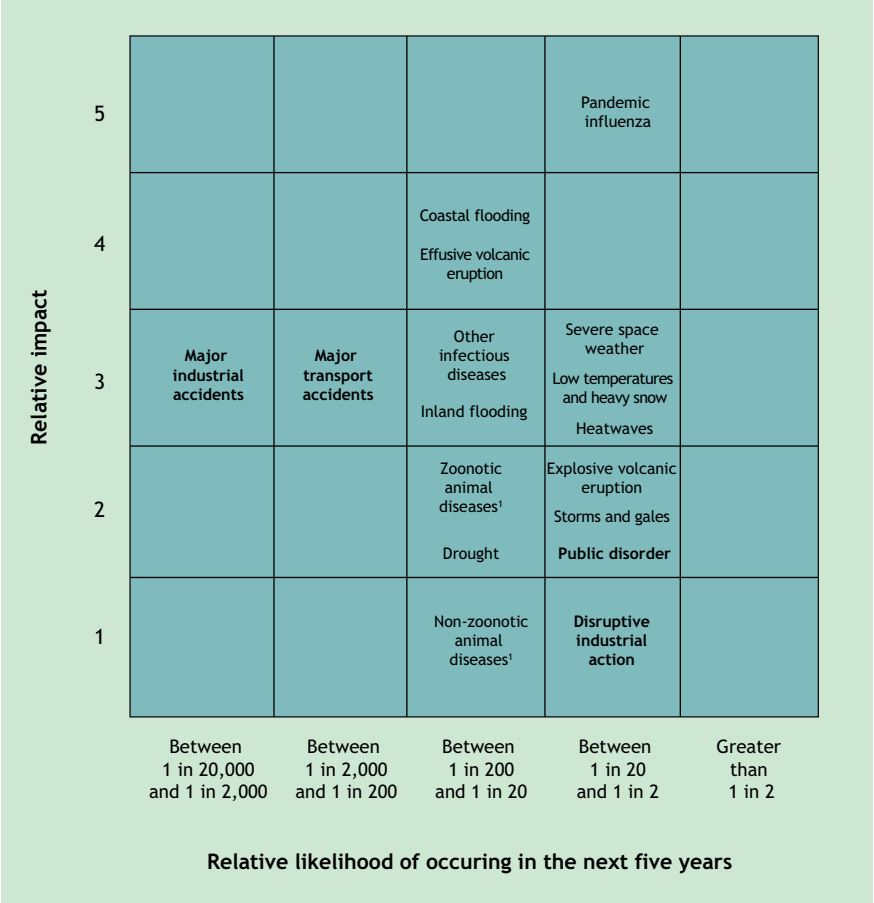

Figure 1. Relative impact and likelihood of disaster occurring over the next five years. Source: National Risk Register

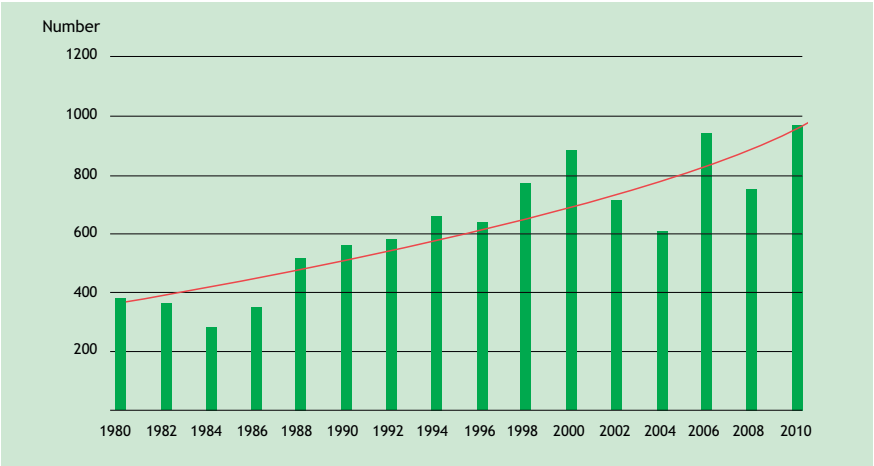

Figure 2. Increase in number of severe weather events. Source: Munich Re.

moving up the risk register both in terms of frequency and severity.

One of the problems I have faced as Chief Scientific Advisor was in dealing with climate scepticism. The evidence base is getting stronger and stronger, though. And in countering scepticism, the work of the business community has been really useful. Munich Re – the major re-insurance organisation – has been tracking the incidence of disasters (see Figure 2). It is very clear that since 1980 there has been a large increase in weather-related events.

There are other records chronicling extremes of different types of weather, such as those gathered over time by various states in the USA. In 2012, there were 3,200 instances of extremes occurring since those records began. For example, 2010 was the wettest year on record for the USA and last year has been the hottest. There is an important underlying detail here: variability is increasing. Not only that, it is rising faster than the mean: in fact, at double the speed of the mean. So, there are not only increases in temperature and in precipitation, but the variation of those extreme events is going up at double that pace.

Take a look at the UK: 2012 was composed of four or five months of extraordinarily severe drought in the winter followed by some of the rainiest periods we have ever seen in the English summer. This is the sort of variation that now has to be expected and it has consequences for how people respond to the threats to humanity (and the UK as a subset).

International efforts

Yet where is the global community in terms of international commitments on human-induced climate change? There was an international commitment after the Copenhagen meeting to restrict warming to a 2°C increase. This goal is now almost impossible in my view: the required changes in global emissions compared to the current pledged emission levels imply an extremely low chance of meeting that goal and approximately a 50 per cent chance of exceeding 3°C.

Stepping out of my role as Chief Scientific Advisor and becoming a commentator for a moment, I find it virtually impossible to imagine that there will be a dramatic decline in the export of fossil fuels. For instance, a dramatic image emerged recently in the UK press that illustrates the scale to which shale oil and gas are being exploited (to us in Europe, this still seems like an emerging technology). Released by NASA, satellite images show the Bakkan formation in North Dakota. This is one of the major shale oil reserves and exploitation sites in the USA. Seen from space at night, the flaring of waste shale gas is comparable to the street lights of some of the largest cities in that country. The reason for the flaring is that the price of this gas is now insufficient to make it economic to export. This contrasts markedly with gas prices in the USA only a few years ago. Cheap energy has, of course, major economic benefits and may be a significant factor in the relative outperformance of the US economy over other industrialised countries in its emergence from recession.

Shale oil and gas are more recently exploited resources, but there are still massive reserves of conventional fossil fuels – the emerging economic giants China and India have substantial resources, as do Russia, Australia, USA,

South Africa and Brazil. Again, it is hard to imagine that these fossil fuel resources, (and there are new ones being discovered too) will not be used. The Arctic is opening up, due to climate change, and ironically is likely to be a major new source of fossil fuels. Shale oil exploitation means that the USA will be a bigger and more important producer of oil than Saudi Arabia over the next decade. So is it hard to envisage the world (in which economic growth is currently problematic) making a dramatic decision not to use fossil fuels.

A pre-set path

Another aspect of climate change is the importance of time delays in the system. The greenhouse gases already in the upper atmosphere will determine the trajectory of climate and weather for about 20 years. Even if the world could reduce the level of greenhouse gas emissions and change the trajectory, the next 20 or 30 years are already determined. The situation in 2015 will determine the weather for the next two or three decades. So the story of climate change in the first half of the 21st century has been pretty much sewn up by the failure of the world community to cut back now.

One hope for improvement is technology, but we must avoid pitfalls. Take geo-engineering, discussed in a recent report by the Royal Society. One proposal is to use cloud ships to put droplets into the atmosphere and manage the weather. Yet Met Office analysis shows that after doing this, even for a longish period, there would be a very quick reversion to the existing trajectories once such activity ceases. Geo-engineering of this sort is therefore only a stop-gap – although it might be long enough to enable the community to act, it might even save areas of the planet from massive drought or significant heatwaves, but it should also be appreciated that changing the climate on one part of the globe may well have unintended and detrimental consequences on others. It remains an interim solution, it will not solve the problem and in some cases will do nothing to address serious problems.

The oceans, for example, are not going to be helped by geo-engineering. Acidification is happening apace. There is a real problem here because the basic physics and chemistry of the interaction between the atmosphere and the ocean mean that ocean acidification will have significant effects – with impacts on coral reefs, coastal economies and food. A technology that might, arguably, provide a long term solution is carbon capture and storage. It is less problematic – the carbon is actually being put back under the ground. Ultimately, though, humanity needs to develop technologies which will actually reduce or reverse greenhouse gas emissions.

Population and urbanisation

One of the most worrying challenges for the 21st century is population growth. There are likely to be one billion more people on the planet by 2025 – 500 million in Africa and 500 million in Asia. That is an increase of 50 per cent for Africa. The proportion of the population living in cities will rise to about 65-70 per cent and that includes the developing world. This means that in just 12 years time there will be the equivalent of about 1,000 new cities the size of Edinburgh in Africa – a staggering statistic. In addition, the global population is getting older and so more vulnerable.

Africa will have a total population in 13 years time of close to 1.5 billion. Although a large increase, compared to other parts of the world this is not necessarily an unsustainable population but resources, which do exist, will have to be carefully managed. For example, recent work by the British Geological Survey, funded by the Department for International Development (DFID) has mapped the very significant sub-surface water deposits in Africa. That the resources are there is tremendously good news, but then look at the experience of India. There was very substantial sub-surface water in India but today there are many over-exploited aquifers, a number of which are now saline and of no practical use. We do not yet have the technology, the management or the understanding in place to sustainably manage these major aquifers, let alone the rivers. So developing and communicating the science that will underpin water management is essential.

It is painfully clear that today, around a billion people do not have enough to eat and another billion have insufficient nutrition. What sort of demands will be made on the three basic resources – food, water and energy – as the population grows? The deficit on potable water in about 20 years is likely to be about 40 per cent. Energy demand is soaring, almost entirely driven by demand in the developing world. Despite real successes by the agricultural community – agronomists and agricultural scientists – there is already a significant deficit in terms of crop yield. A quantum change is needed in the delivery of productivity gains in agriculture.

In terms of feeding the world, biotechnology (and not just GM) has a very significant role in helping to address the challenge. GM in agriculture has had a difficult birth in the UK and Europe despite the significant domestic R&D capabilities. The situation is very different in most other parts of the world, where GM is increasingly being adopted: examples include Bt cotton which is now widespread and the recent introduction of vitamin-A-enriched Golden rice in the Philippines. This is a very exciting development that looks set to play a significant role in addressing one form of malnutrition.

The situation is gradually changing in the UK and the successful handling of protests at Rothamsted Research last year is a welcome sign that the national debate is increasingly being conducted thoughtfully, and on the basis of evidence. This is a trend that is badly needed if we are to address other future challenges.

As I have mentioned before, disasters will happen and it is the poorest of the poor who will be affected by them. How can our science help them? Well, in one example, meteorological science and weather forecasting are improving the whole time which allows communities to have more warning about events.

Urbanisation trends mean that people are vastly more vulnerable in cities and around coasts. Increasingly, though, science has the ability to concentrate and model risks in a very detailed way. As an example, the Met Office modelled the area around Weymouth during the

DISCUSSION

The Risk Register and regulation

The National Risk Register may not encompass all the threats that could emerge in the next 15 years, such as the threat to energy security and the consequences of global population growth. Energy security will inevitably be a risk, not only from foreign wars and other threats, but also because more investment in generation and transmission is needed. Nuclear energy is of great importance, but it needs to be properly regulated and not burdened with excessive or inappropriate regulation.

Olympic sailing events, coming up with brilliant predictions of wave height and wind direction, how it would vary over time, extremely valuable information in a competition. They then proceeded to share that information with all the teams but, despite such good sportsmanship, team GB still won a lot of medals! Our capabilities and skill in such areas are constantly growing and their positive impact will gradually spread to other areas and include developing countries.

Regulation

Regulation is a fraught issue in the UK and Europe. Whilst undoubtedly important in delivering a safe and productive environment, it is vital that regulation and standards are developed carefully, proportionately and with a sound evidence base. Current regulation is, frankly, in many cases a nightmare.

It has been known since the time of Paracelsus in the 15th century that risk is a function of hazard and, crucially, exposure. Yet in the EU, legislation has been proposed by a number of states that would introduce a purely hazard-based approach: if something is a carcinogen or an endocrine-disruptor it should be banned, irrespective of the dosage. If that happens in the case of agricultural chemicals, which is being considered in the Commission at the moment, the resulting loss of capability in established pesticides is likely to lead to a 25-30 per cent decline in crop yields, in most of Northern European agriculture. The licensing of Genetically-Modified crops is also a painfully slow process.

Faulty regulation is pervasive – it does not just affect the ability to grow food. One reason why volcanic ash proved such a problem was a regulation that if there was any ash present, then planes could not fly. Yet, it is not the concentration, let alone the presence or absence of volcanic ash, which is important; rather it is the accumulation of ash during the flight. Clear, scientific considerations of risk should inform the regulatory process. There is an important role for the scientific and engineering community, particularly manifested through the various academies and bodies such as the Royal Society. The study that I asked the Royal Academy of Engineering and the Royal Society to carry out on the risks associated with shale gas exploration is one example of the way in which science can help give timely and focused advice on emerging issues and so provide badly-needed impact assessment.

Regulation in ignorance may improperly involve the precautionary principle. There is evidence of this in Europe and it should be resisted.

The future

At the beginning of 2011, the *Economist* featured on its cover the question: 'Are We Running Out of Innovation?' Well, from my perspective, I am quite confident that we are not. In the privileged position I have, I am able to visit our universities and laboratories in order to understand what is happening in our research base, and it is fantastic.

Finally, among the major challenges facing humanity I will highlight just two. Population is now at a tipping point. The world is at a stage where, if we see declines in fertility associated with increasing prosperity, better education and the availability of contraception, there is a chance of stabilising population at around 9-10 billion. If we cannot do this, then population growth could take off and I do not think that can be sustainable. So I think the tipping point on population is of profound importance and much neglected. We are also reaching tipping points in the climate system. By 2050 we need much more food, much more water, much more energy and a lot less greenhouse gas emissions. □

The National Risk Register: www.gov.uk/government/publications/national-risk-register-of-civil-emergencies

The issue of health

Sally Davies

As Chief Scientific Advisor, looking after the Department of Health's research budget, I am most interested in the clinical, applied and policy-based aspects of that research. Looking at the main behavioural risk factors for disease, alcohol ranks third highest. High alcohol intake causes liver disease and deaths, but also increased risks of cancers. There were 15,400 deaths from conditions wholly and partly caused by alcohol in 2010 and 1,220,000 alcohol-related hospital admissions in 2012, as well as just under 1 million alcohol-related crimes.

Looking at the EU15 (the pre-2004 members), alcohol deaths are coming down while ours have been going up. In the UK, deaths from conditions wholly and partly caused by alcohol rose by 7 per cent between 2001 and 2010, while overall deaths in the UK fell by 7 per cent. Over many years, there has been rising alcohol consumption in the young (with binge-drinking) and in middle age – particularly women who come home and 'need' that glass of alcohol.

Dame Sally Davies DBE FMedSci is Chief Medical Officer (CMO), Director General of Research and Development, and Chief Scientific Advisor at the Department of Health. The CMO advises the Secretary of State for Health on medical matters. She is also the professional head of the Department's medical staff and head of the Medical Civil Service. As Director-General of R&D, she established the National Institute for Health Research (NIHR) with a budget of £1 billion.

Addressing this means researching many different areas: behavioural science for instance. Sheffield University has modelled the estimated impacts of alcohol minimum unit pricing; the Prime Minister picked this up and a consultation has just ended concerning a minimum price of 45p per unit. There are other issues such as the inclusion of health issues in local alcohol licensing, with a view to controlling the density of premises – Sheffield University has modelled these impacts also. In all, a wide array of aspects has been examined, involving a new set of researchers as well as the more traditional disciplines.

While obesity may be stabilising in children, it is still terribly high: in 2012 some 16 per cent of children in the 2-15 year old age were obese while 30 per cent were overweight or obese. This problem is increasing everywhere; it is to do with calorie-dense food and tackling it effectively means understanding not only behavioural and regulatory intervention,

but also neuroscience. The brain 'lights up' in pleasure centres when we enjoy food but perhaps these reactions can be interrupted.

There are ethical issues raised by the possibility of a pill which prevents obesity: is that something the NHS should pay for? The cost-benefit analysis is a different issue; obesity is costing the Health Service a great deal in morbidity and mortality. It increases the risk of cancer, liver disease and many other things. We are working hard in this area, working with a wide range of stakeholders and we have put £5 million a year into a school for public health research looking at what interventions work in reducing public health issues.

Ageing

Not only is the population ageing, but in England it is growing. Given that in the over-75 age group, one-in-three will have dementia, the burden of disease will double by 2030 – and that is a real problem.

Vascular dementia is the second most common form of dementia after Alzheimer's Disease and controlling risk factors here is an important treatment strategy. For the rest though, the cause is not yet known. There is not even an effective diagnostic test. So there are very few disease-modifying treatments and while some new antibodies show promise, because of our regulatory system they are only being tried in late-stage disease.

It may be that the regulatory system needs to change or people with early-stage disease could be asked if they want to try these things: there is however no doubt that much more research is needed. We are working to more than double the spend on dementia research, and a translational research collaboration in dementia has been set up through our National Institute for Health Research (NIHR).

A further problem is that many in the medical profession believe that patients should not be told they had dementia because it will upset them. Actually the evidence from social science is that people want to know so they can put their lives in order and do things they want to do before the disease goes too far.

Non-communicable diseases

I am lucky; I have never smoked so I do not know what it is like to be addicted. It is very difficult for people to stop once they are. Interestingly, while the most recent anti-smoking campaign was aimed at those who do, feedback suggests that many children saw the adverts and were put off the idea of starting. Clearly, those who do smoke have an increased risk of cancer, chronic airways disease and cardio-vascular disease.

The Department of Health puts a great deal of money into managed clinical research networks and these support industry and public sector trials by our partners – the Medical Research Council (MRC), Cancer Research UK, and many other charities – and the results in cancer are excellent. Some 22.9 per cent of cancer patients went into studies between 2011 and 2012. In the USA, less than 3 per cent of patients take part in studies. The UK now puts more patients into studies than they do in the whole of the USA. In the last financial year, just less than 90,000 patients were involved in cancer studies, a five-fold increase on 2001. These are important trials, they have been through peer review, they are properly funded – this is important work.

Genomic technologies

There are multiple challenges facing genomic technologies. While the UK is a world leader in research in this area, that has to translate into having a health service at the cutting edge of genomics. It might seem easy: there is a real opportunity as the NHS is the single national healthcare provider, but it is also a complex healthcare provider. So, just before Christmas, the Government launched an initiative to sequence 100,000 whole genomes in NHS patients with a focus on cancer, rare diseases and infectious disease. The procurement will be done by the NHS Commissioning Board that does not have a scientist on it.

The Secretary of State, Jeremy Hunt, has now agreed to the setting up of three groups looking at: the science priorities; the principles determining which ones should be implemented; and data issues (structure, storage, ethics, etc). Meanwhile, the chair of the Commissioning Board has held meetings of his strategic board.

Antimicrobial resistance has become very serious. It is not something the Department of Health can solve on its own: in the international context it is working with the World Health Organisation but also nationally with input from other expert groups such as Defra. There is a great deal of work being carried out to counter the threat and even more will be done by the MRC.

About 7 per cent of patients in the NHS have rare diseases and advances here lead to new treatments for more common diseases – statins were introduced through that route. So the Department is funding research into phenotyping and genotyping through the biomedical research centres and units as well as coordinating greater collaboration across the NIHR-funded research infrastructure in order to maximise on the investment and expertise in rare diseases.

A final point is about the make-up of the workforce. In the biological sciences, about 22 per cent of researchers are women. For academic medicine that drops to 11 per cent, yet over half the students leaving medical school are female. I have set a challenge to all of the medical schools in a letter of August 2011. It said they would not be shortlisted for significant grant funding unless they achieved the Swan Athena Silver Award – that is proving quite a challenge for all of them. □

The role of the Government CSA

Mark Walport

Lord Zuckerman, the first Government Chief Scientific Advisor, often emphasised the moral neutrality of science. That neutrality is the 'stake in the ground' that provides the anchor for the Scientific Advisor. The task is to advise politicians on science, but it is for politicians to make the decisions that flow from that. Advice is often provided in the context of conflicting policy objectives which go beyond the science itself. In the criminal justice system, for example, there are three objectives – to prevent reoffending, to deter others from offending and to provide retribution. Science may speak to the first two but on the third it cannot help.

In 1966, the Council for Scientific Policy wrote: "Whilst it has always been important to satisfy public opinion that science is worthwhile in each of its aspects

– cultural, social and economic – the scale of the resources devoted to science now makes this absolutely necessary if science is to continue to have the resources it needs. Ironically, this problem may be more pressing because the nation is, at last, genuinely aware that our economic feature rests upon advanced technology which itself depends upon science for its fundamental concepts." *Plus ça change.*

In 1960, Zuckerman had spoken of "industry and government [combining] to see what scientific knowledge can be transformed into industrial technologies and so into greater productivity and wealth". The challenge is now, as then, about collaboration, coordination and interdisciplinarity – as well as effective execution. It is often not where to go, but how to get there.

My predecessor, John Beddington, has been superb at accessing excellent advice in very urgent situations through the establishment of the Scientific Advice Group in Emergencies. SAGE is now very effectively embedded in the Government's civil contingencies procedures. His role during the Japanese earthquake and the overwhelming of Fukushima by the tsunami was a wonderful example of leadership as GCSA and illustrates, importantly, the role of science in international diplomacy. He and his colleagues rapidly assembled a team of talented individuals from different environments and disciplines. This is one of the real challenges for the GCSA – finding the right people very quickly and then distilling the advice received from many voices.

The UK Government's advice to its citizens in Japan, supported by our politicians, was significantly different from that of other countries. Its measured and rigorous approach created enormous goodwill in Japan. By supporting the Japanese in reassessing their nuclear regulatory framework and in rebuilding their communities safely, his work has strengthened the relationship between the UK and Japan which is a key research, investment and trade partner for the UK.

The so-called 'black swan reviews', which bring scientific assessment to the toughest areas of uncertainty, have improved the quality of the National Risk Register still further.

A wider community

Indeed, his ability to obtain the best scientific analysis, wherever that may be, has been extremely important. The report from the Royal Society and the Royal Academy of Engineering on hydraulically-fractured shale gas is a case in point. It required a precise definition of the remit and therein lies the challenge. It would have been tempting to ask for a report on the whole of UK energy policy. In reality, the fact that the final report was well-bounded and tightly focussed on the right question was what made it so important and so valuable.

Sir Mark Walport FRS FMedSci became Government Chief Scientific Advisor in April. Until then, he was Director of the Wellcome Trust and a member of the Prime Minister's Council for Science and Technology. Before joining the Trust, he was Professor of Medicine and Head of the Division of Medicine at Imperial College London where he led a research team that focussed on the immunology and genetics of rheumatic diseases.

Partnerships with business have also been key. For the report on high-speed computer trading, for example, many of the experts were in the private sector, and their input was essential. The Council for Science and Technology has been re-energised and now encompasses a much larger business community.

Resilience, security and well-being will continue as key themes for the Government Office of Science. John has noted: "There is an intrinsic link between the challenge we face to ensure food security through the 21st century and other global issues, most notably climate change, population growth and the need to sustainably manage the world's rapidly-growing demand for energy and water." He added: "This threatens to create a perfect storm of global events. Science and technology can make a major contribution by providing practical solutions." This is a challenge to everyone, but it provides great opportunities as well as threats.

History has much to say about the broader role of the scientist. Sir John Kendrew is a splendid example – a great scientist who had a robust argument with the then Secretary of the Medical Research Council, Sir Harold Himsworth. Himsworth had stopped him from appearing on a BBC programme in 1962. In a letter to him, Kendrew said: "I simply cannot see why a Council employee should not speak publicly on Government policy towards universities or the financing and organisation of research, generally. You may argue that they are not the most effective ways of getting something done and that these matters are better arranged in the manner of the Civil Service, behind closed doors at Ministries or the Athenaeum – and this may often be true. Though if one feels strongly about some problems ... one may conclude that all methods should be tried, including the mobilisation of public opinion by way of the press and the BBC."

Reaching out

That generation of Cambridge molecular biologists worked in the laboratory and won Nobel prizes. But they did much more in addition. They created a new journal for a new discipline; they talked to the media, advised and influenced the Government, and created new institutions, including the European Molecular Biology Laboratory and the Wellcome Trust Sanger Institute. They established commercial links and the technologies which were developed in the Laboratory for Molecular Biology were industrialised. They trained, imported and exported scientists. The diagrams and models they made of molecules were used to engage the public in science.

Our modern world is shaped by science, engineering and technology. Our environment is challenged as never before and it is the responsibility of scientists to contribute in many ways – as did those scientists in the Laboratory for Molecular Biology. □

DISCUSSION

Advising politicians

Many politicians do not understand the importance of science nor wish to understand the arguments. The difficulty lies in delivering advice in terms that are not couched in jargon and in providing it in a timely way. A particular difficulty occurs where there is a fundamental disagreement between scientists. Both sides of an argument need to be carefully and dispassionately presented in such circumstances.

Which technologies offer the best chance of sustained growth for the UK? How should they be supported? These were the questions debated at a meeting of the Foundation for Science and Technology on 14 November 2012.

Embracing a new industrial future

John Parker

The UK faces a challenge. It has not yet established a clear path to recovery, despite its enormous strengths. It is a technocratic nation with world-class engineering and science capability. That is why this country must commit to a modern industrial strategy: these strengths must be harnessed for a new industrial future.

The term 'industrial' is used in its widest sense, encompassing: research, design, engineering and manufacturing of products; the engineering and manufacturing services that support them; and the international engineering consultancy that emerges from the base.

There are five elements that a modern industrial strategy must produce:

- clear signals from the highest levels of Government;
- stable and aligned policies;
- the right skills base;
- support for new and innovative ideas;
- recognition of the importance of large companies but also of the need to grow new ones, especially in emerging sectors

To create a modern industrial strategy for the UK, the Government – led by the Prime Minister and the Treasury – must signal that it means business and that the whole of Government will be aligned in support of industrial growth. After a period of years when industrial activity has been 'below the radar', this kind of reinforcement is critical.

A modern strategy also needs to set the trajectory for core sectors as well as those critical enabling technologies that provide the edge in a host of applications and emerging sectors.

Policy

Government needs to consider how each new policy impacts elsewhere. Take the consequences of converting polytechnics into universities. Polytechnics used to provide a quality education, preparing people for work and, importantly, producing skilled technicians. In doing so, they served the country's industrial base – and its young people – very well. While many polytechnics have become fine universities, that critical mass of professional and vocational learning has been lost. A more recent example is the impact of new visa restrictions on talented people who want to study, undertake research and work.

Sir John Parker GBE FREng is President of the Royal Academy of Engineering and a leading UK industrialist. He is currently Chairman of Anglo American, the mining and resource company, and is on the Board of EADS, the aerospace company and Carnival Corporation, the cruise ship company. Previously he was Chairman of National Grid and Chairman of Court of the Bank of England.

As Michael Heseltine recognises in his growth review[1], policy is a system and must be treated as such. Policy must also be based on the real needs of business. In strong, well-defined sectors such as aerospace and automotive, the leading companies have formed highly effective sector bodies, with strong strategies and leadership. They articulate their needs and those of their supply chain companies. They are developing real dialogue with Government. The development of leadership councils across important high tech sectors such as space and e-infrastructure is to be warmly welcomed. However, it is more difficult to identify, let alone engage in dialogue with, newer emerging sectors or those which are not so well-structured.

In the drive to innovate for an industrial future, the UK's excellent science base is a huge advantage. A strategy for growth must recognise the critical importance of sustained support for science.

However strong academic research may be, translating it into innovations does not happen automatically. That needs coherent, sustained and applied effort. In Europe, the UK's innovation performance is only average; we lag behind Germany, Denmark, Finland and Sweden. There is a pressing need to address this. As part of a much bigger drive, the new Catapult centres are a positive step.

Advanced manufacturing is critical and already a vital enabler for some of our existing sectors. EADS Airbus has a wing factory in Wales which is one of the world's most advanced production facilities. Nissan's factory in Sunderland is the most efficient car plant in Europe.

I have visited the Manufacturing Technology Centres in Rotherham and Coventry and been deeply impressed by the work being done to create advanced manufacturing processes which could enable us to compete with the lowest-cost countries.

Innovation

Innovation comes from creative interactions between science and business. Among the critical issues are:

- *communication* – between universities, businesses and Government in order to understand what each can bring to innovation;
- *access to finance* – where it is not possible to attract private sector investment in early-stage ventures, there needs to be better ways for the public sector to fill the gap;
- *scale* – not just the scale of the growth challenge and of the global competition but also the scale and critical mass of companies needed in order to compete.

To compete globally, the UK has to invest at the right scale or else invest jointly across borders to share the upfront risk. There is a need to identify new ways to support technology entrepreneurs in building their own capabilities, as well as helping potential investors identify opportunities.

The Royal Academy of Engineering is establishing an enterprise hub. This will

give promising entrepreneurs practical support from the Academy's Fellows who are successful entrepreneurs. That support includes mentoring and coaching as well as helping build the confidence and ambition researchers need to commercialise their ventures.

Growing more world-leading companies at scale is vital: our industrial future cannot be built on SMEs alone. We already have great companies, with terrific global brands, such as Rolls-Royce, Arup and Vodafone.

Big, heavyweight businesses like these act as 'traction engines' to pull through long supply chains, skills and R&D. A modern industrial strategy needs to recognise the importance of the major players that we already have and it has to create a climate to grow new companies and supply chain companies which can, in turn, operate at scale.

A stable playing field

Building new sectors, industries and big companies is a very long game. More than anything else, investors and innovators need stability; that means policy, tax regimes and investment incentives must be there for the long term. A case in point is the huge challenge of modernising the energy system. Of late, the policy signals have been anything but clear. There is a balance to be struck of course. In a democracy, the electorate has the right to vote for change. But a modern industrial strategy could create buy-in across the political spectrum for a 20-year vision.

Another practical benefit of such a strategy is the alignment of policy and greater cohesion between Government Departments. It cannot succeed unless every Government Department is playing its part.

In many other nations, policy is tilted in favour of the industrial base. They cherish and nurture their flagship sectors. That produces a real competitive advantage. In a global marketplace, we cannot afford to put ourselves at a disadvantage.

Yet it is not about fending off all comers. Foreign direct investment is increasingly critical to the UK and our relationship with foreign investors must be part of the industrial growth strategy. Strong investment in engineering from Ford and then the Tata Group has transformed Jaguar Land Rover, for example.

People

A modern industrial strategy for growth, backed at the highest levels of Government, sends a message to society and in particular to families. It says that industrial activity in all its forms is important and provides a rewarding career choice for our young people.

As an engineer and industrialist, I am a passionate advocate of engineering industry as a career choice. I want to see the UK creating a home-grown workforce with the skills that employers need. The Academy has research data showing that a career in engineering can provide value not only to the economy but also to the individual. A modern industrial strategy that provides skills for industry gives a real opportunity for young people, whatever their social backgrounds, to enhance their life chances.

As well as graduate engineering skills, the strategy must put the right emphasis on vocational training. A modern industrial strategy should include an even bigger push for apprenticeships and university technical colleges. The Academy welcomed the Chancellor's announcement that the 14-19 Engineering Diploma is to be reworked to create four rigorous qualifications, each equivalent to a GCSE.

The UK's strategy needs to see more engineers – especially young women – ready to fill Britain's skills gap. Prospects, fulfilment, excitement, making a difference – what more could a young person aspire to? □

1. Heseltine Review, No stone unturned in pursuit of growth: www.gov.uk/government/publications/no-stone-unturned-in-pursuit-of-growth

Government response: www.hm-treasury.gov.uk/d/PU1465_Govt_response_to_Heseltine_review.pdf

Systems thinking and industrial strategy

Alan Hughes

Looking at an industrial strategy or policy in terms of systems, there are at least two perspectives that can be employed. The first focusses on sectors; a number have been identified in current industrial strategy thinking and these have a system of interactions connecting firms, consumers and the public and university sectors. The interactions are governed by all kinds of rules that have developed over time. An analysis at sector level involves a consideration of who the key players are and the inter-relations between them. This task is relatively well-defined, although there may be value chains linking different sectors together.

From a technological systems point of view, though, the players are not so easy to define and they do not often map very easily into sectors. In fact, emerging technologies may create entirely new sectors. So a different set of mechanisms might apply to technological systems while system changes may occur over time as players from different sectors come in and the technology develops.

Professor Alan Hughes is Director of the Centre for Business Research at the Judge Business School, University of Cambridge, where he is also Margaret Thatcher Professor of Enterprise Studies and a Fellow of Sidney Sussex College. He is Director of the UK Innovation Research Centre, a joint venture between Cambridge and Imperial College London. Since 2004 he has been a member of the Prime Minister's Council for Science and Technology.

One important element of an industrial or technology strategy is 'selectivity'. Selective intervention causes controversy as it involves the allocation of resources – with the result that some will gain while others lose.

Stand back or intervene?

Stand back or intervene is a question often debated. In terms of science funding, there is a hallowed debate around Government standing back, the so-called Haldane principle. The discussion of science is, in fact, only a small part of the original Haldane report of 1918. Haldane, moreover, identifies two principles. One allows scientists to choose what they want to do. He also emphasises, however, that the work of public sector laboratories and mission-driven research based on consideration of use is a very important part of what the Government *should* do. So Haldane advocates 'stand back *and* intervene'; the

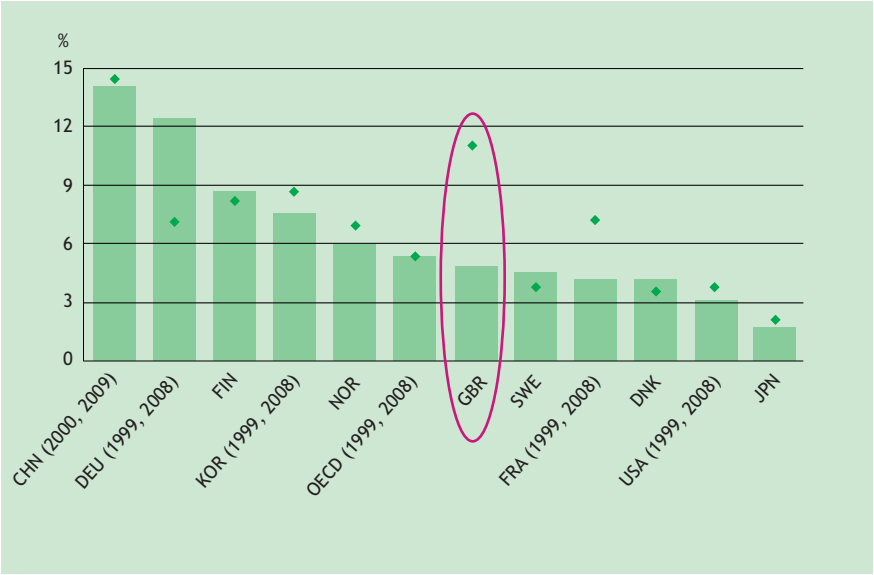

Figure 1. Business-funded R&D in Higher Education and Government sectors, 1999 (diamond) and 2009 (bar). Percentages of total R&D in these sectors. (Different years marked in brackets). Source: OECD.

discussion around the first principle has tended to confuse the debate.

Donald Stokes wrote an interpretation of post-war US history with the title 'Pasteur's Quadrant'. He argued very powerfully that a great deal of science has always been characterised, as was Pasteur's work, by a pursuit of both basic understanding and considerations of use. The real issue for technology and industrial strategy is how to make connections between the underlying science base (as represented by universities and public laboratories) and the commercial part of the system.

Research excellence and application already go very well together and are very concentrated in the UK. The top 15 universities account for over 50 per cent of quality-related (QR) funding, 64 per cent of Research Council awards, three-quarters of charity support, and so on. Their research excellence concentration is matched by extensive application concentration. So those same universities account for around 60 per cent of contract research, 58 per cent of the cumulative patent portfolio held by universities, 60 per cent of external investment in spin-offs, and so on.

There is also a rich set of interconnections between external organisations and the science base. An ESRC project, covering 22,000 academics in all disciplines and universities, showed that 5 per cent of UK academics have licensed research, 7 per cent carry out patenting, while 14 per cent have formed their own consultancies. But many more academics have other important interactions with external organisations. Aside from giving external lectures and attending external conferences, they assist in employment training, sit on advisory boards, advise on curriculum development and are involved in extensive contract and collaborative research. These pathways are both more pervasive and more important in driving impact than direct commercialisation *per se*. There is also a correlation between the role of universities as 'anchors' in local communities and the cultural vibrancy of those systems. Universities are cultural as well as academic institutions and that must be reflected in any industrial strategy.

Research and development

In 2004, the UK Government targeted a rise in investment in R&D to 2.5 per cent of GDP by 2014. To achieve this, it committed to set the rate of growth of public sector R&D to at least match the growth of GDP. Meeting the overall 2.5 per cent target for public and private R&D combined required the private sector to respond by increasing its R&D to 1.7 per cent of GDP.

While Government Higher Education R&D expenditure rose substantially as a consequence, business expenditure did not rise to match it. The failure of the private sector to carry out more R&D is a critical part of reason why the overall 2.5 per cent target was not met.

Just as higher education R&D is very heavily concentrated, so is business R&D. Of the total £16 billion spent, the top 10 firms account for over a third. Very small, independent firms – which, it is often argued, will play a critical role in the economic recovery – make up a very small part of this overall R&D effort, less than 4 per cent. So understanding the connections between large businesses and higher education R&D is of paramount importance.

A distinguishing feature of UK business R&D is its heavy dependence on overseas funding. Industrial or technological strategy must involve an understanding of how to continue to attract this funding or else replace it with internal domestic financing flows (which have so far shown few signs of taking up any slack). The UK science base has also proved very attractive to overseas funders (in terms of EU framework grants, overseas corporations and governments). But UK industry commitment to university funding has been very slow to increase in relation to the rest.

Figure 1 looks at the extent to which university and public sector R&D is funded by the business sector. The diamond in each column is 1999 and the bar is a decade later. Increased public sector support for UK science base R&D has coincided with stagnant or falling private sector funding of science base research. The result has been a significant decline in the share of science base R&D funded by the private sector in the UK compared to other countries.

Although a great deal of effort is focussed on university-based R&D, the UK also has a substantial amount of R&D carried out in other public sector research organisations. They are relatively neglected in discussions, but are an important part of the R&D landscape. In other economies they are more numerous and play a bigger role than in the UK, so our industrial strategy has to either leverage these or create institutions like them that can fulfil mission-led activity.

Where next?

There is actually no simple choice between standing back or intervention. Governments intervene all the time, they are constantly making allocation decisions. Is it possible, then, to ensure informed strategic intervention? In particular, is it possible to attract globally mobile R&D and keep the resulting value -added in the UK?

The reason why industrial policy and strategy went so out of favour was a belief that the Government is a 'blind giant' that cannot out-guess the market and cannot pick winners. Instead, the losers will pick the Government, resulting in policy capture by vested interests.

Much of the work which has led to a resurrection of interest in industrial policy comes from the developing economies. Here it has been argued that the 'blind giant' problem occurs only if the public sector does not engage closely with the private sector and inform itself about the nature of the problems.

So an industrial strategy must be embedded in a particular sector or technology. That implies a much broader 'bandwidth' of private/public sector communication, together with a set of institutions that can lead to useful information exchange and targeted granular policy actions.

Picking winners?

The language used in this context is important. Rather than 'picking winners', terms like 'choosing races' and 'placing bets' reflect better the uncertainty facing decision makers. Resource allocation requires a detailed understanding of the specific sectors and technologies where the policy is going to be applied. That analysis will allow the Government to determine what it can and might do alongside the private sector. Policy must also recognise that there will be 'honourable dead-ends' and that projects have to close. Then, finally of course, there has to be full public accountability of this process once it has been developed.

The road from research through to development looks linear, but actually is full of feedback loops; for example, it may be necessary to go back and do more basic research on the way. Science policy typically operates at the early research end, technology policy more towards exploratory development, innovation policy is much more about encouraging implementation and then industrial policy is usually seen very much at the sharp end of delivering output to the economy. I believe that a 'holistic' industrial policy has to encompass the early stages, too.

A great deal of attention has to be paid to intermediate connectivity and value chain structures. iPads may be labelled 'Made in China' and retail in the USA at nearly $300. Yet only $2 actually stays in China: the rest goes to the other components of the value chain, including retail margins in Apple Stores in the USA. A large part of the value-added created by an innovation may not lie in manufacturing and assembly at all. Expanding and appropriating value-added through industrial strategy requires therefore a deep understanding of value chains. Finally, industrial policy is as much about effective use of demand as it is about giving incentives to supply. Here the strategic and intelligent use of public procurement has a central role to play. □

How can government promote growth through innovation?

David Willetts

Industrial strategy is all about bringing business, academia and Government together. There has been a real shift in thinking over the past few years. Many of us used to think that the only thing Government had to do was to get out of the way. Large numbers of businesses still want that; they simply want lower taxes, easier planning rules, less red tape. Yet an increasing number of businesses and industrial sectors look to Government to play a far more creative role.

There are several powerful reasons for revisiting the idea of an industrial strategy. First of all, Government takes decisions all the time: about where to place limited resources; what to procure and how; when to invest in transport infrastructure and why.

Then consider what happens in America. Behind the free-market enterprise rhetoric, so much Government activity takes place there. The rules about state aid in Europe are far more rigorous than anything they have in the USA! A key distinguishing feature is that they are far better at reducing the risk that entrepreneurs and other risk-takers have to take. Their 'clusters' have been defined as low-risk environments for high-risk activities, an area where you can, as they say in Silicon Valley, "change jobs without having to change your car parking space".

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

The Americans do other things to lower risk for entrepreneurs. Their equivalents of the Research Councils – the National Institutes of Health, the National Science Foundation – take funding much closer to market. One answer to the question "Why don't our venture capitalists take the risks they do in the USA?" is that in the USA they have to take less risk because we stop funding too early. This is where Lord Sainsbury's creation of the Technology Strategy Board comes in, as well other initiatives introduced since (for example, the re-creation of SMART awards, the biomedical catalyst), all aimed at plugging that gap. So the second argument is "They do it in America".

The third is that there is, in the modern world, a crucial form of comparative advantage in the quality of the relationship between Government, business and the research base. That itself contributes to an economy's underlying performance.

So, the two Parties in the Coalition reached a shared conclusion that the country does, indeed, need an industrial policy.

Establishing the framework

A framework is needed and this has five elements:

- first, an identification of the sectors where the comparative advantage argument applies, where relations with Government matter and where Government can contribute;
- second, access to finance which is a real challenge for British business today;
- third, the skills agenda. A legitimate and crucial role of Government is

investing in skills;
- fourth is procurement – the £270 billion a year that Government spends. Another lesson from the USA is that one of the best ways you can finance an SME or a start-up is not to lend it money or have a venture capital investment, it is just to provide it with a contract early on. So the procurement function is critical;
- the fifth part of the analysis concerns the technologies – the general purpose technologies of the future.

Sectors

The sectors that we have identified are:
- Advanced Manufacturing: within this we have identified aerospace, automotive, and life sciences (which in turn actually comprises medical and agri-tech);
- the knowledge-intensive industries of the future, including Education. Now it is fully recognised that there are inherently worthwhile academic reasons for entering the world of universities and that must be protected. Nevertheless, Education – at school, FE and HE levels – is also an important business sector nowadays. Professional business services fall into this category too;
- the 'enabling' sectors that stand behind the economy: first, construction and, second, energy (civil nuclear, oil & gas and renewables).

Add them all up and there are 10 groups – aerospace, automotive, medical life sciences, agri-tech, education, professional business services, construction, civil nuclear, oil and gas, renewables.

The technologies

One thing that can cripple Governments is the recognition that we do not have perfect foresight. In five or 10 years' time someone may come along and say: "Ministers backed this technology and it has failed to deliver". That is sometimes the case (I am still waiting to commute to work using a personal jet pack as used by James Bond in Thunderball). This is an imperfect world with imperfect information, but that should not stop us having a go.

With general purpose technologies, one of the crucial criteria is wider application. We have identified great technologies upon which we should focus.

1. *E-infrastructure*. This includes everything from data-driven discovery in science through to the way in which business is increasingly replacing physical prototyping by virtual modelling. This shortens time-to-market for innovators and you can see a clear parallel between the skills of our leading scientists in the Large Hadron Collider (or, in the future, the Square Kilometre Array) and the needs of our advanced businesses – the Rolls Royces and the Jaguar Land Rovers of this world – to handle very large datasets and use them for modelling. Underlying e-infrastructure was something that concerned me two years ago when I thought Britain was not necessarily investing sufficiently in the IT and e-infrastructure requirements of our academic research base. I was able to persuade the Chancellor of the £150 million investment needed to keep us up with cutting-edge e-infrastructure for the academic community.
2. *Space* – not so much the upstream bit though there are, of course, continuing advances in satellite technologies. Britain is probably the world leader in low-cost, small satellites, because the correct strategic decision was taken not to stick with launch technologies. So instead we have been driven to look at how you can get small, nimble, lightweight loads that can cadge a lift on someone else's great big rocket. Increasingly, too, data collected via satellites will be applied to a whole range of purposes, from disaster-monitoring to parking cars.
3. *Robotics and autonomous systems*. The legislation in California providing a legal framework for driverless cars by 2015, as well as changes in the American regulatory regime for drones and un-manned planes, marks a significant development. With the regulatory regime changing in America, both for aircraft and for motorcars, this could be a technology that is coming to a tipping-point.
4. *Synthetic biology* applies engineering techniques to the life sciences. In many ways you could see that as standing for a wider, crucial trend: the increasing combination of 'dry' and 'wet', the increasing convergence of IT and engineering skills with the life sciences.
5. *Regenerative medicine*.
6. *Agricultural science and agri-tech*. There are crucial challenges here. I think of exciting projects like the BBSRC's 2020 Project to achieve yields of 20 tonnes of wheat from a hectare of land within 20 years (on average you get about 10 tonnes of wheat from a hectare now, or one tonne in the case of organic farming).
7. *Energy storage*. This is a challenge at several levels – be it for the batteries that drive our iPhones or those needed for automotive. Our investment here is one of the reasons for the European version of the LEAF electric vehicle being manufactured in Sunderland. There is also the wider need for energy storage for our energy infrastructure.
8. *Advanced materials* and nanotech matter for aerospace, for motor cars and other functions.

These eight areas of technology are not the personal whims of one Minister, they reflect assessments by scientists in the Technology and Innovation Futures exercise. They are areas where there is significant scientific advance, where it is becoming apparent which technology is going to be used to apply these advances – and importantly, where we have in Britain the capabilities, comparative advantage perhaps, and the business opportunities to apply them.

Effecting the change

First, harness the convening power of Government to get everyone around a single table: the people researching it, the technologists developing it and the businesses that might use it or help pay for some of the R&D.

Second, if a useful conversation is emerging then it may be time to convene a leadership council which represents scientists, technologists and businesses. Crucially, (and this is one of the traps to avoid) it must not be dominated by big incumbents: SMEs and new entrants are crucial.

A leadership council needs a trusted individual – it was Keith O'Nions with space, Dominic Tildesley with e-infrastructure – whose job is to describe a 'technology roadmap', drawing on the advice of all the players around the table. This sets out how the technology is advancing, the actions that Government is taking and those that business is developing.

If the technology roadmap commands the consent of the sector, then a business case can be made to Treasury which is very aware that the business sector in Britain is sitting on £750 billion of unspent cash. With a good enough case and sufficient trust in the leadership council, it is possible to argue: "I think if we do this, they are likely to do that. If we invest and put some research funding or technology funding in, it is clear from the assurances given that businesses will step up to the plate and do their part."

That is how an industrial strategy can be made to work. □

Middle-sized firms have the potential to contribute tens of millions of pounds to economic growth. What should the government do to help these companies innovate and compete in the global economy? The question was debated at a meeting of the Foundation held at the University of Manchester on 26 November 2012.

Unleashing the potential of mid-sized businesses

Tera Allas

Mid-sized companies are often described as 'the forgotten army'. Working with 100–500 employees each, and with relatively low annual turnovers of £25 million to £100 million, they provide about 20 per cent of all business employment and account for around 20 per cent of total business turnover. There are between 10,000 and 15,000 such companies in the UK, and despite their significant contribution to the economy they can be overlooked in favour of large and small businesses when targeted interventions are under consideration.

This is unfortunate, since mid-sized companies are a source of significant growth potential. They play a key role in innovation, deriving a large proportion of their revenue from new or significantly-improved products. This focus on innovation may have helped them weather the recent financial storms more successfully than many other companies. In the relatively flat growth environment during 2009-10 almost 45 per cent of them achieved growth of more than 5 per cent. Innovation is a key driver for these companies (Figure 1) and, in the longer term, a key driver for UK productivity as well.

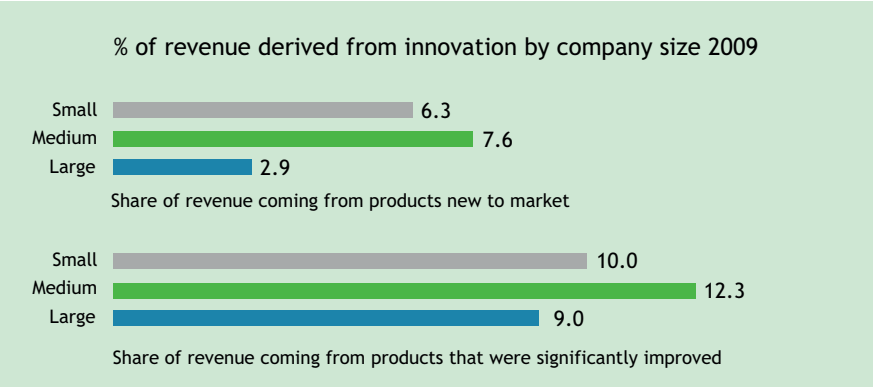

Figure 1. Innovation is a key driver of growth for mid-sized businesses in the UK. Source: UK Innovation Survey, BIS 2009.

Challenges to growth

However, mid-sized companies are also facing challenges. About 45 per cent of them saw negative growth in that year. Their contribution to UK turnover, at 20 per cent, is exceeded by that of similar-sized businesses in France, Germany, Finland and Sweden, where it is closer to 30 per cent. This relative underperformance could have a number of causes. It may be a result of their relatively low numbers – they represent a small proportion of all businesses in the UK. It may be because they have a relatively small number of employees. It is possible that sector mix plays a part, too – they may be operating in sectors that are less productive. Or it may be a result of lower productivity in terms of turnover per employee.

There is some evidence for all of these factors, with the exception of sector mix. Evidence shows that UK mid-sized companies' performance is similar across all sectors. The most striking evidence is in the area of productivity. UK mid-sized companies produce significantly lower turnover per employee than their counterparts in France, Germany, Finland and Sweden (Figure 2).

Research has identified four factors that might be inhibiting productivity. The first is access to finance, particularly growth finance. This can be a tipping point for mid-sized companies. The second is management skills. The third is employment of graduates – in 2011 only around 32 per cent of managers in UK mid-sized companies had a degree, compared with 44 per cent in Sweden. The fourth factor is the low level of exporting by UK mid-sized companies. Only about 26 per cent of them export more than half of their turnover, and, significantly, 46 per cent do not export at all.

Encouraging exports

It might be assumed that these factors are effects rather than causes; in other words, that if productivity is poor then exports will be low. However, it works the other way around too: companies that export tend to increase their productivity much more rapidly than those that do not. Over a 10-year period, 60 per cent

DISCUSSION

Multinationals: friend or foe?

Mid-sized businesses have the potential to make an even greater contribution to the UK economy, especially in areas of high unemployment. More start-ups are needed, which can then grow into mid-sized businesses. Yet many successful small businesses are swallowed by large multinationals before they are able to grow bigger. Foreign ownership of UK firms can ultimately result in the transfer of jobs out of the UK. However, some foreign ownership has brought benefits for mid-sized businesses, notably those supplying car manufacturers.

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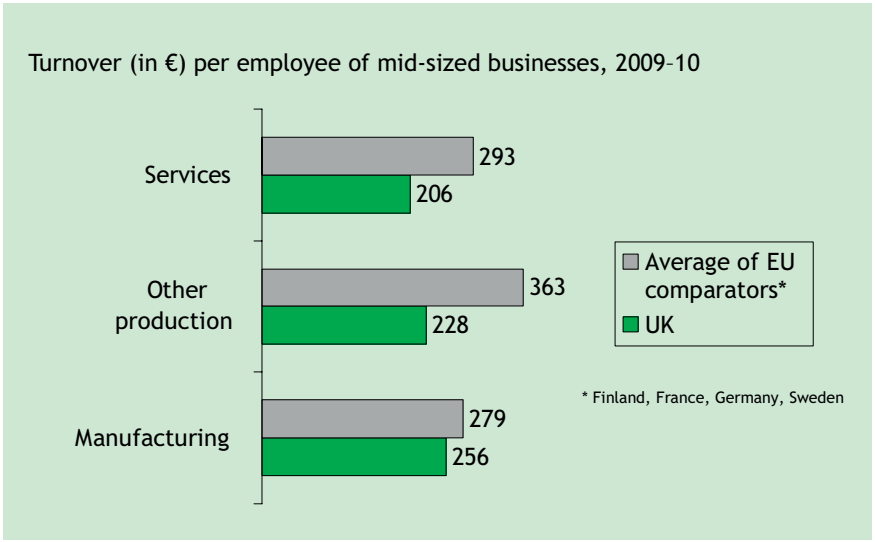

Figure 2. UK mid-sized business productivity is relatively poor in all sectors.
Source: NIESR, 2011.

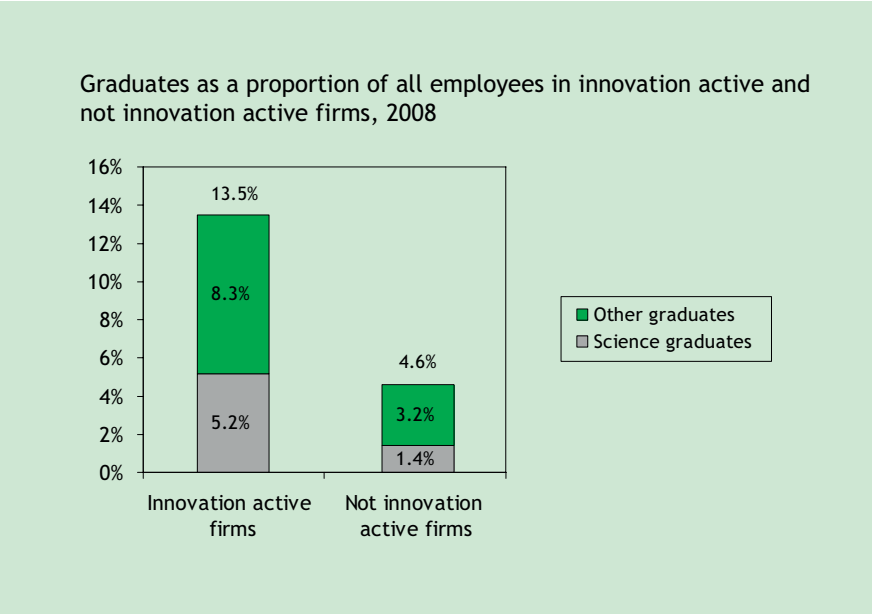

Figure 3. Employing graduates is correlated with innovation and growth.
Source: UK Innovation Survey 2009.

of all productivity growth in the UK came from the 30 per cent of companies that exported. If more companies can be helped to break into exporting, there should be not only an increase in exports but also increases in productivity and growth.

The five key export sectors in 2010 were manufacturing, wholesale, the motor trade, finance and mining. Mid-sized companies' share of turnover in these five sectors was substantial, ranging between 25 per cent and 30 per cent. If these companies are not exporting, it is important to find ways of helping them become more productive and therefore more competitive in global markets.

Finally, there is potential in employing more graduates. This correlates with innovation and growth. In 2008, graduates represented 13.5 per cent of employees in companies that were actively innovating, compared with just 4.6 per cent of employees in those which were not (Figure 3). It is not possible to say whether employing more graduates increases innovation, or whether companies that are innovating employ more graduates, but it is likely to be both. In other words, the more graduates a company hires, the more its absorptive capacity and the more innovative it has the potential to be; equally, a company that has hired graduates and become more innovative is likely to attract, and consider hiring, more graduates. This is the type of 'virtuous cycle' that these mid-sized businesses need to put in place.

The Government's contribution

The Government has put in place a number of programmes to help mid-sized companies unleash their potential. *The Plan for Growth*[1], published in 2011, sets out a number of ways of achieving this. Elements include having the most competitive tax system in the G20 and being the best place in Europe to start and grow a business. The plan also includes ways of encouraging investment and export, as well as creating a more educated workforce that is the most flexible in Europe. These measures should help companies of all sizes.

The work on better regulation, aimed at making the UK a supportive environment for business, will be especially helpful to mid-sized companies. They do not receive the exemptions from regulations that small companies enjoy, yet at the same time they do not have the means that large companies have to hire the lawyers and other experts needed to deal with regulation. Deregulation is crucial for these mid-sized companies.

Other examples of targeted interventions include the Government's Business Growth Fund, which is providing equity finance for businesses in the growth phase. The Red Tape Challenge will remove unnecessary legislation and regulation, while planning reforms will help mid-sized companies acquire the kinds of business premises they need. All of these changes should help realise the substantial untapped potential of mid-sized companies. □

1. The Plan for Growth. http://cdn.hm-treasury.gov.uk/2011budget_growth.pdf

Strengthening links between business and universities

Luke Georghiou

The debate on the relationship between business and academia is by no means new. In 1902, for example, *The Times* complained that a "very large aggregate of smaller English businesses is carried on in a stupidly conservative fashion, with antiquated machinery, traditional modes of conduct, and methods which ignore the scientific advances of recent years". Not much later, in 1919, the great economist Alfred Marshall wrote of "numerous cases in which members of the small band of British scientific men have made revolutionary discoveries in science; but yet the chief fruits of their work have been reaped by businesses in Germany and other countries, where industry and science have been in close touch with one another".

So this issue is clearly deeply embedded in the UK. Statistics and 'mind-set' are part of the problem. A company can be mid-sized but be 100 years old, or be growing from small to large (or indeed shrinking from large to small). What it is that changes about a business when its turnover passes £10 million, or whatever mark we choose to take? What is the difference between a 'static' and a 'growing' business? What distinguishes medium-sized companies in their relations with universities?

'Flows' between companies and universities

The main ways that universities interact with companies in the 'innovation ecosystem' are through flows of people, money, innovation services – and ultimately the flow of knowledge itself, either formally as intellectual property or informally. These flows are channelled via four types of links between companies and universities: collaboration and knowledge exchange; people; networking and reach-out; and commercialisation.

Collaboration and knowledge exchange may involve a company sponsoring research within a university or working together with academics in a collaborative public programme. It could also be consultancy or the use of instruments and other facilities. There are a number of challenges here. The Community Innovation Survey showed that smaller companies make very little use of higher education institutions as a source of innovation – only 2.6 per cent of them indicate universities as a key source compared with nearly half who use information from clients. However, the CBI has reported that 16 per cent of its Future Champions see universities as a key driver of growth.

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Barriers to collaboration

What are the barriers that prevent mid-sized companies from working with universities? There is the practical problem of transaction costs. When working with a global giant, we can have a small number of meetings and discuss, in one go, millions or perhaps tens of millions of pounds worth of activity and a number of projects. In contrast, when dealing with smaller companies we end up with a very large number of transactions that consume both our time and theirs. One way to deal with this is to try and work with the industry's 'eco-system', that is, with supply chains and various kinds of associations. Our links with the big companies (which are often global) can also provide mid-sized companies with a window on the world.

The second barrier concerns the internal functioning of the university and the incentives for an academic to work with a mid-sized company. Credit towards academic career progression needs to be given in such circumstances, because it might be harder to find a stunning breakthrough paper in the area concerned. In the University of Manchester we try very hard to reward impact, broadly defined, and ask our academics to report annually on it. It is written into promotion criteria, along with research and teaching excellence.

The third barrier is the need to identify which medium-sized companies are R&D-intensive and, therefore, more likely to work with us. There are iconic research-intensive companies such as Oxford Instruments and ARM that have very good university links and are spending about one third of their turnover on R&D. But companies that are not doing R&D, or do not have a very clear engineering operation that we can link to, may lack absorptive capacity – so we have to try to stimulate both supply and demand. Nonetheless, there is a broader tendency in business to outsource technology – sometimes called 'open innovation' – and this does present an opportunity.

R&D in a medium-sized company is likely to be focused on immediate business problems and hence the business may be less open to radical ideas. This is not so much a problem as a fact of life, but it may also be a risk because in the long-term these companies may be constrained in their ability to generate new business areas.

One eminently suitable way of working with medium-sized businesses is by sharing research equipment. Small to medium-sized companies (SMEs) spend quite a lot on the use of university facilities and

DISCUSSION

One-to-one communication

The problem of high transaction costs between mid-sized companies and universities could be overcome by more fostering of one-to-one contacts between a business and a university. Greater use of internships and more efforts to get students to focus on manufacturing rather than accountancy and banking will also help. Universities and business should get together (without relying on Government involvement, financial or otherwise) to set up internships in manufacturing.

equipment: this is a long-term, rising trend. We have formed a research alliance of northern universities called N8 that has built a system for identifying and managing opportunities for sharing. N8 has been very active in organising multi-institutional, collaborative R&D with companies, so far in two sectors – advanced materials and active, healthy ageing. Although universities will often simply take payment for the use of equipment, our experience has shown that equipment-sharing works much better if it is a vector for collaborative work and if the two parties have a common interest.

The 'hidden job market'

Medium-sized companies also face problems and challenges arising from the flow of trained people into the economy. The first is one of image from the perspective of graduates. Almost half of graduates are targeting jobs in large firms; only 19 per cent are aiming for small and medium-sized businesses. This image also works the other way around – many firms are not recognising the value of graduates to their business. Even if both sides are willing, there is the barrier of 'search economics' – this is sometimes called the 'hidden job market' because of the large number of transactions that might be necessary. As far as I know there is no effective portal for job search opportunities for this sector. A related point is that only 38 per cent of mid-sized companies offer internships, compared with 54 per cent of large companies.

Employability is seen as a top priority by 70 per cent of firms that recruit students. Universities need to do more to make their students employable. Manchester is a rather nice place to live so 40 per cent of our graduates want to stay here, although currently there are not enough graduate-level jobs to enable them to do so. At the same time, local SMEs perceive us as inaccessible and they think that graduate employees are beyond their means.

To address this, we have set up the Manchester Graduate Internship Programme, which is an exclusive internship scheme for new graduates giving them paid graduate-level positions for a maximum of 12 months. In its first year, around 180 vacancies were generated through the programme with over 100 graduates being placed. The companies involved were highly enthusiastic. Those that had not employed graduates before said the graduate interns were doing a good job and many of the interns were offered the opportunity to stay on.

Enterprise and commercialisation

The University is committed to giving students enterprise training and is working toward providing such training for all students. Additional funding awarded by the HE Innovation Fund is being reinvested to roll this scheme out. There is an annual graduate entrepreneurship competition called 'Venture Further'. One winner was a first year engineering student who developed a new method of constructing a cavity wall with quite considerable environmental benefits and cost savings. This was a real business proposition that is now trading. The most recent winners developed a product that I think will be dearly loved by students – some rather nice jelly sweets packed with caffeine called 'Kaffeination'. Their company has gone on to win European and global student venture awards and investment.

We come finally, to commercialisation. This is familiar territory for many – licensing intellectual property, forming spin-outs and providing the necessary infrastructure and incubation. The university's contribution is to help create new medium-sized companies. Since 2003 UK universities have formed a top 50 of spin-out companies with a collective market or trade sale value of £13 billion.

Summing up, the UK needs more medium-sized companies, particularly R&D-intensive ones. Universities can contribute to this in all of the ways described. They can be a source of new companies that grow into medium-sized companies and beyond. They can be a provider of knowledge and of people. Medium-sized companies and universities need to increase their mutual awareness and develop efficient ways of working together.

Great opportunities exist for these companies to host more internships. On the university's side, we have to promise that if businesses take our interns, then we will equip them with the skills and knowledge to help those firms on the path to innovative success. ☐

Engaging business potential and research expertise

Richard Burslem

The Greater Manchester Chamber of Commerce is the largest in the UK, with over 5,000 members. Its Engineering and Manufacturing Sector Council supports and promotes engineering and manufacturing in the region. Many of the Council's members represent mid-sized companies.

When asked their thoughts on exports and innovation, most members expressed the belief that export relies on innovation rather than price, and therefore innovation is highly important to their companies. They observed that, although universities are in the mix when it comes to innovation, they are not always essential. It is easy for companies of this size to get lost in the university maze – unable to find out who to contact and exactly what a university has to offer. There is also a fear of failure and worry about the cost of innovation projects. Clearly both sides would benefit if universities could be more proactive at communicating the valuable services they can offer to mid-sized companies and simplifying access to their services.

Richard Burslem is Site Director of Wallwork Heat Treatment. He has worked as a metallurgist and director in his current company for more than 20 years. He is the Chair of the Greater Manchester Chamber of Commerce's Engineering and Manufacturing Sector Council.

To illustrate these points, the Insider North West November 2012 survey revealed that two thirds of companies who had never worked with universities did not know what was on offer. Of the companies which had worked with them, though, 92 per cent would do so again. One comment was that

companies would use universities more if they offered a 'one-stop shop' with a very simple, straightforward process.

Wallwork Heat Treatment was founded in 1959 by Robert Wallwork and has sites in Manchester, Birmingham and Cambridge. It employs 245 people and has a turnover of about £15 million per year. The company specialises in heat treatments and metal coatings. It also manufactures some of its own vacuum equipment – because we cannot find anyone else who produces it. We also sell that equipment to other manufacturers. The company has a significant R&D department and its own superalloy foundry.

The business's major market is aircraft manufacture and repair; it is also active in other sectors including automotive, medical devices, pharmaceuticals, oil and gas, general engineering and tool-making. There are over 8,000 customers ranging from sole traders to large aircraft manufacturers.

Wallwork has 16 graduates on its staff, 15 of whom are technology and engineering graduates and one of whom is a metallurgist. Four have PhDs and three have MBAs.

The following three case histories, two from our company and one from a very different type of business, show clearly the ways in which innovation allows companies to grow.

Energy saving

Wallwork Heat Treatment is very energy-intensive, spending around £2 million per year on energy out of a turnover of £15 million. In a bid to save energy, a Knowledge Transfer Partnership was arranged, with a Sheffield University graduate coming to work with the company.

On her first visit to the factory floor the graduate asked: "Why are there two pilot lights on each furnace?" We directors looked at each other and replied, "We don't know, but they've been there for 30 years. Let's turn one off." With that, the project had become self-financing within the first 24 hours! We had saved £20,000 per year just on pilot light gas.

By the end of the project, the graduate had identified further savings of £30,000 per year on the process gas we use. In addition, we had reduced our furnace heating time by half, decreased our consumption of burner gas consumption by two thirds and made a significant reduction in our carbon footprint.

Lighter aircraft

Another innovation was born out of the need to reduce the weight of the A380 aircraft. One way of doing this was to replace the two heavy steel bearings used for landing with lighter titanium bearings. The titanium was not strong enough though, so a new system had to be designed to overcome that. Working in partnership with Sheffield University again, we were able to devise a new coating which has so far brought us £250,000 in sales each year. This is expected to double to £500,000 per year.

The company's investment was quite high at £557,000, and the whole project was only made possible by an additional £287,000 in the form of a grant from the Technology Strategy Board. The growth potential for this type of coating is remarkable, as its application can be widened to include more bearings and different types of aircraft.

Black pudding

Another example of innovation, albeit in a smaller company, is the story of a black pudding seller from Bury. She used to sell her black puddings at Bury market, which is open only three days a week. So she decided to use the internet to expand her business. However, black puddings do not travel well. Her innovation involved creating packaging that would allow her to send out the puddings while at the same time increasing their storage life.

The company now employs 50 people making 35,000 kg of black puddings every week. The point of this example is that small companies should not be ignored; they may soon become mid-sized companies. In addition, not all innovation is high-tech; sometimes it involves very simple changes.

Barriers to growth

There are three main barriers to growth which affect both small and mid-sized companies. The first is the difficulty of obtaining finance, and the impatience of most investors who want to quick profit.

The second is the difficulty of finding suitably trained staff. Unfortunately, many graduates have no idea of what is required for business life. This lack is particularly acute at the level of trained technicians. Colleges no longer run training courses for technicians, and this is something that is being addressed through encouraging the establishment of training courses in colleges.

The third barrier is EU regulation and the law of unintended consequences. Well-meaning legislation to reduce ageism by regulating compulsory retirement can damage a company's plans for growth. Another example is the REACH regulation, aimed at protecting health and the environment from harmful chemicals. Its effect is to require companies to seek separate approval for each and every chemical they might need to use.

The Heseltine report

Lord Heseltine's report, *No stone unturned in pursuit of growth*[1], covers these points, among others, in refreshingly straightforward language. Among its conclusions are:

- an industry council should be established between Government and industry. This would be an excellent way to enhance relations;
- promotion of inward investment;
- private sector involvement in drafting regulation and Government to identify EU regulations well in advance. This would ensure that regulations can be implemented sensibly and avoid unintentional consequences;
- leadership and management skills to be taught at all levels of education and business engagement to be included in the school curriculum. This is paramount. No one should become a company director without leadership and management skills. Businesses should visit schools to increase student awareness of the potential for job satisfaction as well as opportunities for financial success in the world of business;
- long-term and patient loan capital to be made available. Investors must be patient. Our company is an example: it began with three people 54 years ago and now employs 245 people;
- industry councils to work with Higher Education to ensure their courses are relevant. This is essential in order to prepare students for business life. Courses need to equip students with the necessary practical skills and knowledge, including apparently simple but essential training – such as how to answer the telephone.

These are all measures that would benefit my company and those in the Engineering and Manufacturing Council of the Chamber of Commerce. Working together with universities is an integral part of ensuring growth through innovation for mid-sized companies. □

1. https://www.gov.uk/government/publications/no-stone-unturned-in-pursuit-of-growth

At the Christmas Reception on 5 December 2013, a special lecture was given on the challenges facing the continent of Africa and the potential contribution of science to solving them.

Africa: The greatest scientific challenge of our generation?

Christopher Whitty

By the end of this century, Africa will probably be home to more than a third of humanity. All of Europe, the USA, India, China, Mexico and Japan could be encompassed within Africa geographically (Fig. 1). The path that Africa chooses to take is therefore of major importance for its own people, and the world, over the medium to long term.

Sub-Saharan Africa has many of the fastest growing economies in the world (Fig. 2) but also some of the greatest need. Africa has not benefitted from science and technology to the extent of other continents, though. Take any global challenge and, in virtually all, Africa is in a much weaker position than any other continent – yet for many of these issues science can be transformative.

Science can help Africa in a number of ways. It can provide new technologies, as well as reduce the cost – or increase the availability – of current technologies. It can test out how best to deliver services and technologies as well as assess their impact, so helping people to stop doing things that are either not working or are causing active harm; advances in health are a good illustration of this. Science can help in understanding the environment in which communities are operating (including the social environment) so that people can make better policy decisions, with climate change an important example.

Agriculture and new technology

A key example of how better technology can help in Africa is agriculture, which is essential for food security, economic security for many households and economic growth for a large number of African countries. The green revolution had a major impact on the economies of Latin America and Asia – indeed, wider economic growth came on the back of great science that helped them move from hunger to surplus.

In Africa, research is now improving crops both in terms of their yield and their ability to withstand drought, flood and other environmental changes. Traditional African rice, for example, is not a high-yield plant but the NERICAs (new rice varieties for Africa), have led to substantial increases in yield as well as greater drought tolerance. Much of this science was carried out in Africa by outstanding African scientists.

Professor Christopher Whitty FMedSci FRCP FFPM is Chief Scientific Advisor and Director – Research & Evidence at the Department for International Development (DFID), as well as Professor of International Health at the London School of Hygiene & Tropical Medicine. He has worked in several countries in Africa as an epidemiologist and is responsible for DFID's research portfolio including agriculture, infrastructure, climate change and social science.

Science is also making inroads on plant disease and pest resistance of plants. To take one example: striga is a parasite with a serious impact on maize production. Science is addressing this by breeding-in herbicide resistance (but not via GM). The maize seeds are then dipped in herbicide. When the plant-parasite striga gets among those seeds as they germinate, it dies because it is not herbicide resistant and the maize can then grow.

A different approach to the same problem is to grow alternative plants around the side (like napier grass which is used for cattle fodder) which provide a barrier to striga around the growing maize. This has had greater uptake so far, but both approaches are potentially highly effective.

Alongside the improvements in plant yield, weather and disease resistance, there are serious problems with nutritional deficiencies that better technology can address. For example, vitamin A deficiency makes people susceptible to more serious infections, particularly measles. Measles has a mortality rate in Africa of 5-10 per cent, compared to less than 0.01 per cent in the UK. Enriching staple foods with Vitamin A could have a major impact. There are already two examples, pro-vitamin-A-enriched sweet potato (through conventional breeding) and golden rice (using GM). The impact on health at a population level is still uncertain, but early data are encouraging. These are just two examples where a micronutrient can be increased in existing plants. Of course, a better solution would be to diversify people's diets – so this is, in a sense, only a partial solution.

Expecting a single technology to be transformative is usually unrealistic, and often the individual advances are modest, but the collective impact of multiple incremental advances can be substantial. If science can improve yield by, say, 10 per cent, reduce the problems of drought by 10 per cent, improve disease resistance by 10 per cent, as well as improve transport and storage costs by 10 per cent, there is a huge overall gain.

Animals and vaccination technologies

The vaccination of animals is a different area of science where new technology is helping development in Africa. It was announced in 2011 that the viral disease Rinderpest had been eradicated. This achievement was based, like the eradication of smallpox (the only previous disease humans have eradicated) essentially on a single technology: vaccination. Cattle are not just sources of food, they are also capital for many African cultures. When it first reached Africa Rinderpest killed up to 80 per cent of cattle, so eradicating it is an enormous scientific and practical achievement.

East Coast Fever is a serious ongoing parasitic disease of cattle. The preventive strategy involves not a conventional vaccine but rather infecting cattle with the viable parasite and then treating them with doxycycline, a widely-available antibiotic. This infect-and-treat vaccine makes them immune. The method is now economically self-sustaining in East Africa: farmers

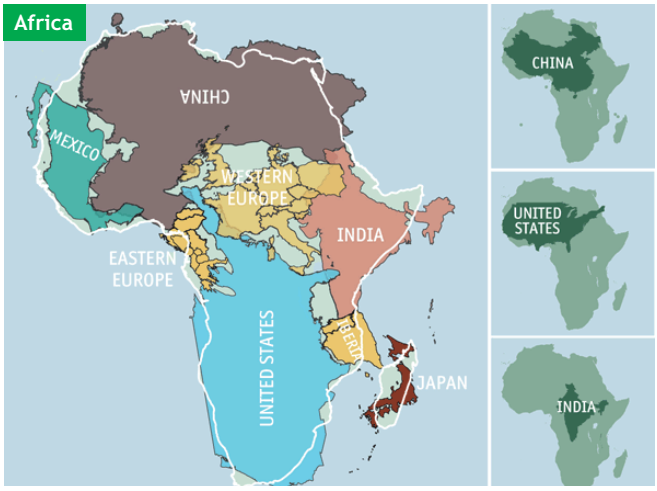

Figure 1. By the end of this century Africa could be home to one-third of humanity.

want to buy it because of the devastation the disease can do to their herds and a factory to manufacture it has been set up in Malawi.

Some animal vaccine research programmes are at a much earlier stage of science. Bovine tuberculosis is a serious problem in Africa but research is underway in Ethiopia. Progress, though, is steady rather than dramatic. Work done in Africa – for African needs – may however have relevance to developed countries where bovine TB remains a problem.

Human health and the science of delivery

When people talk of 'health', they tend to think about doctors, drugs, vaccines and diagnostics, but things like infrastructure are equally important. For example, the kind of house someone lives in and its ventilation will affect their TB, pneumonia and malaria risks. Scientific advances in the built environment, water and sanitation – which are essential to health but are not conventionally seen as part of the health systems – will have a very substantial positive impact.

Science has a lot to offer through new technologies. However, for many diseases of African populations the problem is not that highly effective prevention technologies, vaccines and drugs are not available, but that they are not getting through to the right people. Identifying better ways to deliver services – the science of delivery – is as important as better technology.

Vaccines provide an elegant illustration that sometimes what is needed is more basic science, at others improved technology, or even better delivery – and in most cases a mixture of these. Polio, measles and hepatitis B are examples of where the technology is excellent but there are real difficulties in delivery. The polio vaccine works well and most areas of the world have managed to eliminate the disease. One of the really problematic areas, though, is Northern Nigeria; here is it social science (understanding why people are resistant to polio campaigns) and the science of better delivery we need. A variety of delivery problems mean that this highly effective technology is, at this point in time, still some way from eliminating what should be an entirely eradicable disease.

At the other extreme there are other infectious diseases where affordable and effective vaccines are still not available – HIV, malaria and TB are good examples. There is no effective HIV vaccine, nor is there likely to be one deployed in the next 10 years: for this better basic science is needed. For malaria, the best vaccine at the moment is less than 50 per cent effective and its impact wanes very quickly, so again the basic science still needs to be advanced.

Between these and polio are vaccines like that for meningococcus where we have an affordable effective vaccine against meningococcus type A but the technology for affordable vaccines for other strains needs to be developed. This is not so much a matter of basic science but of the technical development of existing basic science.

Drugs

As with vaccines, there is a need for new drugs in Africa, but probably an even greater need for science to test how to deploy them more effectively. Although excellent drugs exist to counter such illnesses as pneumonia and malaria, deployment and targeting are weak in Africa. The result is that hundreds of thousands of children die every year for want of widely available drugs which cost less than half a pint of beer in London.

Just take malaria as an example. In Africa, there is a very large pool of people who need anti-malarial drugs. There is also a very large pool of people who get anti-malarial drugs; the problem is they are often not the same people. Get those two bits of the Venn diagram to overlap better and the problem of malaria is substantially reduced; by improved targeting, the same number of drug doses will save many more children.

The scientific approach to malaria targeting has traditionally involved developing better diagnostic technologies. What people often forget is that giving people technology does not solve behavioural issues – and this includes people who are highly technically-skilled. To give one example, randomised trials of good new rapid diagnostic tests given to doctors showed they hardly affected treatment at all; doctors asked for the new test, got a negative result for malaria – and often treated for it anyway. Conventional practice is to treat for malaria and that is difficult to change. People ignore behavioural science at their peril.

Despite the problems Africa is experiencing, it is recording some of the biggest falls in child mortality ever seen anywhere – and these are based on many decades of excellent science. In many countries in Africa, mortality rates are falling by 5-10 per cent a year. There has been an overall fall of 40 per cent in childhood mortality in Africa in the last 25 years. That is astonishing, and the reasons for this are many: insecticide-treated nets, improving nutrition, supplementing vitamin A, improving diarrhoea treatment, oral rehydration, zinc, care-seeking, etc. The key point is that to achieve a big effect there must be multiple interventions. Many small incremental advances, based on good basic, translational delivery and social science lead to phenomenal changes in society.

Economics, and the science behind economic growth, are also important for health. Plot all the countries in the world, with GDP on one axis and mortality on the other and they line up remarkably clearly – as a country gets richer, mortality falls. As Africa's economies improve, they will move up along the same line, but it is possible to accelerate the process substantially with better science directed specifically at health.

Climate change

It is common sense that African populations

will suffer more than other continents from climate change. It is the poorest of the continents and poverty reduces people's chances to adapt in response to major changes around them. Africa has a higher reliance on rain-fed agriculture, relative water scarcity in many areas, cold is seldom a constraint, there is an existing high risk of major weather events – the list goes on. This is an example of an area where science can help by expanding our ability to understand change, to predict its effects on a geographical and sectoral basis, and to respond to it.

Whilst the science of predicting what changes will occur and when may currently be relatively crude, it is improving rapidly. Existing models suggest droughts are going to increase and rainfall decrease in many areas, with most current projections suggesting that the Sahel and Southern Africa are going to face a particularly large challenge. Extrapolating projected rainfall changes into predictions on the effects on crop yields is a further level of difficulty: systematic reviews of current studies suggest there will be a significant reduction due to climate change for several major staples, with the possible exception of rice. Of course this assumes all other things remain equal, and science can do a lot more than predict; it can also help African farmers to adapt. While crop yields may reduce by 15-20 per cent due to climate change, science may help provide tools and understanding to erode this decrease (but not remove it) through improved crop varieties, or better use of water and fertiliser.

In terms of mitigation, Africa currently contributes a relatively small amount of global greenhouse gases, but with the fastest growing populations and many of the fastest growing economies globally, the path African countries take on carbon will soon be of global importance. In general, the continent is starting off with a much smaller infrastructure based on carbon systems than most others – so in principle it has greater flexibility to grow a low-carbon economy.

African Finance Ministers worry, reasonably, that when people talk of low-carbon growth they actually mean slower growth. Low carbon technologies are, after all, generally more expensive; if they were not, everyone would switch over extremely quickly. So with current technologies there is some force to their concerns.

Solar power and biofuels are often talked about as potential sources of energy in Africa – there is after all a lot of sunshine. Solar has proved transformational in terms of providing low-energy power to households with no energy (e.g. solar lanterns), but this is marginal when it comes to major carbon saving. For solar to have a major impact on Africa's power needs, several scientific challenges need to be overcome, especially on storage and transmission of energy; after all, the biggest solar potential is not where the major populations are based.

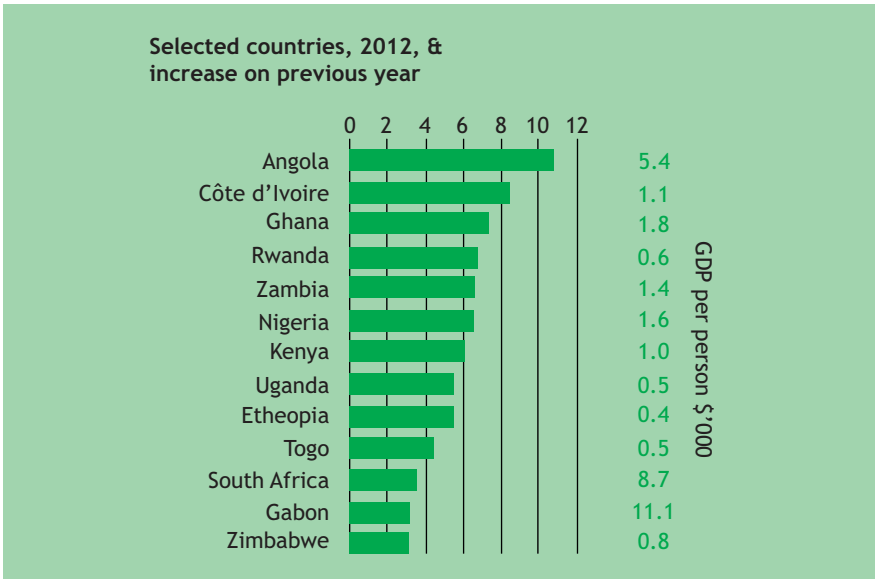

Figure 2. Sub-Saharan GDP growth forecasts for 2012. Source: IMF.

Enthusiasm for biofuels comes and goes and recently they have attracted a great deal of negative publicity because of their contribution to food price spikes. That is partly because, for political reasons, the (food base) crops that make them have been encouraged in northern countries where they make little biological, economic or physics sense (Europe or North America). A better energy return could in principle be achieved in the tropics, but finding biofuel sources that do not compete with food production will be key.

Finally on innovation: Africa has always been a place of innovation. For example, the mobile phone is now used in Africa in ways far in advance of the UK: for banking, telemedicine, warning of equipment breakdown, etc. That is just one example of a platform, the phone, which Africans have used to innovate very effectively. Harnessing African innovation for global science will benefit everybody.

Scientists and engineers

There are many individually outstanding African scientists, but very few compared to other parts of the world, and worryingly few compared to Asian and Latin American countries at a similar stage of their development. Taking the number of physicians per 10,000 inhabitants as a proxy for other technically-educated groups; in the USA and UK it is roughly 25. In Brazil, Pakistan, Vietnam the figure is around 15. By the time you get to the middle-income countries in Africa, the count drops to 1 per 10,000. An analysis of engineers, science teachers, or almost any other science area, will give a similar outcome. This is probably the greatest block to these countries moving up from lower middle-income status. Building this capacity is essential – but given the long lead times and limited post-primary education in most countries, it will be slow and difficult.

On the other hand, Africa has both scientific and political leadership. A Minister of Health in Africa is likely to be a physician, a Minister of Roads will probably be an engineer – the level of debate between technicians and politicians in Africa can often be higher than in Europe or the USA.

Africa has a need for science of many types. Our scientific generation could transform the outlook for most countries in Africa, but by doing multiple small things through many disciplines. Very few advances will come from a single step – they will always come from lots of small improvements, from basic science all the way through to the most applied science, including industrial science development in R&D and economics.

There are many serious problems, but equally there are potential solutions that can be provided within a realistic timeframe. Since Africa is so important both now and for the future, since its current need for scientific solutions is so great, and since this transformation is achievable, I believe it can justifiably be called the greatest scientific challenge of our generation. ☐

At the Christmas Reception of the Foundation, Mr Cyrille van Effenterre gave a report on French scientific policy on behalf of Mme Geneviève Fioraso, Secretary of State for Higher Education and Research in the French Government.

The scientific agenda in France

Geneviève Fioraso

Like the UK, France is at the very top level of scientific endeavour. Yet, contrary to the experience in the UK, the economic impact of French science has not yet reached the expected level in terms of the filing of patents, private investment in R&D or the growth of innovative spin-off companies from our research labs – all these aspects must be improved!

Improving the economic impact of R&D is a key concern for France. We all share the conviction that, in advanced countries, there is no way to stimulate growth without a strong research and innovation policy. Yet how can we promote those changes at a national level?

In France, a national consultation has been running across the second half of 2012. It has been run by an independent committee, chaired by Françoise Barré-Sinoussi, Nobel Prize Winner in Medicine in 2008. More than 100 interviews were carried out. Some 1,200 written contributions were received. About 500 meetings were held, involving around 20,000 participants from all the French universities and research organisations.

Our strategy is to be more integrated within the European Union, focussed on innovation, competitiveness and growth. This includes training highly-skilled young people, so that they are more attractive to employers: that is a prerequisite for competitiveness and growth.

The success of all students in the early stages of their university courses is a priority. We must make the higher education system simpler and more accessible, for French as well as foreign students – and for employers too!

Research excellence must be encouraged. Frontier research must be kept alive, so the budget of the French research councils has been increased. In addition, 50 per cent of the budget of the National Research Agency is being devoted to science-driven programmes.

I have recently asked this agency to encourage the winners of our Young Researcher national programme to apply for European Research Council grants at the end of their contracts.

Global challenges

Today's global challenges – from climate change to unemployment – are both economic and social. The world's demographic and economic growth means we face huge societal challenges in terms of energy, climate, global health but also wealth inequality. All scientific disciplines have to work more and more together, with a focus on global societal issues. Interdisciplinary approach is an absolute necessity. Humanities and social sciences have to be fully engaged in research programmes.

I am also promoting 'Technological Research' which has not traditionally stimulated partnerships with SMEs. I am convinced that we have the capacity to accelerate the transfer of knowledge into industrial products and services. I am also promoting an important initiative of new regional platforms, dedicated to 'local' technological innovation, conducted by 'CEA Tech'. Three new locations are being established in Nantes, Toulouse and Bordeaux. These will develop close links with local industry but also involving academic partnerships with public labs and institutions. This has already been successfully trialled in the Grenoble area and has generated an innovative ecosystem.

Knowledge transfer and innovation

More globally, we have to make our transfer and innovation system more efficient in terms of economic impact. A key focus is SMEs, which are more comfortable with disruptive innovation.

A new 'Transfer Policy' has been announced. This has four main themes:

- development of a culture of innovation and entrepreneurship;
- strengthening regional ecosystems for innovation;
- reinforcing efficient tools devoted to innovative SMEs;
- boosting spin-off companies arising from public research labs.

For instance, the National Research Agency is about to fund new public-private labs, involving SMEs, as well as the French nodes of the European Institute of Innovation and Technology (EIT).

The French innovation landscape will be structured around French competitiveness clusters. The country has more than 70 of them, including 15 world-class clusters in key strategic fields, such as Aerospace, Healthcare and Biosciences, IT, Nanotechnology, new materials...

World-leading companies, innovative SMEs and public research organisations are involved in these clusters. After two four-year programmes focused on R&D, the third stage will emphasise economic growth concerns.

In my view, our ability to build these regional innovative ecosystems is the key issue. As an analysis of the leading entrepreneurial regions shows us, the necessary ingredients are well known: high-level universities and research labs; access to public and private funding including venture capital and private equity; high-level tech-transfer managers and, above all, an entrepreneurial spirit!

The European perspective

The context for higher education and research in France has changed in recent years. Still, we must try to make our system even more creative, more responsive and more open to European and international partnerships.

The best way to realise the European Research Area (ERA) is to build concrete actions on long-term trust and partnership. I have no doubt that at the scientific level, everyone is convinced. The successful mastering and deployment of key enabling technologies by European industry is a key factor in strengthening Europe competitiveness for growth and jobs.

The ability to build a relevant and efficient research and innovation policy is a key issue for our countries. This underlines the role of organisations like the Foundation for Science and Technology. Of the fifteen measures that define the new French transfer policy, perhaps the most important is to build a think-tank devoted to innovation, embedded within the research labs that are active in science for science and innovation. □

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

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

16 April 2013

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

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

6 March 2013

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

Threats and opportunities - scientific challenges of the 21st Century

6 February 2013

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

Science, Innovation and International Development

5 December 2012

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

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

26 November 2012

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

Delivering the industrial strategy - how can government promote growth?

14 November 2012

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

Energy policy: selecting the right options for future electricity supply

7 November 2012

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

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

25 October 2012

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

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

3 October 2012

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

The future strategy for the management of mental health in the UK

11 September 2012

Lord Layard FBA, Director, Wellbeing Programme, Centre for Economic Performance, London School of Economics and Political Science
Professor Simon Wessely FRCP FRCPsych FMedSci, Chair and Head of Department of Psychological Medicine, and Vice Dean, Institute of Psychiatry, King's College London, and Consultant Liaison Psychiatrist, Maudsley and King's College Hospital, King's College London
Professor Sir Bruce Keogh KBE DSc FRCS FRCP, Medical Director, National Health Service in England

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