THE ROYAL SOCIETY

Response to the Treasury's consultation *Science and innovation: working towards a ten-year investment framework*

Ten key messages

(i) The Treasury's paper is an acknowledgement that science (in its broadest sense) is crucial both to the economic success and to the general well being of the UK. Science is a powerful tool for dealing with the present. It drives economic growth. It creates our options for the future. It is key to our global competitiveness.

(ii) The role of Government in science is to foster an environment within which science and scientists can flourish – providing infrastructure and funding geared towards the needs of public sector research, and actively stimulating the private sector to invest in research and innovation. The relative shortfall in business investment in R&D is a major problem for the UK, which business itself must address but which the Treasury can also take steps to facilitate. And, despite recent improvements, there is still much to do on infrastructure. As the Treasury paper admits, on overall R&D spend 'the UK falls behind even the EU average'. For a country with the UK's scientific ambitions, this constitutes a major failure in policy.

(iii) Ten years is a long time in science. A ten-year framework must therefore avoid any temptation to prioritise specific areas of research, and concentrate instead on getting the capacity and mechanisms in place so that we can seize the foreseeable and unforeseeable opportunities that will arise. The framework must embody a sustained commitment to fundamental research, which has repeatedly proved to be the source of great practical benefit.

(iv) The single most important element of this capacity is the skill base. The UK is facing an increasing shortfall especially in the supply of mathematics, engineering and physical science graduates and in people with technical skills. Nor are we doing as well as we should in the international competition to attract the best postdoctoral researchers. The framework will fail unless these issues are addressed urgently and energetically.

(v) Research is done in many different institutional settings, from universities and research council institutes to research associations and the industrial sector. For the health of UK science as a whole, active linkages between all these are vital. Government must ensure that its policies do not create unintended obstacles to such linkages, as, for example, the Research Assessment Exercise in its present form arguably does.

(vi) UK science cannot flourish in isolation from the rest of the world. Most of the world's science is done in other countries. Science is a globally competitive business, and UK scientists must be able to engage with the best scientists throughout the world if they are to measure up to the standards being set elsewhere. The ten-year framework has to be permeated by this international perspective. The perspective must include a clear vision of the future development of EU science, to which the health of UK science is increasingly bound. The perspective must also appreciate the opportunities for the UK in scientific capacity building in developing countries, where substantial UK commitment is strongly warranted. The UK's presidencies of the European Council and the G8 during 2005 provide early opportunities to exercise leadership in these matters.

Policy document 11/04

April 2004

ISBN 0 85403 601 6

This report can be found at www.royalsoc.ac.uk

(vii) Government uses science to guide policy-making across the board and to implement policy in such sectors as agriculture, defence, environment, health, industry, international development and transport. Government use of science for policy has improved in recent years: this improvement must be sustained and accelerated if the ten-year vision is to be delivered. The Royal Society, as the authoritative, independent voice of UK science, is particularly active in providing advice on science policy and takes a close interest in how science impacts on Government thinking and practice.

(viii) The growing public interest in the uses of science demands a response. For each broad area of research it is important to recognise the full diversity of stakeholders and to develop means for engaging effectively with them. This will require more detailed and collective thought than is occurring at present. Transparency and consultation tailored to the context are key, as is the capacity for non-scientists to contribute to framing the policy agenda.

(ix) There is a real danger that systems of public accountability could seriously hamper the creativity that lies at the heart of high quality research. The framework must avoid this. The framework needs also to address the role of regulation in setting boundaries to the practice of science, and mechanisms for ensuring that regulations do not generate unintended consequences that undermine their objectives.

(x) The Royal Society warmly supports the Chancellor's wish to put science at the heart of economic policy. As the UK's independent Academy of science, the Society makes a vital and very practical contribution to the scientific vigour of the UK. With its unparalleled connections to the national and international scientific communities, its freedom of thought and action, and its focus on promoting excellence, it plays a central role in oiling the wheels of UK science. We are strongly committed to active participation in the scientific life of the nation.

The Royal Society

1 The Royal Society is recognised as the world's leading academy of science, having supported science continuously for longer than any other academy in the world. Our mission is the pursuit of excellence in science by encouraging and supporting the best individual scientists to practise and communicate and by providing the highest quality independent science advice. We do this to increase knowledge, to improve the quality of life both nationally and internationally and to improve the UK's competitive position. Our remit encompasses all of science and technology including medical and engineering sciences. The Royal Society fills three roles: as a learned society, as an academy and as a funding agency.

2 The Society's excellent reputation in the UK and throughout the world is based on the scientific credentials and achievements of its Fellows. Fellows contribute enormously, free of charge, to our activities – indeed, they pay to do so, through the annual subscription. The Society is also able to attract many experts from outside the Fellowship to participate voluntarily in its work. Its funding schemes and activities are open to a wider audience still.

3 The Royal Society is an independent, self-governing body, established under Royal Charter and managing its own affairs under the terms of that Charter and the requirements of charity law. About two-thirds of its annual £40M budget comes as Parliamentary Grant-in-Aid through the Science Budget. This constitutes just 1.6% of the Science Budget, but it leverages significant extra private funding and has a powerful catalytic impact on UK science as a whole. Almost all is given out directly in support of UK science for the purposes agreed with the Office of Science and Technology (OST). Details of the Society's programmes are given in Annex A.

4 The Society's vision for the period of the science and innovation framework is that, through its unique Fellowship and associated networks, it will:

- identify and support as many outstanding researchers as possible in developing their careers in the UK;
- contribute to making the UK an attractive place to do research, able to compete for the best researchers in the world;
- strengthen the interactions between the different elements of the UK science base so that each becomes as effective as possible and contributes to national well-being;
- exercise a leadership role within European science and strengthen the UK's linkages with the best of world science;
- contribute effectively to building up the scientific capacity of the developing world;
- provide independent, influential policy advice based on the most up-to-date understanding of the underpinning science;
- influence what and how science and mathematics are taught in schools;
- promote mutual engagement between scientists and non-scientists so that society can secure optimum benefit from science.

General comments on the framework consultation

5 The Chancellor's initiative in announcing a ten-year investment framework for science and innovation is an important policy move that recognises how central science and innovation are to the UK. The ten-year perspective allows the Government to look beyond immediate political imperatives. It is essential that the outcome is a framework that sets broad guidelines for future development rather than a straightjacket that constrains developments to follow a closely specified path.

6 The key is flexibility. The most important research issues in 2015 are unlikely to be our forecast first choices now. Indeed, the highest priorities in ten years time may not yet have achieved any profile within the research community. We have to be able to seize opportunities and deal with threats that are not yet apparent. This does not mean that it is futile to plan ahead, but rather that the objective of the planning has to be to establish a system – people, equipment, funding mechanisms – that can deal with a sometimes rapidly changing environment.

7 The consultation is right to stress that, while Government obviously has a key role in shaping the investment environment and supporting those activities that have a claim to public funding, a strong and effective R&D Base[1] in the UK requires commitment from others as well. Indeed, about two-thirds of the effort has to come from the private sector. Success will come from all playing their part and from all taking responsibility for ensuring good communication among those involved.

8 In this response we combine an analysis of the nation's scientific needs with an analysis of the Society's own role as a key element of the UK Science Base in addressing them. As the UK's independent National Academy of science, we have a particular responsibility to comment and advise on the policies needed to promote the effective use of science in the UK. At the same time, we contribute directly to the wellbeing of science through the various schemes that we manage with the public and private funding at our disposal (over £40M in the current year). This is a minor portion of total UK spend on science and technology, but it allows us to achieve a major and distinct catalytic impact. This impact derives from our independence, our unparalleled reputation for excellence, our extensive international connections and our cross-disciplinary character.

9 Our responses to the specific questions in the consultation are attached. While these cover a wide range of issues concerned with the ten-year framework, the questions themselves do not cover all of the points that we wish to raise. In the following sections, therefore, we first address some generic issues that need to inform long-term thinking about science.

Skilled people

10 It is a truism that the UK depends on the skills of its workforce for its competitive success. This is emphatically the case for its success in science. It is vital that everyone is exposed to science at school, whatever their future career paths. It is also vital that sufficient of the best young people then take their studies in science through to undergraduate and postgraduate levels: a training in science is an excellent preparation for a wide range of careers: beyond that lies the challenge of retaining an increased proportion of the best people in scientific careers.

11 A key imperative is to reverse the current increasing shortages in mathematics and science teachers (particularly physics and chemistry subject specialists). While statistics of recent years show successes in recruitment to initial teacher training, these are offset by the attrition from the profession caused by number failing to achieve qualified teacher status and by the number of teachers leaving the profession (particularly in their first 5 years) or retiring. Shortages of qualified science teachers across the whole education sector are already having a severe negative impact on the numbers of young people studying science post-16, and undermine initiatives designed to enhance the wider engagement of young people in science issues. The recent inquiries by Gareth Roberts (Roberts 2002) and Adrian Smith (Smith 2004) both recommended enhanced financial incentives to address the shortages of science and mathematics teachers. It is clear that radical and urgent action is needed if we are to increase significantly the attractiveness of teaching as a career.

12 Retaining top quality researchers within the UK's R&D base requires adequate salaries, which means attention both to overall levels and to increased differentials. The current academic salary levels and lack of clear career structures in both the academic and private sectors are a significant disincentive to young people considering science as a career. Arrangements for greater interchange between the various research sectors would broaden career options as well as increasing mutual understanding.

13 The Society's most direct contribution to promoting research careers is its University Research Fellowships, which currently support over 300 of the UK's brightest young scientists for up to ten years in conditions that give them maximum scope to establish themselves as world leaders in their chosen fields. The URF scheme is characterised by its focus on individual excellence irrespective of discipline, by the flexibility of its arrangements and by the personal attention that the Society gives to each Research Fellow. This scheme and the Dorothy Hodgkin scheme, funded largely from public sources but also to a significant extent from private sources, form the centrepiece of the Society's long-term strategy for contributing directly to securing adequate numbers of skilled researchers to underpin the UK Science Base.

14 It is not only at the research level that we need to build up and retain expertise. We also need to reverse the run-down of high quality support staff (RS 2002). In particular, Funding Councils' measures of volume must not discourage universities from appointing such staff, and there should be appropriate initial and in-service training courses for them.

15 More flexible working arrangements are needed to provide more family-friendly arrangements directed in particular, but not exclusively, at women. It is important to monitor employers' actions in the area of encouraging gender and ethnic minority diversity. By hosting the Athena project, by its Dorothy Hodgkin scheme (see Annex A) and in other ways, the Society continues to demonstrate in very practical ways its commitment to increasing the gender balance in

[1] The R&D base of the country can be defined as the combined strengths of the Science Base (ie the research and post graduate training facilities of the universities, and the institutes and laboratories of the Research Councils and charities), Government laboratories, the applied research and technology organisations and the R&D facilities of business.

science and technology at all levels. The Dorothy Hodgkin scheme is proving outstandingly successful in retaining good female scientists in research careers. There is an increasing need for initiatives such as these to tackle what is a long-term issue.

16 The skilled people issue is EU-wide. A recent report by an expert group estimates that, to achieve the level of R&D activity envisaged in the 3% target, an extra 500 000 graduate researchers will be needed across the EU (Gago 2004). This is a tall order by any standards, and emphasises the seriousness of the issue.

The international dimension

17 Science is a key element in the UK's efforts to compete economically with other countries. However, perhaps paradoxically, it is also an activity that flourishes best in conditions of global collaboration. Most of the world's science is done outside the UK, and British scientists must have access to the best science and the best scientists in other countries if they are to stay at the forefront of their subjects. A ten-year plan for science and innovation must pay full attention to this international dimension, which is seriously underplayed in the consultation document.

18 Much international collaboration is informal and small-scale, carried on by individuals sharing ideas and data with like-minded colleagues. The Society plays a key role in facilitating such sharing, particularly at the postdoctoral level, through its schemes for international exchanges and joint projects and through its grants for attendance at international conferences. Here relatively modest sums of money can have a major impact on the effectiveness of UK science. The Government has recently taken steps to increase its engagement with science in other countries, but more needs to be done in this respect.

19 Larger collaborations, sometimes underpinned by inter-Governmental treaties, are needed to support research that depends on expensive equipment for experiments or observations at extreme conditions or at widely dispersed locations. These, and the provision of large facilities at the national level, need to be factored into the long-term framework.

20 The Society also plays an important role as the independent voice of UK science in the international context. This role contributes directly to maintaining and enhancing the UK's international reputation and to attracting the best scientists to study and work in the UK or collaborate with UK colleagues.

21 Collaboration specifically at the European level is set to increase markedly during the next ten years and must feature in any ten-year framework. At the political level, there are plans for significantly increasing and re-organising the Framework Programmes. All member states have also signed up to the Barcelona target of increasing their gross expenditure on R&D towards 3% of GDP (see paragraph 23 below). This will require a significant increase in private sector funding of R&D, which governments can influence only indirectly. Related to this is the movement towards establishment of an independent European Research Council, as outlined in the December 2003 Mayor report (Mayor 2003), focused on the support of the highest quality European teams engaged in fundamental research, which the Society has endorsed (RS 2004c).

22 The consultation document is silent on the needs for capacity building within developing countries, an issue of growing practical concern to the Royal Society. The Commons Science and Technology Select Committee's inquiry into the Use of Science in UK International Development Policy, and other initiatives such as the recent report by the InterAcademy Council and the forthcoming UK Presidency of the G8 countries, are pushing this up the policy agenda. This is not a matter of charity: it makes good sense from a variety of perspectives for the UK to be actively involved in helping developing countries to build their capacity to engage in science. In the wider context of the Government's overall policy for science, it is important to develop a more coordinated scientific strategy for development policy across all Government Departments.

Putting science to use

23 The coupling of the 2000 Lisbon agenda (to make the EU 'the most competitive and dynamic knowledge-based economy in the world') with the 2002 Barcelona agenda ('that overall spending on R&D and innovation in the Union should be increased with the aim of approaching 3% of GDP by 2010') sharply highlights the practical importance of R&D (EASAC 2004). The consultation document underlines this, adding that, on R&D spend, 'the UK falls behind even the EU average'. This must lie at the heart of any ten-year framework for science and innovation, even if political commitment to the 3% target itself wavers.

24 University research in research-intensive departments is largely non-proprietary, with the assumption that the work will be openly published. Such research can sometimes lead to major practical applications, not necessarily foreseen at the time. Business R&D is very largely directed at product and service development. It is important for business to have staff who can understand the implications of relevant technological or more basic scientific advances to their business and its competitive position in the market place. This can be achieved through in-house research facilities, or collaborative research undertaken largely within a university setting. These activities are valuably complemented by the applied research and technology organisations, which largely specialise in specific technology areas.

25 It is business R&D that largely produces the marketable product or service. In the UK, as in most of Europe, there is a significant shortfall in business R&D compared with the

situation in the USA. Government policies can significantly influence business investment decisions in R&D, through fiscal measures, the overall economic environment, the strategic use of public procurement (especially but not only defence and NHS procurement) and, crucially, through ensuring the availability of highly trained people and access to a powerful intellectual environment.

26 It is crucial that there are strong linkages between the various elements of the R&D base, encouraged by a variety of fiscal and other incentives. Much has been written about this, including most recently a report by the Engineering and Technology Board (ETB 2004), but the issue remains perennial. The Royal Society is playing its part in promoting linkages, eg through its Industrial Fellowships scheme, the privately funded innovation awards and targeted discussion meetings, and would be keen to do more given the resources. The ten-year framework must include a focus on these linkages, and should pay attention to the possibility that actions in one area may have unintended negative consequences in another.

27 Science is, of course, used not only in innovation and wealth creation but also in policy-making. The consultation document comments that Government Departments 'invest considerably in research in developing evidence-based policy'. In the context of the ten-year framework, Departments must ensure that their scientific operations are closely tied into the rest of UK, and indeed international, science so that they stay at the forefront of new developments. Departments must also be open to – actively to seek – advice from outside. The Royal Society is the major source of independent, authoritative advice about science, at national, European and international levels, and is committed to sustaining and developing this function. Much of this work is initiated and funded by the Society itself, but increasingly we are also taking on projects under contract to Government in particular circumstances. Government needs to make more use of this unique resource.

Fundamental research

28 The UK has a long history of excellence in fundamental research, and has benefited greatly from this in many ways. Active engagement in fundamental research both forms and nurtures an invaluable skill base and generates knowledge that may have uses far from the original context (RS 2004b). So fundamental research is not something that can be left to others while we concentrate on apparently profitable applications. At the leading edge, only those who contribute to the pool of new knowledge have early access to the latest developments elsewhere and have the ability to discern their significance. If we want to be globally competitive in the long term, it is necessary (though not sufficient) that we maintain a serious commitment to fundamental research.

29 Both the volume and the quality of UK output compare very favourably with the other main scientific countries on the available metrics. This is a result of the UK having both some world-class institutes and individuals, and strength in depth across a wide range of disciplines. A key policy issue for the ten-year framework is therefore how to ensure that the best UK research teams are able to continue at this highest level, without reducing the underlying strength of the other excellent research teams. In terms of university funding, this implies that there must be sufficient funding in the system to maintain the vitality of a range of research departments. A further crucial issue is to ensure that the bureaucratic burden is kept to a minimum.

The social dimension

30 The scientific input into decisions on Government action, regulation and other policies has already been raised in paragraph 27. It is, however, important to consider the social dimension if these decisions are to be acceptable to stakeholders and the public in general. In an open democracy, scientific endeavour has to secure broad-based social acceptance if it is to flourish. This implies that public engagement has to feature in the ten-year framework – as the consultation recognises. The Royal Society has been particularly active in such work, and is running a five-year programme to promote various forms of dialogue between scientists and non-scientists (see Annex A). This is a long haul, with all concerned needing to learn new approaches, understand each other's contexts, and be exposed to unfamiliar ways of thinking.

31 Related partly to public confidence is the issue of regulation and its impact on research activity. There are two aspects of this. First, the research community already needs to ensure not only that it acts responsibly, but also that it is clearly seen to be acting responsibly, and can be trusted in appropriate cases to regulate itself. In the context of research processes, the UK has some of the strictest regulations in the world but this is not yet widely recognised. Second, where there is a need for regulation, for example in areas of health and safety or animal welfare, it is important for the regulations to be proportionate and for all involved to be alert to the possibility of unintended consequences negating the desired benefits of the regulations (such as increases in animal experiments or sweeping restrictions on the research uses of historical sample collections).

Responses to summary questions

Q1 Are these the right areas for the Government and its partners to target over the next ten years? What are the underlying components of success in these areas and what roles do Government and other funders of the science base need to play in achieving these aims?

The six areas identified[2] are obviously important. The overriding issue must be to ensure that the education system as a whole (schools through to postdoctoral training) is delivering sufficient well-qualified scientists and engineers to meet the needs of the UK into the future. In particular, there are currently acute problems with attracting young people into the physical sciences and engineering, and in the mathematical underpinning of those entering higher education more generally. A related issue is ensuring that schools and universities are able to attract and retain high quality teachers and, in the case of universities, high quality researchers. This is discussed further elsewhere.

UK Science: Performance and impact on innovation

Q2 Which strengths of the UK science base could be further developed; what are the weaker areas that need to be addressed; and what are the risks to the UK's continued production of internationally competitive levels of research? What criteria should the Government use to help determine its overall commitment to science?

Along with its top research teams, one of the key strengths of the UK's science base is its breadth, and there are dangers in this being reduced as a result of boosting areas of research that appear at this time to have the most promise. An important aspect of breadth is the encouragement of activities at all timescales of relevance. The research frontiers that may be important in 10 years time will probably not be the ones that we forecast now. Indeed, some of the areas may still be in early formative stages or not yet even at any level of visibility. It is therefore important to retain flexibility, not only in funding, but also in human and capital resources, so that the UK business can quickly pick up and run with new advances.

Given that the UK undertakes less than 10% of world research, the UK Science Base must be outward-looking, accustomed to engaging with the best in other countries. Imaginative ways of facilitating this are an excellent investment. By the same token, the UK must be strong enough that the best in other countries want to engage with us.

Q3 In which key technology-based sectors does the UK have the potential to maintain and grow internationally competitive value added over the coming decade? What are the barriers to capitalising on our strengths and addressing areas of relative weakness in business innovation and R&D? How can investment in the UK science base and Government support for business R&D best contribute to that growth?

The UK is potentially well placed in most areas of science and technology to support the likely challenges over the next ten years provided we maintain the skill base in depth and breadth. There are, however, some worrying trends in the decline in undergraduates and in the size of the academic research community in the physical sciences and in engineering. While the trends in undergraduate numbers need action earlier in the education system, action is also required within the science base to address shortfalls in these key disciplines. There is also a need to encourage multi-disciplinary research in many areas.

A wide range of barriers is identified in the Lambert Report (Lambert 2003; see also the DTI Innovation report (DTI 2003)) and in the Williams report coordinated by the ETB (ETB 2004). The three main generic problems are:

- the funding of work to take research findings to the stage where there is a marketable product, improved process or service;
- lack of the expertise required to take forward new ideas to the marketplace where the main shortfall appears to be in management and in incorporating design and marketing considerations into the development of products and services; and
- the relatively small scale of R&D investment in some important business sectors.

To a certain extent these problems are exacerbated by the relatively weak business pull of ideas from the science base compared with the US. It is therefore often necessary to develop novel ideas to a stage where their potential is more obvious. The necessary funding can be found through so-called third stream funding, and developing further venture capital arrangements, including early support from Government in appropriate cases (eg Amersham). The Williams report (ETB 2004) makes a number of suggestions for fiscal encouragement of the necessary funding.

In addition to the problems of insufficient funding, there is a shortage of management expertise within many spinout and start-up companies, and this needs to be addressed urgently.

2 The areas listed in the consultation document were:
- World class research at the UK's strongest centres of excellence
- Sustainable and financially robust universities and public laboratories across the UK
- Continuing step change in the responsiveness of the research base to the needs of the economy and public services
- Increased business investment in R&D, and increased business engagement in drawing on the UK science base for ideas and talent
- A more responsive supply of science, technology, engineering and mathematics skills to the economy, and greater flexibility within schools and universities to attract the skills they need
- Confidence across the UK society in scientific research and innovative applications.

More generally, the Government's role is to create the right environment for innovation to flourish within UK business, and show a continued commitment to investment in R&D within the science base and business at all stages of the economic cycle (EASAC 2004).

Q4 In order to inform decisions on the future investment framework, and building on the Research Councils' extensive consultations with stakeholders, in what areas are there opportunities for the UK research base to excel and contribute to the economy and society, which might form the basis of future strategic research programmes over the next ten years?

We have already commented on the importance of flexibility and avoiding the temptation to be too prescriptive.

It is important to retain a balance between totally responsive mode support for fundamental research and programmes directed at strategic areas. The main reason for the latter is to encourage research in order to build up a capability in new areas that are seen to be of importance in the future. However, there is a danger of long-term favoured support reducing the competitive imperative to strive for the highest quality. The aim of strategic funding should be to build up centres of excellence that will be able to compete in their own right.

Management of the Science Base

Q5 In the light of the changes to be made to the next RAE, how can funding mechanisms build on existing resources and research assessment reforms to reward excellence and underpin sustainability?

The overriding aim here should be to reduce the administrative burden on academic researchers. The proposals for the next RAE, as set out in HEFC's document (HEFC 2004), are a significant improvement, and the removal of step changes in the funding at rating borders ought to reduce some of the pressure on researchers and administrators. We note that the HEFCE impact assessment of the new arrangements assumes that the RAE 2008 will have no effect on the cost of the RAE to institutions compared with the situation in RAE 2001. This is too pessimistic, and the burden should be further reduced. In any case we have argued (RS 2003a) that the Funding Councils should during RAE 2008 undertake an evaluation of possible metrics, tailored to the disciplines being examined, with the aim of reducing the administrative load on universities in the subsequent RAEs.

Other issues that need further consideration before RAE 2008 are the way that multidisciplinary and multi-institutional collaborations will be handled.

As to the overall dual funding system, we agree that there should be two main public funding streams. As a general point we note that many other countries, notably the US, have much relevant experience of the funding of research projects that could be input into the debate, in particular to inform the decision on the optimum level of detailed management information that is required to secure sustainability without overburdening the system. More specifically, in our response to the OST report on sustainability (RS 2003b), we suggested that as a long-term goal the Research Councils should be funded so that they can pay the full economic costs (FEC) of the research that they sponsor, but that:

- the salaries of PIs should be excluded; and
- the indirect costs should not have to be calculated at a project level. Too great a degree of precision is unnecessary and increases the administrative load on universities.

Furthermore, it is necessary to have transparent arrangements with the charities so that in the totality of what they contribute, their contribution to full economic cost is clear.

Finally, while we agree strongly about the need for selectivity in general underpinning funding for research, there are limits to the optimum degree of selectivity. Current HEFCE practice is already at those limits.

Q6 What are the main barriers or challenges to the achievement of a sustainable public research base in the medium term? What further action could the Government take, in partnership with universities and other funders of research, to create robust incentives on all parties to work together to deliver greater financial sustainability of the UK's research base?

Q7 How could funding for universities provided by Government and other funders create stronger incentives for the effective creation management and usage of the research base infrastructure over the next decade?

The underpinning technology required by the research base is developing rapidly and this puts constant pressure on institutions to update the equipment and other facilities in their laboratories to keep the research at the cutting edge. It will also be important to safeguard and to develop key generic infrastructure and facilities such as ICT and the maintenance of large-scale databases including those associated with bioinformatics. The provision needs to be taken into account the appropriate balance of local, regional, national and international facilities.

It is always difficult to prioritise expenditure for future resources against immediate demands of research programmes. Resource accounting methodologies should now make it clearer when resources are being run down and not being renewed.

The re-instatement of a significant capital component in the HE Funding Council grants is a welcome development over the past few years, coupled with the special joint grant schemes with the Wellcome Trust and the RS/Wolfson laboratory refurbishment scheme. However, the on-going capital grants are unlikely to be sufficient for major schemes, and it would be worth considering a range of options including the feasibility of universities issuing tax-free bonds.

Q8 What is the optimal means of developing access to large research facilities at national and international level? How should funding of large facilities be prioritised?

The phasing of capital projects is essential, and the long-term capital infrastructure plan being developed by RCUK is a major step forward. This must take into account international collaboration, especially within Europe, and such plans must be constantly updated to take account of changed research priorities.

Access arrangements to large facilities, whether national or international, must be based on criteria of excellence rather than juste retour.

Knowledge transfer and the Lambert review

Q9 The Lambert Review was based on extensive consultation during 2003. Reactions to the analysis and proposals set out by the Lambert review, and in particular to the Government's proposed response, are very welcome.

The Royal Society has commented in detail on the Lambert review of business-university collaborations, and the related DTI innovation report (RS 2004d). The review highlights a number of proposed changes to business and university collaboration. One of the key proposals, which we endorse, is the establishment of so-called 'third stream' funding to support knowledge transfer in the academic sector as a permanent, substantial input to university funding, alongside that for teaching and research.

The review also states the need for extra funding for departments that do not receive significant dual source funding but still carry out industrially relevant research, and suggests a new stream of business relevant funding of up to £200 million pa. We are not convinced that this separate stream of business-relevant research is necessarily required if the arrangements for determining the funding councils' stream are properly assessed. However, if the present arrangements and level of selectivity continue there may be no short-term alternative to the creation of a separate business-relevant stream.

We also note the recommendations in the Lambert review for an IP protocol, but it is not clear that this is any different from the present situation. Arrangements need to be flexible, and should neither restrict future research nor interfere unduly with the publication process.

Education, skills and public engagement with science

Q10 Following the 2002 review by Sir Gareth Roberts of the supply of scientists and engineers and the Government's response, what is the emerging evidence on the prospects for the supply and demand of science, technology, engineering and mathematics skills? What further steps could the Government take to ensure that the supply of these skills is responsive to the demands of the economy over the coming decade? How could women and other low participatory groups be more encouraged to pursue higher education in science, technology, engineering and mathematics and to pursue careers in these areas?

We have highlighted earlier the urgent need to reverse the increasing shortages of mathematics and science teachers.

Policy development is hampered by the disparate nationally available data for many key education indicators (including the numbers, profile and qualifications of teachers and support staff). A comprehensive database needs to be created by DFES covering all sectors of education to determine reliably resource needs and funding requirements. Data would be best collected via the 'single annual conversation' with schools and made publicly available via the internet. This process, if established with proper consultation, would significantly aid an evidence-based approach to education policy and also remove the existing need for independent organisations and research departments regularly to survey schools to establish bespoke datasets. We would be willing to explore with DFES which data indicators are needed within the science subjects and maths.

Teachers, technicians and teaching assistants deserve to be valued highly and given a proper career structure: continuing professional development (CPD) for all three groups must become a statutory entitlement acknowledged by a fully funded and integrated system of professional recognition. We welcome the establishment of the National Network of Science Learning Centres (NNSLC) and the analogous structure for mathematics currently under consideration. However, the success of such networks will depend on schools allocating sufficient funds (and, crucially, freeing-up time) for their staff's CPD; Government must actively encourage this. A change in school culture must be engendered, by Government and others, such that subject-specific CPD (in addition to pedagogy-related CPD) becomes highly prized; one step towards this should include earmarking to subject-specific professional development at least one day of the existing annual teacher INSET entitlement. Successful initiatives such as the Society's Partnership Grants, which enable teachers to meet and work with scientists and engineers, play a crucial role in helping teachers keep up-to-date with current developments in scientific knowledge. We will continue to seek support from both government and industrial partners to allow the scheme to grow.

The Government must also commit to the long-term survival and development of the national networks currently being established. The NNSLC has DFES funding for 5 years; plans must be put in place now for the longer term, including specific contingency for scenarios in which some or all of the regional centres fail to achieve financial self-sufficiency within 5 years. It is important that Government ensures all such subject-specific regional networks (eg NNSLC, the proposed mathematics network, SETPOINTs, etc) work closely together, including capitalising where appropriate on the advantages that shared premises bring.

Science teachers need high-quality equipment and facilities. The out-dated laboratories still found in many schools prevent engaging science practical work being undertaken and damage the perception of science in the minds of young people. We therefore welcome the Government's pledge to invest in school buildings and the priority given to school laboratories in capital funding guidance, particularly since reports from Ofsted show that laboratories in secondary schools are generally in a worse state than the school estate overall. It is crucial that such guidance is acted upon urgently if the Government is to meet its commitment to bring all school laboratories up to a 'good' or 'excellent' standard by 2010 (HMT 2002). It is vital that the programme of modernising school labs is not delayed to meet the more relaxed time-frame of 10-15 years attached to the 'Building Schools for the Future' initiative. A public reiteration of the Government's 2010 target for school labs is required, and DFES must monitor the way funds are spent to ensure that school labs are indeed being prioritised. The Society has undertaken extensive work regarding school lab provision and would be happy to discuss ways we might support Government action in this area. Alongside the substantial investment in school science infrastructure must go appropriate curriculum developments to ensure practical work maintains its rightful place at the centre of science learning.

More generally, if we are to achieve the vision set out in the ten-year framework, it will be vital that any work seeking to reform the education system be required to dovetail into the framework aims. Government must not allow a situation to arise where education reform is put in tension with the future health of the science base. We would expect, for instance, the Government to require the final report of the current Tomlinson Inquiry to include explicit and unambiguous statements as to how the reforms it proposes address the long-term objectives of the ten-year strategy, including the need for a strong supply of scientists and engineers.

Q11 Do UK business leaders and managers have the necessary skills and knowledge to exploit new technology and research to maximum effect? Where are the areas of greatest weakness and opportunity in terms of sector size of enterprise and level of management? What can and should be done to bridge the gap?

We do not feel able to comment on the question of whether the UK's business leaders and managers within the largest firms are appropriately equipped to exploit new technology and research to maximum effect. However, there does seem to be evidence that for smaller firms, especially those in the early years of spin-out or start-up, there is a lack of management and financial expertise.

Q12 What should the role of Government be in improving the interaction between science and society? Are there areas where Government could improve the promotion of science in society? How can we improve public confidence in the Government's use of science? What should we be aiming to achieve in this area in the next ten years?

The main role of Government should be, first, to ensure that its own science-based policies are underpinned by the best possible science advice and that this process is transparent, accessible and has appropriate public input. Second, further work on engagement with the general public is required both to increase the public's confidence in the science advisory system and to ensure the continuation of science's licence to practise.

We strongly endorse the rigorous use of the May Guidelines (OST 2000) in terms of integrity in collecting and assessing factual evidence, openness in soliciting and interpreting advice, honest acceptance of scientific uncertainty and full public explanation of how the advice received has been applied to policy-making. We welcome the strategic role of OST's Science in Society Directorate in working across Government, while recognising the extent of this challenge, and strongly emphasise the importance of highlighting the role of science and its societal dimensions within public policy. The role of Departmental Chief Scientific Advisors should be strengthened in this regard. There needs to be a meeting of minds between the science and social science communities.

In order to achieve increased levels of public confidence in decision-making about issues involving science, areas of potential concern need to be identified early (eg by: Foresight panels, Departmental Chief Scientific Advisors, regular consultations with groups like supermarkets, journalists, NGOs who are sensitive to public concerns, horizon scans involving scientists and the public of the type organised by the Royal Society in 2003). In issues of clear public interest, the public will need to be involved. The Government should seek to fund such involvement adequately and take its results seriously.

In the general area of public/science engagement activities, the Government should encourage a greater emphasis on quality, and ensure that those seeking funding for science engagement list clear objectives that allow for meaningful evaluation. These activities should be widespread, with benefits maximised through an effective media and communications strategy. In order to maximise the benefits of the varied activities currently taking place and to

encourage the adoption of good practice, there needs to be more cooperation across the scientific community. Academia, research council institutes, charity-funded institutes, learned and professional organisations, the Science and Discovery Centre network and schools need to learn from and support each other. The national database to be developed with OST funding will help in this respect, as will the Royal Society/British Association annual Science Communication conference, which seeks to contribute to national strategy. As the national science communication effort increases, there should be an underlying aim to see the culture of scientific organisations evolve to embrace issues of engagement and transparency.

With regard to independent scientists, Government should encourage universities and funders of science to provide adequate resources for training in aspects of communication skills. Recent market research undertaken by the Royal Society, canvassing views from 500 scientists, found that while 81% and 74% of scientists thought that it was important to communicate with the public and young people respectively, only 20% and 19% thought they were effective in doing so. The potential for science communication to be integrated with funding streams for particular science research should be examined (for instance this approach has currently been adopted for the EU 6th Framework programme).

In addition to experiences within the formal education system, other opportunities must be utilised to enthuse young people. For example, initiatives such as the recent Genetic Futures project should be encouraged and supported. This project, conducted by the Royal Society and other partners, was a national-scale initiative engaging schoolchildren in discussion of some social and ethical impacts of science and technology.

Many young people can also benefit from engaging with science in informal learning situations. Some of the best examples of such informal learning may be seen around the country at the Science Centres, which engage adults and the young and alike. The UK is fortunate to have a number of world-class Science Centres and these will have a vital role to play in the drive towards life-long science learning and for the wider public engagement with science. It seems likely that continuing government subsidy for these Centres will be required if they are to survive the next 10 years.

The overall aim should be a clear agreed vision for science engagement, with measurable objectives being delivered and findings communicated effectively. It should be a vision that the science engagement community, science institutions and Government have helped to shape. Science engagement activities should be more coherent, with good practice being shared, networks functioning well, with universities integrated into the process.

The Royal Society gives a high priority to the science in society dimension. Its current five-year programme devoted to this is outlined in Annex A.

Partnership funding

Q13 What is the outlook for business investment in R&D over the next decade? How can business investment contribute to the success of a ten-year framework for science and innovation?

As the Lambert review indicated, business involvement with R&D – both in-house and in collaboration with the science base – is key to increasing innovation in the UK. However, with exceptions in only a few sectors, UK business, in common with most other European states, lags significantly behind the US in its investment in R&D. Attainment of the Barcelona 3% target, or anything even slightly close to 3%, depends critically on rapid improvement in business spend on R&D. The ETB report (ETB 2004) suggests fiscal ways in which Government can catalyse such improvement.

Q14 What are the research aspirations and funding plans of the medical charities over the coming next decade? How best can Government and charity funders work together to enhance the impact of their complementary research efforts on national and global health outcomes and contribute to the development and maintenance of a sustainable UK science base?

The medical charities play a key role in the UK's research effort in their fields, with some world-class institutes and research units. However, the tradition of philanthropy that gave rise to these charities seems to be much more widely established in the USA than in the UK, especially in respect of donations to higher education – in part, no doubt, because of the greater personal wealth in the USA. Government should examine what more it could do to promote the philanthropic support of research in the UK.

Q15 Are there ways in which Government support for medical research – in terms of both institutions and the distribution of funding - could be better structured in order to maximise the benefits of investment from partners in industry and the medical charities? What should Government and the NHS be doing over the ten years of the science and innovation framework to ensure successful partnership working in medical science in the long term?

Q16 In light of the second Wanless Report, where are the weaknesses in public health research capacity? How can we improve the links between academics and deliverers of public health, to ensure a strong evidence base both on causality and on effective, well-targeted interventions? How should the roles of the various research bodies be better coordinated in relation to public health, to ensure the public health research requirements are met in a structured and coherent way?

The creation of an effective research system that delivers both economic activity and quality of life by increased quality of care requires the establishment of effective bridges between healthcare delivery (the NHS), industry and academia (including those partly within the health service).

One of the key steps required is that the market pull of the NHS is integrated to identify the underlying research needs and that these needs are communicated to industry and other members of the supply community. Although potentially it represents one of the largest markets in the world, because of its scale and culture the NHS is highly fragmented, and this diminishes the strength of its market signals to innovators. The DTI Innovation Report identifies that NHS estates should have a coordinated procurement approach to drive innovation. This should be extended into other areas, including for example medical devices. The NHS innovation hubs should also be sustained as gateways for a longer period than is currently envisaged because of the level of culture change required in the NHS.

Two issues underlie the question on public heath. The first is that the nation needs to move to 'early health' models of healthcare from the present largely 'late or disease oriented' models. The second is that we need also to focus on more effective delivery within the healthcare system without impacting care or creating sub-optimal sub-systems. Healthcare delivery faces the continuing requirement for cultural change, ie inserting effective management into a system that is driven by care without damaging the core value. Working from a shared view of the real economics of healthcare delivery should drive a more realistic research agenda that is not overly politicised. A mechanism should be put in place to generate and communicate this.

A crucial issue is the question of regulation, including that arising from central EU initiatives and Directives. It is important that the impact on research of any new regulations, such as those concerned with the retention of tissues, animal testing and stem cells be carefully considered. This requires particular care in identifying potential instances of unintended consequences.

Science and research across government

Q17 What are the public service objectives and priorities for science and research over the next decade to contribute to policy development service delivery and the wider economy? How can the wealth creation potential of investments in R&D across different Government programmes be increased?

It is important for the R&D programme for each Department to address its specific needs in terms of Departmental statutory responsibilities and policy developments. In some cases this will be through a mixture of in-house and commissioned and contract research, and in other cases entirely outsourced. However, in all cases it is important for the research outcomes to be subject to transparent and independent peer review arrangements, such as through standing advisory committees or ad hoc referees. This is essential to ensure that Departmental decisions are based on sound policies, and should also go some way to increasing public confidence in the work and decision-making process of the Department.

Where the Department relies on the academic community for important areas of its advice, it must take some responsibility for the development of the necessary expertise, especially where this is very specialised.

The DTI report outlines arrangements to improve the innovation potential of Government research. When determining value for money in placing contracts Departments should be able to take a long-term view on the overall returns. The Treasury needs to consider how best this could take into account returns that are outside the responsibilities of the Department itself.

Q18 How can Government best secure greater synergies between research funding, investment and strategies across different public programmes, and link the Government's overall objectives for research outputs with the capabilities in the UK science base?

The Chief Scientific Adviser has a significant role to play, as have Departmental Chief Scientific Advisers in those Departments that have one. However, there needs to be a resolution of the conflict between the responsibilities for which Departmental expenditure is appropriate and the overall benefits to the UK as a whole.

It should be the responsibility of each Department to be aware of the education, training and research outputs and capabilities of the UK science base. For example, one of the main conclusions of a recent Royal Society report on detection and decontamination of chemical and biological agents is that there is considerable relevant expertise, eg in universities, that is not being fully exploited by Government (RS 2004e).

Departments, individually and collectively, should examine their procurement policies to see how they could be used to promote the R&D capabilities of their suppliers.

Q19 How can the Government and the Regional Development Agencies and their equivalents in the Devolved Administrations help integrate funding of science research on a predominantly national basis with development and delivery of regional economic strategies? In particular how can Government and RDAs strengthen partnership working to facilitate more effective knowledge transfer and research collaboration?

The strength of the RDAs is their short lines of communications to universities and SMEs. While they should not be involved with peer reviewed grant allocations, there is scope to involve them further in aspects of third stream funding, especially that involved with spinouts and collaborative projects between universities and SMEs. However, there is an urgent need to strengthen the expertise in this area within some of the RDAs.

Q20 Are there barriers facing business and the science base in effective engagement with EU research programmes? How can the UK more effectively influence and benefit from EU research funding and policies? In what ways can action at Community level add value to UK science and innovation policies? How can national and community funding complement each other more effectively?

It is most important to highlight the need for UK science policy to take account of the European dimension and for the UK to be at the van in the development of European policies. Treasury policies have in the past led to reticence by UK public bodies in taking the initiative in Europe.

The proposals for a European Research Council to support the very highest quality fundamental research in Europe should help ensure that EU research will remain competitive into the future. It will be important to ensure that the ERC is established on sound footings, with an adequate budget, minimum bureaucracy and full independence from political pressures (RS 2004c). ERC funding should not be at the expense of national or existing EU funding; this would be totally counter-productive in the context of the Barcelona target for overall levels of R&D funding.

Statistics on national business involvement with EU framework programmes appear to be difficult to obtain, but with some exceptions, UK businesses appear to be somewhat less keen than their EU counterparts to be involved with collaborations with their national universities.

Annex A: The Royal Society

1 This annex builds on the brief description of the Royal Society given in paragraphs 1-4 of the main text and outlines some of the Society's main activities related to the themes of the consultation paper.

Supporting skilled researchers and encouraging interdisciplinary work

2 Our largest programme comprises a series of research fellowships and professorships designed to strengthen UK science by developing individual talent. These schemes fund over 400 of the UK's best scientists and engineers to undertake cutting edge research, and play a vital role in fostering their careers. Funds are allocated on the basis of scientific excellence irrespective of discipline; they are not constrained by the subject-specific priorities of the research councils. The schemes are administered with as light a touch as possible, and we provide personal support to every research fellow.

3 We are keenly aware of the need to encourage women to pursue careers in scientific research. Over 30% of our 310 University Research Fellows are women. Our Dorothy Hodgkin scheme supports 55 scientists and is unique in providing flexible funding at the early stages of postdoctoral careers when researchers, particularly women, tend to leave science. Other activities include: the promotion of successful women as role models; ensuring that women are represented in our activities (including strategy and policy making, research appointments and selection of new Fellows); and providing a contribution to child care in our conference grants. We are also leading a project – Ready Set Go – that seeks to involve under-represented groups in S&T careers.

4 The vitality of the UK's science base depends on attracting and retaining the best scientists. The Wolfson/OST Research Merit Awards enable us to attract researchers from universities such as Princeton and California to the UK, and approximately 30% of the University Research Fellows return from abroad to take up their posts. We have increased the opportunities for the best and brightest postdoctoral scientists in USA to come to the UK by establishing a new fellowship scheme and we hope to extend this to other countries of scientific strength with additional government funding.

5 Our industrial fellowships encourage industry/academic collaboration and our most senior awards (Royal Society professorships) allow UK universities to compete with industry and overseas universities for the world's leading scientists.

6 Our research fellows often undertake the type of interdisciplinary research projects that can fall between the remits of other funding bodies. Our international discussion meetings generally have an interdisciplinary focus. Moreover, we have are launching a new interdisciplinary journal called Interface, which will be published initially on the Society's website and will cover where biological and physical sciences intersect.

Promoting international communication

7 The Society plays a vital role in ensuring that the UK engages with the best science around the world. We support excellence in science internationally through the provision of a range of grants and fellowships that enable high calibre scientists to move to and from the United Kingdom to initiate collaboration, access unique sites or facilities, exchange ideas, gain new skills or link centres of excellence for scientific research. We represent UK scientists on a wide range of European and international bodies, taking a leading role in a number of international programmes, and have formal agreements with over 50 scientific organisations overseas.

8 Our scheme of conference grants is a practical means of helping over 1000 UK scientists per year to participate in the international conferences that play such an important role in driving the agenda of international science.

9 Acting as a focal point for the presentation of the latest research results has always been central to the Society's work and our international discussion meetings, journals and specialist lecture series provide the world's top scientists with many opportunities to contribute to the advancement of knowledge.

Policy advice

10 Many areas of public policy have a scientific dimension and policy-makers need access to reliable advice about the science. It is vital that policy-makers make use of advice from independent, authoritative and credible organisations outside government. Providing such advice is a high profile and influential element of the Society's work, and accounts for much of the Society's visibility beyond the professional scientific community. Our advice work is openly published, and we consult widely to ensure that we take account of all relevant information.

11 The Society's advice work extends to the international sphere. At the European level we are leading a consortium of national Academies (EASAC, the European Academies Science Advisory Council – see www.easac.org) that gives policy advice to EU institutions. At the global level, we are closely involved in the InterAcademy Panel and the InterAcademy Council.

12 Today's school pupils are the scientists and engineers of tomorrow. Too few young people are receiving a proper grounding in science and mathematics and we are trying to

tackle this problem in a number of ways. We influence the content and delivery of the curriculum by contributing to the formulation of national education policy through representatives on government working groups and influential reports. We also work to highlight the many achievements of UK scientists and engineers and to create opportunities for schools to collaborate with universities and industry.

Public dialogue

13 We fully recognise the importance of addressing the question of public confidence in science and communicating with the public whose attitudes and values are influential in the progress of science. Through our privately funded Science in Society programme and our policy advice work we are providing innovative and effective ways for scientists and policy makers to engage with the public. Recent activities have included a national forum for science, a series of public dialogue meetings throughout the UK, the MP pairing scheme and the creation of a dedicated website with an online dialogue facility. This is in addition to a diverse programme of lectures, exhibitions and debates targeted at a public audience. In seeking to bring leading scientists into debate with the public, our work on science in society is at the forefront of best practice.

14 For further information on any aspect of the Society's work, please see www.royalsoc.ac.uk.

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Royal Society reports can be found at www.royalsoc.ac.uk/policy

Further information on this and other Royal Society documents can be obtained from:

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The Royal Society

As the UK's independent national academy of science, the Royal Society promotes excellence in science, engineering and technology, both in the UK and internationally. The Society encourages public debate on key issues involving science, engineering and technology and the use of high-quality scientific advice in policy-making. We are committed to delivering the best independent advice, drawing upon the expertise of the Society's Fellows and Foreign Members and the wider scientific community.

The Royal Society's objectives are to:

- recognise excellence in science
- support leading-edge scientific research and its applications
- stimulate international interaction
- further the role of science, engineering and technology in society
- promote education in the sciences and actively engage the public in scientific issues
- provide independent authoritative advice on matters relating to science, engineering and technology
- encourage research into the history of science

ISBN 0 85403 601 6

Founded in 1660, the Royal Society is the independent scientific academy of the UK, dedicated to promoting excellence in science

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Printed by OML 4–5 Warner Yard London EC1R 5EY