The Fruits of Curiosity: science, innovation and future sources of wealth

Institute of Physics response to a Royal Society call for views

A full list of the Institute’s submissions to consultations and inquiries can be viewed at www.iop.org

5 June 2009
Dear Dr. Wilsdon

The Fruits of Curiosity: science, innovation and future sources of wealth

The Institute of Physics is a scientific charity devoted to increasing the practice, understanding and application of physics. It has a worldwide membership of over 36,000 and is a leading communicator of physics-related science to all audiences, from specialists through to government and the general public. Its publishing company, IOP Publishing, is a world leader in scientific publishing and the electronic dissemination of physics.

The Institute is pleased to submit its views to inform the Royal Society’s inquiry, ‘The Fruits of Curiosity: science, innovation and future sources of wealth’. The response was prepared with input from the heads of UK physics departments, the Institute’s Science, and Business and Innovation Boards, and from comments made to previous inquiries, including the RCUK Review of UK Physics.

In addition, the Institute is undertaking several pieces of work with the aim of demonstrating the economic and societal impacts of UK physics research, which we would be happy to share with the Royal Society.

The attached annex details our response to the questions listed in the call for input.

If you need any further information on the points raised, please do not hesitate to contact me.

Yours sincerely

Professor Peter Main
Director, Education and Science
The Fruits of Curiosity: science, innovation and future sources of wealth

1. What role should science and innovation play in any ‘rebalancing’ of the UK economy following the current economic downturn, and in identifying and prioritising future growth opportunities?

Science and innovation have a key role to play in providing a much needed boost to the UK’s economy: science with its ability to attract the brightest students into higher education which will lead to highly skilled graduates that make significant contributions to many sectors within the UK’s economy; academics who will undertake internationally leading research, which is the foundation for new discoveries and applications; and innovation, which is the ability to transform great ideas and concepts into products and services, creating jobs, and contributing to UK GDP.

The Institute appreciates the wish to identify potential growth opportunities in the current economic downturn, i.e. picking winners, but would urge the UK government to find a healthy balance between the need to fund curiosity-driven research, and the focus on the need to translate knowledge into products and services that can contribute to UK GDP.

Many technological advances have their origins in curiosity-driven research, where the outcomes of the research cannot be easily predicted; physics research has an excellent track record in making significant contributions to UK GDP. For example, PET, MRI, X-rays, lasers and semiconductors are all technologies which are widely used in every aspect of our lives, and are enormously beneficial to society.

On this point, a report by the Russell Group\(^1\) showed that curiosity-driven research can have a far greater economic and societal impact than research carried out with a specific commercial application in mind. It showed that the commercialisation of curiosity-driven research generated significant returns for Russell Group universities. Therefore, the UK has a strong and vibrant research base, which needs continual support.

But in terms of making the UK a place to do R&D, the UK currently does not have the investment in the transitional research and industrial capability which would allow the more direct products of curiosity-driven research to be widely exploited by UK companies operating within the UK. At the core of such success would be continued public investment in curiosity-driven research, but for this to benefit the UK there must be absorptive capacity within UK industry, both for the trained employees and the knowledge produced by this research.

\(^1\) The Economic and Social Benefits of Research; http://www.russellgroup.ac.uk/home.html
2. After 10 years of growth in public spending on science and innovation, and given the current poor state of public finances, should the UK maintain, increase or decrease levels of investment?

In the last decade, the UK has had unprecedented support for science and innovation. This was reflected by the positive comments made by the 2005 International Review of Physics and Astronomy Research panel\(^2\), which stated that it “…was struck by the general improvement in the research environment and the positive outlook of those involved with the research effort at all levels. Progress has clearly been made and the UK is now well placed to reap the benefit of the investment that has been made since the 2000 review. This progress, however, is predicated on maintaining the increased level of funding that has taken place over the last few years. The Panel cannot overstate the importance of this funding for the continued health of the subject, and for continuation of the benefits it brings to society and the economy.”

In addition, the recent RCUK Review of UK Physics\(^3\) stated that physics “…is in a generally good state of health, with departments performing curiosity-driven research of the highest international quality and having benefitted from a significant increase in research expenditure in recent years.” And it recommended “…that the UK government should continue to fund research in both basic and applied physics across a broad spectrum of subdisciplines at the level required to retain international competitiveness.”

Furthermore, the results of RAE 2008: in physics and astronomy\(^4\), showed a strong platform of internationally excellent curiosity-driven research, with strengths in a great many different fields, marking an improvement in the amount of international quality research since RAE 2001. Across the discipline, the UK is now perceived as a good partner in international collaborations, and improved funding has attracted a stream of talented early career researchers since 2001, particularly from elsewhere in Europe. The key message was that much of the world-leading research presented at RAE 2008 was carried out under small, responsive mode grants.

Therefore, the Institute wholeheartedly concurs with the recommendation of the Sainsbury Review of Science and Innovation\(^5\) that the government continues to fund increases in basic science in line with the Science and Innovation Framework 2004-2014, and with the Prime Minister’s, the Rt Hon Gordon Brown, statement at the Romanes Lecture\(^6\) earlier this year, where he said, “…the downturn is no time to slow down our investment in science but to build more vigorously for the future. We will not allow science to become a victim of the recession – but rather focus on developing it as a key element of our path to recovery.”

But it was disappointing that the government decided against providing a mooted £1 billion cash boost for scientific research\(^7\) at the recent Budget\(^8\), following the lead of the USA which allocated $8.9 billion for scientific research\(^9\). On the contrary, £106 million will be reallocated within the Science Budget in order to ‘support key areas of

\(^{3}\) RCUK Review of UK Physics; http://www.rcuk.ac.uk/review/physics/default.htm
\(^{5}\) The Race to the Top: A Review of Government’s Science and Innovation Policies; http://www.hm-treasury.gov.uk/sainsbury_index.htm
\(^{6}\) http://www.ox.ac.uk/media/news_stories/2009/090227_1.html
\(^{7}\) http://news.bbc.co.uk/1/hi/sci/tech/7946371.stm
\(^{8}\) Building Britain’s Future; http://www.hm-treasury.gov.uk/bud_bud09_index.htm
economic potential', i.e. the research councils will have to reallocate funding from other parts of their budgets to provide additional support to the cross-council research programmes. This may lead to cuts in curiosity-driven research funding.

3. What are the emerging fields of science and research where the UK has, or could soon have, a position of global leadership?

As already mentioned the prediction of the best prospects for future discovery and invention is notoriously difficult, hence it is essential for the UK to support a broad research base and not attempt to pick winners. It is not clear whether focussing on select, narrow areas will result in short-term economic gains, but it is obvious that in the medium- to long-term, it will undermine the UK’s ability to retain the highly trained, inventive and innovative scientists and engineers who will maintain and strengthen the UK’s international competitiveness. It is these people, particularly those that have been attracted to the UK by a funding system and academic ethos that allows them to pursue curiosity-driven research, who will enable the UK to respond to new discoveries for which the economic and societal impacts are manifold, but which are broader and harder to quantify than for example, profits in a manufacturing company.

4. Could a similar leadership position be achieved through strategic alliances with other partners in Europe or internationally?

The Institute concurs with the Sainsbury Review of Science and Innovation5 that international collaboration is important if the UK is to remain at the forefront of international science and innovation and benefit from research excellence in other nations. Particle physics research is a good example of this, where the UK’s leading physicists collaborate with those from all over the world at CERN, centred on facilities such as the Large Hadron Collider, thus sharing expertise and reducing the participation costs incurred by each nation.

The advantages of working within European infrastructures are clear, both in terms of the increased scale of budgets which can allow the UK to compete with the likes of the USA for larger or more speculative projects, but also through the opportunities to collaborate with leading research groups and companies from other EU nations. Over recent iterations of the Framework Programmes, UK universities have attracted a large proportion of the funds available.

However, the problems that can be encountered by both academics and companies within the EU funding structures are equally well documented: a primary, practical problem is that all EU nations have different employment rules, tax and financial regulations. A further difficulty is the perception of an overly bureaucratic application process which can require a substantial commitment of time and money, with no guarantee of any reward. This has resulted in companies sometimes finding it easier to form links with the USA, China or India; it is interesting to note that the RCUK has set up offices in the USA, China and India, with the aim of facilitating collaborative research in these nations. More needs to be done to add greater transparency and efficiency to the EU’s processes.
5. What other niche advantages can the UK benefit from (e.g. geography, manufacturing capacity, public sector procurement) and how can these be aligned with research policy and investment?

To identify areas where the UK can do more, a wide ranging and creative study of the UK’s essential assets and how they should be used should be undertaken. The UK has several ‘clusters’ that are world leaders, for example surrounding Cambridge and Oxford, which could be a starting point for such work. The Northern Way recently completed a similar study\(^{10}\) in its region which highlighted the strength of science infrastructure facilities. Following such a study, an informed view of the future of key scenarios could then be formed and the results compared with where the UK is currently.

If utilised properly, the UK’s public procurement budget has the potential to play an important role in promoting science and innovation. Through providing access to a valuable and innovative end consumer, the government can work to bring science from the laboratory to the marketplace, supporting science-based industry and thus scientific research. This could be aligned with specific areas of public policy using the ‘challenge’ model, currently being operated in a limited way by the TSB\(^{11}\). Through aligning national needs with research council funding, strong science research can be further strengthened through industrial interaction.

6. How will increased support for science in the US, China and elsewhere impact on the UK’s international standing and attractiveness as a place to undertake world-class science?

This is an area where the strength of the UK’s curiosity-driven research is a real asset – attracting high-calibre academics and fostering a climate of excellence.

The UK has a small cadre of highly-gifted scientific individuals that make a disproportionate contribution to its progress. The UK has various schemes, such as the Royal Society Research Professorships, which identify and support outstanding excellence. These should be continued and strengthened, in line with the Sainsbury Review of Science and Innovation recommendation of attracting the best researchers to the UK from overseas\(^{5}\). In addition to optimising the leadership role of such individuals, such schemes confer freedom and flexibility. At lower levels, the relative absence of a strongly hierarchical research organisation in the universities is a strong factor in attracting the best talent to the UK.

However, the obvious danger is that if investment in UK science and innovation was to stagnate or decrease, there is a possibility of the best UK-based scientists considering moving overseas, particularly to the USA, following its stimulus package, to undertake research in well-funded and refurbished laboratories. The UK has recently reversed the brain drain and it will be most unfortunate to lose this talent. In addition, there is the distinct possibility that overseas students and researchers will no longer view the UK as a leading nation in terms of scientific endeavour and discovery and it may lose out on the fees income from overseas undergraduates and postgraduates, and on the pool of world-class researchers and technicians who may decide to seek employment in the UK’s leading competitor nations.

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\(^{10}\) Major Innovation Assets in the North of England; http://www.thenorthernway.co.uk/document.asp?id=615
\(^{11}\) Connect and Catalyse - a strategy for business innovation; http://www.innovateuk.org/ourstrategy.ashx
7. How can policy balance the need for return on investment with the long-term and often unpredictable pathways between research and its eventual economic or social benefits?

The Institute appreciates why, after doubling the Science Budget since 1997, the government is increasingly looking at demonstrable evidence of a return on its investment. Physics is a discipline which often leads to economic and societal benefits, but usually after around a 15 year timescale from essential breakthrough in the science to the application. It is not so long ago that the laser was dismissed as a physicist’s toy and not many people thought that atomic clocks would lead to the ability to navigate to within a metre at any point on the Earth’s surface. The Institute is of the view that more focus needs to be given to where the barriers actually are within the science and innovation base, such as the reluctance of companies to invest in long-term R&D. In addition, we disagree with the notion that curiosity-driven research has to defend its ability to contribute to the economy, and challenge the implicit economic argument that more industry-focussed research leads to greater economic impact as it is not possible to engineer major technological advances.

This is well demonstrated by the Russell Group report which, as mentioned earlier, showed that the commercialisation of curiosity-driven research generated average returns of £44 million for Russell Group universities; more than twice the average returns from applied research. The report concluded that the government’s push to direct more funding at applied research, where economic impact is predicted in advance, would have resulted in a loss of £1.2 billion to the UK economy.

There is no shortage of examples illustrating the significant contributions that have been made to the UK’s economy by curiosity-driven physics research. In terms of innovation, physics is more likely to produce new paradigms, whilst engineers are more likely to perfect existing ones. A combination of the two approaches is clearly vital to wealth creation in any developed economy, and this is the challenge facing UK policy-makers.

The research councils, with a strong steer from the government, are already adopting policies which imply that the emphasis is shifting to one of funding research that shows potential, in advance of a research project being undertaken, of economic and societal impact. This is evinced by the request for two-page impact plans for grant applications and, in EPSRC’s case, it was reported that it would reduce its responsive mode funding budget by up to 15% to support its mission-based programmes.

8. How can we ensure that research careers – within academia or industry – attract sufficient numbers of the brightest young people, both within the UK education system and from abroad?

The 2008 annual report of the Science and Innovation Investment Framework stated that on the number of researchers in the workforce, the UK performs less strongly, and is sixth in the G7 nations. There has been little change in the UK’s performance over the last decade. This is of concern as training and retaining more UK-based researchers, and attracting researchers from overseas, particularly those

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who are physics trained, will be crucial for a science-led economic recovery.

Of all disciplines, physics has one of the highest rates of continuation of education at the postgraduate level. Many physics graduates choose to study in other areas, such as meteorology, environmental science, engineering, etc. The increase in stipends, thanks to the Roberts Review, and the extra flexibility introduced by the doctoral training accounts has led to a considerable improvement in the lot of postgraduate students in recent years. Generally, physics has a high PhD completion rate and doctoral graduates have good career prospects outside academia. It is worth noting that, because the more exotic, leading-edge areas of physics often attract the most able postgraduate students, PhD graduates from these areas are often in the highest demand from employers.

In the international context, however, there is a general feeling that UK PhD graduates are between one and two years behind their counterparts in other major industrialised nations; this has implications, particularly in light of the Bologna Process\(^\text{14}\) which could affect the mobility of UK graduates to work and study in mainland Europe, as they could be discriminated against on the basis of their qualifications. It is essential that this issue is addressed before the academic career prospects of UK-educated PhD graduates diminish to the point of affecting the recruitment of postgraduate students.

Even though evidence for this is anecdotal, in the last 5-10 years there has been an ongoing and dramatic shift towards the employment of overseas research assistants (RAs) instead of those trained in the UK. This shift has almost certainly improved the quality of UK research but it does raise some concerns about future leadership in the UK if these people choose not to stay after completing their projects.

In general, RAs have not been treated well in university departments. The Institute’s ‘Women in University Physics Departments’\(^\text{15}\) site visit scheme highlighted many of the problems, which included very poor provision for career guidance. It is hoped that initiatives such as the Institute’s ‘JUNO Project’\(^\text{16}\) and the revised RCUK Research Careers Concordat will contribute to major improvements. One area that has been very successful has been the various research fellowships offered by the Royal Society, the research councils, etc., as well as the fellowships that emerged following the recommendations of the Roberts Review. These have given high-quality researchers an opportunity to kick-start their careers, allowing them to spend several years undertaking research before becoming involved in teaching and administration. Unfortunately, as these Fellows have been popular recruits for permanent positions, not least due to their personal funding, other RAs have suffered diminished prospects. While, in one sense, this is inevitable given the few academic jobs available, it is nonetheless the case that some RAs working on long-term projects are employed on a series of short-term contracts; there is a need to develop a permanent career path that recognises their vital contribution. For other RAs that perhaps are less suitable for research, there is a need for better, disinterested careers advice.

On this point, the RCUK Review of UK Physics\(^\text{3}\) stated that due to the high numbers of physics RAs compared to other disciplines, there is a lack of sufficient careers advice provided to them and that there is a need “…for universities, Funding Councils and Research Councils [to] work together to develop the research concordat, so that realistic career advice is given to junior researchers, and that

\(^{14}\) http://www.europeunit.ac.uk/bologna_process/index.cfm
\(^{15}\) http://www.iop.org/activity/diversity/Gender/Diversity_and_academia/University_site_visits/page_25130.html
mechanisms to ensure early career opportunities are maximised in strategic areas of the research base."

Almost a half of new staff appointments in the last few years have been overseas physicists who have not been through the UK educational system. This situation undoubtedly reflects the high quality of UK physics as well as the flexible, meritocratic appointments procedure. The appointments also probably raise the standard of research. However, there are potentially devastating consequences on the ambitions of young UK scientists. The international flavour of departments in part reflects the global character of the discipline but there is evidence that the influx of overseas physicists is not matched by a corresponding rise in the number of UK nationals obtaining posts in other nations.

The research councils, EPSRC in particular, have taken care to encourage academics early in their careers, with specific programmes for those who are making their first applications. However, STFC tends to fund large research teams and even EPSRC is indicating that it would like to fund larger programmes over longer time periods. This approach is probably sensible but it does make it much more difficult for new researchers to make an impact and to develop a portfolio of grants to build up a reputation.

9. What role will research play in accelerating the shift towards a low carbon economy, and addressing the environmental challenges of the next twenty years?

Physics underpins a wide range of such technologies, including key aspects of renewable energy generation (see ‘The Role of Physics in Renewable Energy RD&D’) and, through building on the existing science base, the UK is well placed to be a potential global leader in areas such as photovoltaics; an important area where physicists are contributing to RD&D, where they are carrying out much of the fundamental research required to develop novel types of cell that may result in step changes in the cost of photovoltaic generation.

In fact, fundamental concepts and quantitative methods in physics underpin all of the required innovations – in energy generation, conversion, storage, networks, control and end use, at all scales. Training in physics, uniquely, provides the basis and the flexibility to contribute soundly and imaginatively across all these fields. But with entries to A-level physics remaining low, there is a genuine concern that the UK will fail to provide the number and quality of physicists needed for the low-carbon challenges that lie ahead. Both DIUS and the CBI have suggested that the number of STEM graduates needs to double over the next decade to meet employer demand, and this figure may yet need to be revised upwards given the likely increased demand from low-carbon enterprises. As such, to support employment in environmental industries and meet future demand, support for STEM training at all levels must increase.

For instance, UK studies which examined the renewables supply chain have reported that technology and project developers have found a lack of suitably qualified personnel at all levels in the implementation chain – both general technical and also more specialist skills. Hence, encouraging physicists, and indeed other scientists

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18 The Demand for Science, Technology, Engineering and Mathematics (STEM) Skills: Analysis to understand UK's future needs for STEM skills; http://www.dius.gov.uk
and engineers, to consider a career in renewables could help to plug the skills gap. Currently, there are relatively few university departments with the relevant expertise and few courses or UK students applying for posts. For those who have undertaken postgraduate training the career path in the UK is limited by the lack of companies and research posts and financial rewards.

Furthermore, the UK is facing a critical skills shortage in the nuclear technology sector. The energy portfolio, nuclear decommissioning, radioactive waste management and new nuclear build are very much in the nation’s strategic interest, and this is a crucial time to ensure that the nuclear skills base is not eroded but built-up to meet the long term challenges of the proposed new build programme, and the decommissioning programme laid out by the NDA (particularly radiation protection and health physics). There is an urgent need to maintain and develop a nuclear skills base, particularly in the core sciences (especially physics), engineering, materials science, project management, and technician level skills. The UK’s supply of nuclear engineers is dependent on a healthy nuclear physics research community, which provides a large part of the nuclear training and education at undergraduate, masters and doctorate level. In addition, the UK’s nuclear skills base may need to be supplemented by the international supply chain, but the government’s focus should be on a core UK workforce, for reasons of cost, sustainability, and national energy security.

10. How can the UK’s Research Councils and other research funding institutions deliver improved efficiency and outcomes, while maintaining research freedom and sustained support for excellence?

A perennial problem for the UK’s research councils is that of low responsive mode success rates, which are currently too low and need to be raised somehow.

The problem, especially for physics in terms of EPSRC, is perfectly stated by the 2005 International Review of Physics and Astronomy Research panel\(^2\): “...there is some unease about the current system of ‘responsive mode’ funding within EPSRC, although the basic idea behind this funding scheme is widely supported. The problem is that when the perceived success rate, for proposals submitted through this channel is very low, the whole system can become unstable: referees are unwilling to make critical comments, proposers are unwilling to propose high-risk research, and as more proposals get rejected, even more are submitted. This situation poses a strain on the organisation of the research councils and it wastes the time of the proposers, referees and grant panel members...It is essential to consider new strategies that would enhance the success rate of excellent high-risk proposals...the research councils should aim to ensure that high-risk research in new topics or entirely new fields should have resources for appropriate funding.”

As a response to the pressures that low success rates place on the peer review system, EPSRC announced a policy to limit repeatedly unsuccessful grant applicants\(^19\), which caused uproar amongst the physics and chemistry communities. The Institute recognises that EPSRC has a difficult situation to manage, as the continuing increase in the number of grant applications, combined with a real-term reduction in the volume of funding, is threatening to overwhelm the peer review system. Even though the Institute supports EPSRC’s underlying aim of safeguarding peer review, which has proved its value over many years as the most effective mechanism for evaluating research proposals, there is a need to carefully monitor the

\(^{19}\) http://www.epsrc.ac.uk/Content/News/PolicyAmendRUA.htm
impact of this policy, which will be implemented in April 2010, to ensure that
academics who submit high-quality curiosity-driven research proposals are not
disadvantaged in favour of those that submit risk-averse proposals.

In addition, the research councils need to focus more on increasing the effectiveness
of the translational research that brings scientific innovations to the market, building
on the strength of the UK’s curiosity-driven research. There needs to more strategic
coordination between the different research councils and an increased recognition of
the importance of funding for translational research and development. There seems
to be a real danger of a widening gap between the research councils and the TSB in
this respect, which conflicts with the Sainsbury Review of Science and Innovation5
recommendation of closer collaboration “…to help identify complex, high-value-
added production technologies that current and emerging industries require and
which are likely to flourish in high-cost economies.”

11. In the context of debates over higher education reform, how can the UK
maintain and strengthen its world-class research universities and
departments?

The 2008 annual report of the Science and Innovation Investment Framework13
stated that the financial sustainability of the UK university system, assessed by the
funding councils in July 2008, concluded that in 2006/07 only a small proportion
(1.7%) of research is undertaken at HEIs over which there are concerns about their
long-term sustainability. Coupled with the results of RAE 200820 which revealed that
“…the UK continues to set a high global watermark, with ‘world leading’ research well
distributed throughout the sector, and 87 per cent of research recognised as of
international quality.”

But this position of strength must not result in the UK resting on its laurels (the
Institute would welcome an open national debate on the future of the UK’s university
system, which has too many universities competing for what potentially could be an
increasingly limited set of resources for both teaching and research) or a perception
that the science and innovation base has no room for improvement.

The Institute would like to see the government reinstate a scheme like the Science
Research Infrastructure Fund (SRIF)21, which previously provided capital funding to
universities, specifically for science facilities. The third and last round of SRIF was
operational in 2006-08, with the government committing £500 million. SRIF was
lauded by the 2005 International Review of Physics and Astronomy Research as a
key factor in improving the environment for physics research. A new round of SRIF
would undoubtedly have a continuing impact in improving the quality of the UK’s
research environment. Furthermore, the 2005 annual report of the Science and
Innovation Investment Framework22 stated that SRIF boosted staff morale, attracted
new staff from overseas, increased student numbers at all levels, established the
credibility of universities among local business communities, and encouraged greater
use of facilities by SMEs. In addition, a recent report by Technopolis on the wider
benefits of SRIF223 reported that, “SRIF investments have contributed to national
science and innovation policy objectives on institutional sustainability and enhanced

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20 http://www.hefce.ac.uk/news/hefce/2008/rae.htm
21 http://www.rcuk.ac.uk/research/resinfra/srif.htm
22 The ten-year science and innovation investment framework annual report 2005;
http://www.diius.gov.uk/science/science_funding/ten_year_framework
23 SRIF: a review of Round 2 and wider benefits; http://www.hefce.ac.uk/pubs/rdreports/2009/rd07_09
the rate at which investment in public research is converted into social and economic benefit."

SRIF has been moved to become part of fEC and there is some concern that this income is not being spent within universities in support of research infrastructure, hence a return of SRIF would be most welcome, particularly as it offers transparency on where money is allocated.

The funding of university physics departments has been a controversial issue for over 15 years, during which time more than a third of physics departments have disappeared due to either merger or closure. A number of factors have contributed to these closures, not least the abolition of the binary divide, which led to a change of mission for many of the former polytechnics, plunging them into direct competition with the more research-led universities. The subsequent introduction of the RAE then sounded the death knell for many of these departments. Another effect of the RAE has been to ‘purify’ physics: many of the departments that closed (Aston, Bradford, Brunel, etc.) had a strong applied flavour. Only time will tell what effect the new REF will have.

Another major factor that was instrumental in causing closures was the general decrease in the unit of resource in the 1990s. Contrary to popular belief, the number of entrants to physics degrees has not altered greatly over the last 20 years. However, the fall in the unit of resource encouraged the larger, more popular, departments to take increasing numbers of students, squeezing the smaller ones, making many of them financially unviable. Exacerbating this effect, it is a well-accepted view that the HEFCE banding profile for funding undergraduate teaching tends to undervalue physics; in short, the funding appears to be around 20% too low (see ‘Study of the Finances of Physics Departments in English Universities’...the Institute has commissioned a follow-up study to be published later this year)²⁴.

Recognising this issue and partly in response to departmental closures, HEFCE allocated an extra £75 million over three years from 2007-08²⁵ to support the teaching of students in certain high-cost subjects, including physics. This amounted roughly to an extra £1,000+ for each FTE, an increase of around 20%. Prior to this extra money being available, unpublished and informal Institute surveys indicated that the majority of departments were running at a loss according to their university financial models, so the extra funding was certainly well received. Furthermore, we are pleased to note that HEFCE announced its decision to provide £25 million per annum on a recurrent basis from 2009-10, while it uses TRAC-based costing data to underpin key elements within its teaching funding formula, i.e. to critically analyse the actual spend of university departments to determine the ‘true price’ of teaching high-cost subjects. It is hoped that this exercise results in additional weighting bands which reflect the true cost of teaching. If these are introduced, then there is a real prospect of an improvement in the financial position of physics departments, and therefore their long-term viability.

Currently, UK physics research is heavily dependent on research council support, although physicists have been particularly successful in attracting EU funding (which is discussed further below). With a few exceptions, income from business and charities tends to be very low. This concentration of funding has been driven by the notion, reinforced by successive RAES, that the best physics is concerned with

²⁴Study of the Finances of Physics Departments in English Universities; http://www.iop.org/activity/policy/Publications/file_21216.pdf
²⁵http://www.hefce.ac.uk/NEWS/hefce/2006/science.htm
increasing the level of fundamental knowledge and that, when the physics is ripe for application and exploitation, the process is carried out elsewhere, either in another department or in a spin-out company. Although this state of affairs gives some cause for concern, it does have one very positive side for physics. Due to the heavy emphasis on research council income, physics departments have benefited more than most from the introduction of fEC. Some universities have chosen to pass some fEC income directly to physics departments leaving them rather better off than they have been in the past, in terms of allowing them to underpin local infrastructure. In addition, fEC, in the long term, should help physics departments to secure their long-term financial sustainability by topping up the QR component of their income; a conclusion which the RCUK Review of UK Physics concurred with.

However, the introduction of fEC does lead to some concerns. It appears that many universities do not have a clear plan as to how the fEC will be used to support future infrastructure demands. There is the undesirable possibility that many departments will use the windfall to support growth in non-capital items, principally new staff, while not paying sufficient attention to their future infrastructure needs. This matter needs attention before the fEC funding element becomes locked into university financial models.

12. How do we maintain an appropriate balance in funding for curiosity-led, response-mode research, and more targeted or programmatic funding?

While there is a role for both types of research in the UK, the balance of the system has swung too far towards targeted funding in recent years. The success rate in EPSRC responsive mode panels in both physics and chemistry has, quite often, been between 5-10% in the last year. This is a real threat to the platform of internationally excellent research that a decade of improved science funding has generated, and that the RAE 2008 measured.

As already mentioned, one of the main problems the UK has to overcome is that it is simply not being innovative enough in commercialising its scientific endeavour. More attention has to be given to the translation of research into product.

The RCUK Review of UK Physics\(^3\) reported that, "It is important to point out here that it is absolutely vital that fundamental, curiosity driven research continues to be conducted within all the sciences, engineering, mathematics and medicine. An important observation made within a variety of different evidence sessions was that there is a clear need to adequately fund core research within the [physics] discipline in order to maintain the capacity to innovate and propel future interdisciplinary activities. There is a substantial body of evidence that demonstrates that many technical aspects of the modern world have their origin in fundamental research conducted without any such applications in mind. Demanding and fundamental challenges can drive developments that then find application in a much wider (and sometimes radically different) context. The recent report by Lord Sainsbury illustrates this vividly and also points out the long timescale often associated with such developments."

For example, graphene could not have been discovered through targeted programme-mode funding, as the researchers based at the University of Manchester did not set out with the target of revolutionising carbon-based electronics – theirs was a curiosity-led investigation of fundamental condensed matter physics – of a type which is now becoming increasingly difficult to obtain funding for. However, that is not
to say that there is no value in targeted funding – once the importance of the science has been recognised by the research councils.

Even though graphene was discovered in the UK, there is a fear that the ‘big spending’ on graphene is going on outside the UK, in the USA, Japan and elsewhere in Europe – that somehow the UK does not have the industry or the connection between university and industry to exploit this discovery rapidly for the benefit of the UK economy. Graphene is in danger of conforming to the national stereotype – a great discovery, exploited by others. The question of how we improve the speed and effectiveness of university-industry knowledge exchange in the UK should be a key topic for this inquiry.

13. How can we strengthen science and innovation in all parts of the private sector in the UK, and further improve the exchange of knowledge and expertise between the public and private sectors?

People are the instrument of science- and technology-based innovation and of knowledge exchange, as such there must be mutual knowledge, trust and respect between science, industry and government.

The RCUK Review of UK Physics\(^3\) recommended, “…that DIUS and RCUK work together to develop mechanisms which enable the easy flow in both directions between industry and academia (though this point is not specific to physics).”

In keeping with this, we need to make the boundaries between the private and public sector more ‘porous’ so that there is a better exchange of people and hence information. A system that encourages academics to be seconded to industry for short periods and for industrialists to go into universities to explain their needs and requirements should be developed.

To strengthen indigenous R&D and innovation in physics-based companies, the reasons that R&D is in decline and why companies choose to relocate overseas needs to be better understood. One of the key reasons for companies choosing not to conduct R&D is the level of risk that must be undertaken, particularly in these uncertain times. This is something that can be particularly acute for smaller businesses. One means of mitigating such risk is through giving the confidence of a strong market for a final product. Through innovative procurement strategies the government can act as a lead consumer to benefit science-based companies of all sizes.

The Small Business Research Initiative (SBRI)\(^{26}\), re-launched in 2008, funds R&D to 100% and promotes access to procurement contracts for small businesses. The scheme demands that 2.5% of extra-mural R&D of government departments should be ring-fenced for small businesses, engaging them through progressive contracts to produce innovative solutions. The most promising products that result from this R&D can then be taken up by government through its procurement arms, with intellectual property generally retained by the company. The Institute is of the view that to truly promote innovation and R&D in science-based small businesses in the current environment, the 2.5% of departmental R&D spending reserved for small businesses should be raised to 10%. In addition, it should be emphasised that the programme is not limited to direct purchases from small companies, instead the contracts allow larger companies to bid, stipulating that the supply chain for the eventual products

should include innovative small businesses. Through such multi-party contracts, and long-term vision, the best ideas can be promoted and the small businesses that generate them can prosper. For such programmes to truly work in promoting R&D and innovation, they require true cross-government support. It is essential that there is commitment from procurement leaders in all government departments, particularly the key purchasing departments such as the Ministry of Defence and the Department of Health. Finally, it must be appreciated that the implementation of the SBRI has the potential to do so much more than develop innovative procurement solutions. The success of the scheme should also be measured by its wider impact, including the benefits to the businesses involved and any intellectual property or jobs created in their communities.

14. How can policy better support interdisciplinary research, and other changes to the practice of science that may occur over the next twenty years?

Just because a piece of work or a department is interdisciplinary does not make it good, and there is a need to focus on excellence rather than artificial constructs. Practically, it currently can be very challenging to perform interdisciplinary research, especially in the early stages. Those involved have to learn a lot from each other and there is often a large time-lag before outcomes are seen and this has been noted to slow down publication rates and thus stifle careers. There is no doubt that the present reward system does not place value on interdisciplinary research.

The Institute concurs with the 2005 International Review of Physics and Astronomy Research panel, that the research councils need to implement mechanisms to stimulate more interdisciplinary research; that the managed programme mechanism is not the right way of supporting this research, and that flexibility must be created within the research council’s existing responsive mode funding system to recognise and accommodate high-quality interdisciplinary research proposals.

There are two specific barriers to interdisciplinary activity, in addition to the normal cultural differences between disciplines. The first is that the role of physics is often to provide instrumentation or to underpin research in other areas. Consequently, the physics employed in such collaborations is often not leading edge in physics terms. Therefore, in RAE terms it is not considered high-quality and tends to be driven out from, or at least not encouraged to stay in, physics.

The second barrier is undoubtedly funding. It is very rare for an interdisciplinary collaboration to be excellent in all the disciplines involved. The underpinning nature of physics often means that its application in other areas involves building upon advances made, i.e. it is developmental rather than leading-edge. Currently, while recognising the problem, the research councils do not have a satisfactory means of resolving it and, all too often, in a very competitive environment, peer review tends to downgrade interdisciplinary work in comparison with physics work at the leading edge. Interdisciplinarity is hindered when applications pass through two or more separate funding council review systems, and are therefore subject to ‘double jeopardy’. The way out of this longstanding problem would appear to be a change in the peer review system and, in particular, a need to fund good science, interdisciplinary or not, without an artificial split between disciplines being introduced at the review stage.

The European Commission does a good job in fostering interdisciplinary research albeit with an unwieldy bureaucracy and an unhelpful requirement for ever larger consortia. They specifically fund networks that comprise scientists and engineers...
from a broad range of backgrounds. In contrast, there are very few calls from EPSRC that require extensive cross-discipline collaboration, and these are typically focused on two named disciplines, such as chemistry and chemical engineering or physics and the life sciences.

15. How can we better understand the links and interdependencies between the sciences, engineering, social sciences, arts and humanities within the UK and international research base?

No comment.

16. How can a policy focus on the economic impacts of research be broadened to take account of other forms of social, public and intrinsic value that may flow from the research base?

The 2008 annual report of the Science and Innovation Investment Framework\textsuperscript{13} stated that there are key examples demonstrating how research contributes to increased economic and societal welfare through a diverse range of outcomes, including health, environmental, and social cohesion outcomes.

The Institute concurs with this as demonstrating how research and innovation can deliver economic benefits to the UK at the aggregate level, by way of financial indicators as company turnover and employment creation, is only part of the story. Technologies can have a number of catalytic benefits to the UK economy, such as human capital, knowledge transfer, environmental, and health benefits.

The Institute notes that the following RCUK definition of economic impact\textsuperscript{27} already encompasses all of these intrinsic values, so there is no apparent need for a policy focus to be broadened any further:

“The demonstrable contribution that excellent research makes to society and the economy. This accords with the royal charters of the councils and with HM Treasury guidance on the appraisal of economic impact. Impact embraces all the extremely diverse ways in which research-related knowledge and skills benefit individuals, organisations and nations by fostering global economic performance, and specifically the economic competitiveness of the UK; increasing the effectiveness of public services and policy; and enhancing quality of life, health and creative output.”

But one major impact which is often overlooked is the production of highly trained workers – people that are trained though curiosity-driven research are able to give industry the capacity to exploit and build on the results of this broad base of research. Skilled workers are essential both in the industries where this knowledge is applied, and across the UK’s economy. For example, if we had tracked physics graduates we would find them all over the business, industry and engineering communities adding immense value to their companies and the exchequer. The current practice of asking academics to predict the economic impact of their work is flawed, and it is equally incongruous and perhaps counterproductive to attempt to justify past expenditure on specific areas of curiosity-driven research by retrospectively trying to measure the economic impact of selected technologies which have resulted from developments in such curiosity-driven research.

\textsuperscript{27} http://www.epsrc.ac.uk/ResearchFunding/Changes/EconomicImpact.htm
In addition, what needs to be better understood is that the actual amount spent on UK research is tiny in government terms, given its importance to the UK economy. In 2007-08 the total Science Budget was just under £3.4 billion; this equated to 0.6% of the UK’s total resource budget that year. For this small investment, a recent Institute report\(^{28}\) showed that, “physics-based sectors are typically more productive relative to the UK average. The economic activity of physics-based sectors, measured in terms of gross value added, stood at £70 billion in 2005 – making up 6.4% of the total UK economic activity. This is almost as high as the economic output produced by companies in finance, banking and insurance.” Therefore, what is required is greater awareness of what the actual Science Budget is; for example, because CERN is so impressive, people think it must be expensive. But for the UK it amounts to about £80 million per annum, a small amount of money in the grand scheme of things, as the UK is one of many international partners, contributing to just over 17% of CERN’s total annual budget.

17. How are public attitudes and the culture of public engagement with science and innovation changing?

Public attitudes towards science have been measured by a succession of surveys both within the UK and Europe-wide (Eurobarometer). According to the 2008 annual report of the Science and Innovation Investment Framework\(^{13}\), a national survey of public attitudes to science shows that interest in science has increased since 2000, with 82% agreeing they are 'amazed by the achievements of science,' up from 75% in 2000.

In addition, research into the public perceptions of physics commissioned by the Institute has highlighted that, when given the time and space to discuss scientific topics, many people found they were much more interested in the topics than they had previously stated. However, focus group participants were clear that finding time in their normal lives to think about science was not going to be possible. The Institute’s Physics in Society programme\(^{29}\) includes projects that are designed to overcome this barrier of a lack of time.

These surveys have consistently shown that members of the public hold broadly positive views about science and innovation but there are issues surrounding media reporting, on whether scientists can be trusted and how risk is understood. The challenge for society is not that we need to persuade people to be more positive about science, but that we need to work with people from all walks of life to explore how science is done, how it is regulated and how to base decisions on a realistic measure of risk.

The UK is a world leader in developing and delivering dialogue activities which allow members of the public to explore in-depth issues within science and innovation. The outputs of the best of these dialogue activities have a role to play in helping to develop better and more informed policy. With the inception of the Sciencewise Expert Resource Centre (ERC)\(^{30}\) for dialogue, the culture among policy-makers is hopefully changing for the better. With the support of the ERC, policy-makers can develop their own dialogue projects with the ultimate aim of creating better policy.

\(^{29}\) http://www.iop.org/activity/outreach/index.html
\(^{30}\) http://www.sciencewise-erc.org.uk
Despite these positive moves with policy-makers, there is still a culture within academia which makes it difficult for many early career researchers to get involved with public engagement projects. The impact of the Beacons for Public Engagement\textsuperscript{31} is yet to be seen and many academics are still unaware of their existence or remit.

Culture change takes time and it will be some years before the time spent by academics on public engagement activities is seen not as a hobby or a waste of time, but as a way of not only garnering the support of the public, but also a valuable way of developing skills.

\textsuperscript{31} http://www.rcuk.ac.uk/sis/beacons.htm
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