

Introduction

- 5.1 Investment in research provides much of the foundation for innovation and the new products and services that result. However, such exploitation depends on ideas and skills transferring between universities, other research organisations and businesses, a process which has not always worked well in the UK. So it is imperative that, as we renew the research base, enhance the flow of skilled scientists, and invest in further growth for new science, we also ensure that there are effective two way links between research and the market.
- 5.2 As shown in Chapter 2, the track record of UK business in producing commercially successful new products and services is poor relative to our major competitors. For example, according to the Second European Community Innovation Survey, the percentage of UK business revenues generated from new and improved products was 23 per cent compared with an European Community average of 31 per cent.
- 5.3 This chapter describes the importance of knowledge transfer and accelerated diffusion as a means of capitalising on the wider potential benefits of publicly funded R&D, to ensure that they are developed into successful products and services. Chapter 6 then sets out the Government's approach to establishing a supportive yet challenging environment which enables and stimulates business to invest in innovation to deliver productivity growth.
- 5.4 Innovation involves intricate connections between research and business. Simple linear models, which assume that investment in the supply side (knowledge creation) will automatically result in marketable innovations, do not fully capture this complexity. Innovation is far more interactive. The major drive for this must come from the private sector, responding to competitive challenges and market opportunities. Leading edge businesses are not just passive recipients of science and technology – they actively explore new fields, helping to generate new solutions to innovation challenges, and also play a role in shaping agendas of academic research. An important role for Government, though, is to remove artificial blockages within the innovation system, and to create the right framework conditions for the efficient functioning and development of the system.
- 5.5 There is no single model of what an innovation system should look like – this will vary from country to country and sector to sector. Further, there is an increasingly international dimension to the process of innovation. R&D knowledge and human capital are mobile across borders. But to exploit these assets here, UK business needs to be able to deploy the skills and financial capital to attract, absorb and develop them into commercially successful products, processes and services. As the Roberts Review highlighted, the UK may be enjoying a 'brain gain' rather than a 'brain drain' at present, but

both Government and business must do more to recruit and retain the UK's best scientists and engineers to support innovation here. Multinational businesses will often assess the quality of the science base in deciding on the location of their European research facilities. So the climate for business innovation in the UK is closely linked to the depth and breadth of knowledge transfer from the science base.

- 5.6 Perhaps the most significant forms of transfer from the science and engineering base to business and the community are through the supply of highly skilled people. Chapter 4 describes how the Government intends to address the issue of people and skills.
- 5.7 Knowledge transfer between the research base and business depends on:
- the capabilities of the research base and the extent to which it is orientated towards the needs of business;
 - the technological capabilities of business and its propensity to innovate; and
 - the coverage and strength of the links between them.
- 5.8 Action by both the public and private sectors is therefore needed if publicly funded research is to be effectively translated into marketable products and services. The role of business is crucial, and any measures which strengthen the technological and innovation performance of business will tend to support knowledge transfer from the research base. The private sector also needs to have easy access to university research and to understand how universities operate. Equally, universities and the public sector must have a realistic awareness of the possibilities for the commercial exploitation of their research, and an understanding of the priorities and needs of the private sector.
- 5.9 Knowledge transfer requires the right economic environment to support and stimulate business to link with suppliers, customers and the research base. These linkages will primarily be created and financed by industry. But there is a key role for Government to help redress identified market failures in particular activities or regions, and to invest strategically in new strands of science and technology and its exploitation. This chapter considers how the Government can work with both research and business organisations to stimulate knowledge transfer.

Increasing knowledge transfer

Encouraging industry to build on publicly funded research

- 5.10 Companies whose competitive advantage derives from technological innovation should spontaneously seek out the skills and research knowledge they need, pulling through ideas from the UK's science and engineering base. But there are potential barriers to this process operating efficiently. From the point of view of the individual firm, the results of long term research are uncertain in terms of their relevance to the firm's business, their timing and the commercial returns they eventually yield. Often the results of research

carried out by the firm benefit other organisations. For these reasons, firms may undertake less long term research than is desirable from the point of view of the economy as a whole.

- 5.11 There are three main reasons for Government financial support to encourage long term R&D and knowledge transfer. As elsewhere, any particular intervention needs to ensure that Government resources and activity are truly supplementing the private sector's own efforts and are likely to deliver net economic benefits:

Collaborative research

- Collaboration between firms can help solve barriers to innovation. For the same amount of money per firm, a coalition can undertake a much wider range of research increasing the chances of a successful technological and commercial outcome. A group of firms may be able to capture a much greater proportion of the results of their joint research than an individual firm acting alone. However, research collaborations between firms are not always easy to arrange. Firms may encounter difficulties in identifying partners, problems over intellectual property rights, and the process may involve heavy use of the scarce time of senior management. Government can help to bring firms together, acting as an impartial co-ordinator and intermediary. Government support for collaborative R&D also allows a combination of the scientific excellence of the science base with the greater understanding of potential commercial applications of the private sector.

Lowering risks

- For large firms the vast majority of R&D projects involve only modest financial risk; the bulk of expenditure on innovation comes later. However small and medium sized enterprises (SMEs), particularly high technology SMEs who wish or need to grow quickly, often have to undertake R&D projects which are relatively large in relation to the financial value of the company. Raising external finance against uncertain future assets generated by technology investment may be difficult. Potential lenders may lack understanding of both the technology and market involved. Government co-finance can lower the financial risk to the firm and to potential private sector sources of funds. Project appraisal by DTI can ease the burden of due diligence for private investors.

Diffusion of technology and best practice

- Government can provide information on how adopting new technologies can improve a business, drawn from business best practice and exploiting economies of scale not available to private providers. Firms are having to incorporate an increasing number

of technologies into their products and processes, and to keep up with an increasing number of changes in business practice. Combined with the quickening pace of technological change, this imposes a burden on the firm, particularly heavy on SMEs, to monitor and evaluate an increasing range of technologies and business practices which may be relevant to their business. As a result, many SMEs do not adopt new technologies or business practices as soon as they should.

Government interventions to encourage knowledge transfer

- 5.12 DTI is giving greater priority to innovation and has established a new Innovation Group headed by a Director General for innovation and technology. This, together with DTI's current review of its business support functions, provides the opportunity to direct resources most effectively to those interventions which truly augment the private sector's own efforts and contribute effectively to the UK's growth potential. The Department will in future have a better informed and more sharply focused objective of driving innovation, including knowledge transfer from the science base, into the business sector. One of its aims will be to increase the exploitation of the knowledge created in the UK's world class science base as well as from abroad. Improving the UK's innovation performance is also one of the pillars for supporting manufacturing success here.
- 5.13 DTI's current portfolio of programmes to encourage knowledge transfer between the science base and industry includes:
- Support for collaboration through the **LINK** programme and **Faraday Partnerships** which together currently provide £52 million annually of Government support, and cover a very wide range of technologies from textiles through food processing, polymers chemical measurements to nano-composites. Around a thousand firms of varying sizes are involved, many of which would not have otherwise taken part in collaborative projects. Working with the Research Councils facilitates the participation of universities and Research and Technology Organisations (RTOs), at the interface between the science base and business. This helps strengthen the technological knowledge outputs of the research, capture the additional scientific knowledge that the research will yield, and disseminate any advances in research methodology and 'know how' to the wider research community.
 - Lowering the commercial and technological risks of investment in R&D and innovation, especially for SMEs, through programmes such as **SMART** and **TCS** (formerly the Teaching Company Scheme). SMART provides grants for R&D in technologically innovative products, amounting to £27 million in 2001-02 for 800

projects. TCS provided £22 million of support in 2001-02 to businesses (up to 900 at any one time) for employing high quality graduates on two year projects and giving firms the opportunity to take direct advantage of the science and engineering base, thus reducing the risk of expanding their technological range or even of doing R&D for the first time.

- Support for spreading information on technology developments abroad through the **International Technology Service** and the spread of best practice through **Industrial Forums**. For example, in 2002-03, ITS will have organised some 40 missions to other countries; and there are currently eight Industrial Forums in areas such as aerospace, oil and gas, and chemicals.

5.14 An increasingly important element of DTI's knowledge transfer activities has been investing in the diffusion and development of new or emerging technologies with the potential to have pervasive impacts and to disrupt traditional businesses and markets. Examples to date are biotechnology, genomics and e-science, where there is also a high degree of complementarity with the Government's investment in science. Prospectively, nanotechnology now holds out major potential to influence products and processes across many sectors (see box below). The current budget for DTI's overall portfolio of knowledge transfer activities (including the space sector) has increased in recent years to some £250 million in 2002-03.

5.15 The Government recognises that well targeted and evaluated interventions which address market failures can help stimulate valuable collaboration between the public and private sectors, and can lead to long term benefits for the economy. **In this Spending Review, therefore, the Government will increase the resources available to DTI for knowledge transfer activities to £300 million by 2005-06.** With additional resources and a sharper DTI focus on innovation, there is an opportunity now to re-evaluate the current portfolio of programmes to ensure that resources are allocated to complement the private sector's own efforts, in as efficient and effective manner as possible. DTI will take this forward.

Box 5.1: Nanotechnology – redefining products and processes

Nanotechnology – the application of science at the atomic and molecular level – is set to redefine our lifestyles and the way we manufacture products – from pharmaceuticals that are formulated for individuals to tiny computers based on biotechnology and groups of molecules. Nanotechnology is disruptive and pervasive – it forces rapid change and will make many accepted products redundant as well as making more efficient use of natural resources (for example, digital cameras do not need photographic film).

A recent report¹ by the UK Advisory Group on Nanotechnology Applications, chaired by the Director-General of Research Councils, indicates that although the UK possesses a strong basic research capability in nanotechnologies, it is not achieving critical mass or securing adequate industrial engagement. Too many in UK industry still believe that nanotechnology is some way over the horizon. The reality is otherwise. The report proposes a five year strategy based on increasing industrial capability to turn research into new products and processes with clear and effective routes to market, including establishing new national nanotechnology fabrication facilities to offer firms – especially leading edge SMEs – high quality equipment and expertise where they can test ideas practically.

Industry itself also needs to be alert to the threats and opportunities that nanotechnology brings. This means working closely with the Government and the research and education sectors to ensure that public and private investment can be made with confidence and with sufficient critical mass to deliver commercially successful new technological applications in an ever more demanding market place.

¹ DTI/OST (2002), *New dimensions in manufacturing: a UK strategy for nanotechnology*

Encouraging links between the research base and business

5.16 Knowledge transfer takes place naturally through the movement of trained researchers between the science base and business, and from the publication and patenting of research results. The investment in research output described in Chapter 3 should strengthen the flow of ideas into the economy, augmented by the measures to improve the supply of scientists and engineers highlighted in Chapter 4. Beyond these steps, the quality and volume of knowledge transfer can be improved by tackling a range of factors which would otherwise impede this process:

- Capacity building in universities and public sector research establishments (PSREs) so that they can develop better relationships with industry, create networks and exploit intellectual property. There may be barriers to establishing this activity initially: once overcome through public intervention, the resulting links with business could become self sustaining.

- Relationships between SMEs and the science base, where many smaller firms do not readily have the means, information or incentives to invest in engaging with universities, despite the commercial and wider benefits which this could bring.
- Support for collaborative research into technologies at a very early stage of development or which mainly benefit society as a whole. Examples of the latter include technologies yielding environmental, health or regeneration benefits, while the former include disruptive technologies, which may have wide applicability to new and growing industries but may be less immediately relevant to today's companies.

Support for these technologies will be decided in the light of the potential for long term economic, social and environmental benefits and the extent to which these benefits are expected to be widely distributed.

- 5.17 There are thus clear rationales for well targeted Government intervention to counteract the tendency for sub-optimal interactions between business and the research base and for business itself to undertake too little research. The main purpose of Government interventions to assist universities and the public sector in improving relations with, and relevance to, the private sector – detailed in table 5.1 below – has been to generate new capacity for commercially focused innovation in universities and PSREs.

Table 5.1: Government programmes to increase knowledge transfer

Scheme	Objective	Outcomes
University Challenge – first round (1999)	To close the funding gap between basic research and private sector investment by overcoming difficulties faced in trying to fund proof of concept and prototype development work, to demonstrate sufficient success so private investment will follow.	37 institutions (28 universities and 9 Research Council institutes) have access to £65 million (£45 million from Government and charity sources, and £20 million from universities).
University Challenge – second round (2001)	As above.	Five funds established in which 17 institutions are involved. Each consortium received £3 million of Government funding to establish the fund, or in some cases to add to funds in the first round.
Science Enterprise Challenge – first round (1999)	To encourage the emergence of a culture that is open to entrepreneurship, which is required for successful knowledge transfer from the science base.	12 centres of excellence were established with £29 million of Government funding. Following external contributions, the centres have access to around £57 million funding.
Science Enterprise Challenge – second round (2001)	As above.	7 consortia (involving more than 30 institutions) were successful and £15 million of Government investment was made. The majority of awards provided additional funding to centres established by the first round.
Higher Education Innovation Fund (2001)	Third stream of funding for universities (additional to teaching and research) building on Higher Education Reach Out to Business and the Community Fund.	Government allocated £140 million over three years from 2001-02.
PSRE Fund (2001)	To enable bodies carrying out research in the public sector to support commercialisation and access seed capital funding.	£10 million was awarded in 2001-02, £4 million in establishing a seed fund, and the remaining £6 million to enable 14 consortia, comprising PSREs and more than 30 NHS Trusts, to develop capacity in knowledge transfer.

5.18 Institutions have responded positively to the measures introduced and as a result the capacity for, and the amount of, knowledge transfer occurring between universities and business has increased considerably. There is clear evidence³² of this improvement. For example:

- 199 spin off firms were created in 1999-2000 compared with 26 in 1997, and an average of under 70 per year over the previous five years;
- in 1999-2000, total patents filed by universities rose by 22 per cent from the previous year to 1,534;

³² HEFCE (2001), Higher education business interaction survey

- more than 90 per cent of universities employed specialist staff to support commercial work; and
 - one spin off firm was identified for every £8.6 million of research expenditure in UK universities in 1999-2000, compared to one for every £53.1 million in the US.
- 5.19 Schemes such as the Higher Education Innovation Fund (HEIF), University Challenge and Science Enterprise Centres are enabling universities to generate capacity for knowledge transfer. The £10 million commercialisation fund for PSREs was launched with the aim of stimulating a similar culture change in those institutions.

Higher Education Innovation Fund

- 5.20 HEIF was introduced in 2001-02 and will be worth £60 million a year by 2003-04. The funding has been allocated to universities by an advisory board chaired by the Director General of Research Councils and the programme managed by HEFCE on behalf of OST and DfES, with the aim of building on universities' potential as drivers of growth in the knowledge economy. It has supported more than 70 universities in activities such as the employment of specialist staff, establishing business incubators, improving the intellectual property infrastructure, and providing enterprise training for staff. Much of this funding has gone to non-research intensive higher education institutions, which adds valuable diversity to the range of knowledge transfer activities across the UK.
- 5.21 University Challenge, to which the Government has allocated £60 million over the last two Spending Reviews (including £18 million from the Wellcome Trust and £2 million from the Gatsby Charitable Foundation), provides seed capital funding for the development of new commercial initiatives. Science Enterprise Challenge has provided £44 million over the last two Spending Reviews to allow universities to teach science, engineering and technology students business and entrepreneurial skills. These measures have been extremely successful in stimulating activity from a low base and improving the awareness and experience of knowledge transfer within universities. These specific initiatives have helped catalyse new innovation activities across a wide range of institutions.
- 5.22 It is important to ensure that there is continued support to overcome persistent barriers to efficient market driven innovation. To do this, the Government will continue to support knowledge transfer between universities and business through the Higher Education Innovation Fund (HEIF). The Government is also restating its commitment that HEIF should form the basis of the permanent third stream of funding (in addition to teaching and research).

- 5.23 **In this Spending Review, the Government will increase the funds available through OST and DfES for HEIF, combining funding previously allocated to University Challenge and Science Enterprise Challenge into the new HEIF budget³³. A total of £170 million will be allocated to universities via another round to fund two further years of activity to 2005-06.** In this way, the Government will be supporting knowledge transfer in universities and research institutes through a single stream of funding. This funding will aim both to build on success which has been demonstrated so far in knowledge transfer, and to broaden the reach of these activities through support for non-research intensive university departments.
- 5.24 Having developed momentum in the higher education sector in support of knowledge transfer activities, universities can now play a greater role in targeting available resources at identified priority areas, be it capacity building, seed funding or other activities. Universities will, if they choose, be free to bid for HEIF funding to support the type of activities that were previously supported by other schemes, for example to top up venture capital funds which are now proving themselves or to build on their earlier investments in entrepreneurship education. In order to remove the constraints on funding imposed by ring fenced schemes, there will therefore be no further separate rounds of University Challenge or Science Enterprise Challenge.
- 5.25 The new expanded HEIF should support:
- work to promote enterprise in universities and to promote networking between the university, business and other user communities for the outputs of research;
 - the infrastructure and capability to transfer knowledge from universities into business and the community through applied research, technology and knowledge development, and consultancy, linking with all types and sizes of business; and
 - the formation, through seedcorn funding, of companies to spin out new knowledge, or the development of commercial enterprises to pursue the activities above.
- 5.26 HEIF will be awarded for a two year period beginning in 2004-05, based on a programme of work proposed by universities, building on their earlier successes. Universities will also have to propose measures by which their progress and success can be judged. These should over time provide a basis for establishing measures to ensure that this money increasingly follows success. Stakeholders should continue working to identify what these measures might be. As part of their proposals for using HEIF, universities must consider how they can better engage businesses in knowledge transfer activities. To ensure that HEIF proposals are relevant to the needs of local and

³³ HEIF is currently an England only (devolved) scheme, while Science Enterprise Challenge and University Challenge are UK (reserved) schemes. The new HEIF will be a devolved scheme. The devolved administrations will receive their share of the additional funding in the normal way, and will, if they so decide, be able to continue to use it to fund knowledge transfer schemes.

regional economic development, Regional Development Agencies (RDAs) should be involved in the development and prioritisation of universities' proposals for use of HEIF.

- 5.27 Through this approach, the Government is increasing both the amount of funding for these activities, and the flexibilities for universities to determine the best ways in which to stimulate knowledge transfer activities.

Public Sector Research Establishments (PSREs)

- 5.28 Research Council and departmental PSREs have also begun to embrace the commercialisation opportunities arising from their research. They have recruited specialist technology transfer staff, and are identifying opportunities for exploitation of their research. To provide further support and guidance, Partnerships UK have established a dedicated science and innovation unit, focused on developing and spreading best practice in commercialisation amongst PSREs.
- 5.29 Those PSREs for which exploitation is a relatively new concept are beginning to respond positively to the commercialisation opportunities. **To create parallel incentive mechanisms for knowledge transfer from the Government's own research organisations, to those provided for universities, the Government will provide a further £15 million over two years to support increasing commercialisation among PSREs.** This will increase by 50 per cent the amount of funding devoted centrally to knowledge transfer from PSREs since the last Spending Review. This recognises the opportunities that exist, and the significant potential that these organisations hold.
- 5.30 Universities and PSREs should be incentivised to step up their activities in knowledge transfer by the rewards of income from successful development of research ideas, and from enhanced and more user relevant research. Government support for these activities is, except when addressing clear market failures, largely stimulating activity which can be taken forward in the medium term by universities and PSREs.

Cambridge-MIT Institute

- 5.31 The Cambridge MIT Institute (CMI) provides an international dimension to the UK's knowledge transfer programme. This project brings together the expertise of two of the world's leading research universities to provide joint educational and research initiatives aimed at improving entrepreneurship and productivity in the UK economy, sharing the results with other UK universities. CMI is now starting to deliver tangible benefits to UK research and business. Although funded separately from the entrepreneurship activities developed in Science Enterprise Centres, the CMI is increasingly integrated into this UK network to deliver wider benefits beyond the Cambridge-MIT axis. The Government as major investor (with business co-finance) will continue to require substantial dividends in the form of enterprise education and research for the UK in return for continued backing over the remaining three years of the funding period.

Links between basic and applied research

- 5.32 Universities differ markedly in the balance of their research, teaching and business interface activities. With research becoming more interdisciplinary, linking departments and institutions across the spectrum of basic and applied research, there are increasingly varied combinations of activities which together contribute to knowledge transfer. This means research results are less likely to be developed into commercial innovations in a formulaic, predictable way.
- 5.33 Many universities build on their basic research presence in order to provide knowledge transfer services and research relevant to industry. Those universities which specialise in links with industry and applied research often have an underpinning core of basic research on which their industry links rely. Other less research intensive departments in universities have the potential to add a further dimension to the knowledge transfer process. By using their organisational focus on interacting with regional businesses, and by working in partnership with other universities, they can help translate research outputs to engage SMEs and less technologically sophisticated businesses. The extra money for HEIF will be used by OST to fund such initiatives, where there are demonstrable skills and motivation in the universities to lead these ventures and they are clearly supported by business and integrated with the needs of the regional economy.

The regional dimension of knowledge transfer

- 5.34 Government spending on science and research is largely organised on a national basis, giving priority to funding excellent research and development, wherever it is found. This secures value for money, and is the most effective way of ensuring the UK's research capability remains internationally competitive. But wherever research and development activity takes place, in universities, research establishments or business, it has the potential to contribute directly to regional economic development as well as innovation at the national level. Just as national productivity growth in the long run depends on harnessing innovations to add value, so regional growth is likely increasingly to be founded on the innovation performance of business and the research base in the region.
- 5.35 Research and innovation rely crucially on human interactions, to share ideas and experiences in a richer dialogue and working more closely together than the exchange of the written word. Firms and universities benefit from proximity to other research intensive organisations in geographical clusters, both to enhance the dialogue between their personnel and to tap into thicker and more liquid labour markets. Clusters (defined by the OECD as 'networks of interdependent firms, knowledge-producing institutions, bridging institutions and customers, linked in a production chain which creates added value') are important building blocks of regional innovation systems. Efficient knowledge transfer between a range of inter-dependent bodies within a region is therefore crucial to successful clusters.

- 5.36 The Regional Development Agencies have been given increased funding and flexibilities, building on the earlier £50m per annum Regional Innovation Fund, which will enable them to assist in the development of clusters of strategic economic importance and in understanding other regionally focused innovation activities. RDAs are developing and refining an understanding of the strengths and weaknesses of their regions, including how their regional science and engineering base can integrate with the needs of business as part of regional economic strategies. RDAs are therefore best placed to identify mismatches between regional industrial strength and relative research weakness, or vice versa. Some of these mismatches can be addressed by co-ordination from the RDAs, bringing together business and universities to secure agreement to common regional innovation objectives. The Government will therefore also be encouraging RDAs to establish regional Science and Industry Councils or equivalent bodies, along the lines of those in the North West and North East, to provide local leadership in strengthening regionally based innovation. RDAs will also be able to invest their own funds, or lever in external funding, to develop capacity where necessary.
- 5.37 The Government will also be considering how best to make use of the RDAs' regional knowledge in the allocation of knowledge transfer funding, such as HEIF and DTI's portfolio of innovation programmes. The RDAs will be in a good position to advise Government on regional priorities reflecting relative performance on innovation across the country, and to work with universities on the development of proposals which avoid duplication, and encourage complementarity and connections with regional economic development priorities.

Conclusions

- 5.38 The Government's aim is to improve the UK's innovation performance as a central part of its strategy to raise productivity and economic growth. Previous chapters have set out how the Government will act to ensure that universities can continue to produce world class scientific research over the long term and to provide an adequate supply of highly skilled scientist to carry out research and development.
- 5.39 As UK companies face ever increasing global competition, it is critical to their long term survival that they move up the value added chain through investment in innovation, leading to new and better products and processes. The positive benefits of this lead to both increased productivity and further economic growth as new or improved products and services are also taken into new markets. This requires two way interaction between the science base and the private sector, and the private sector having the ambition, opportunities and capacity to innovate. This chapter has shown how the Government will continue to support and encourage knowledge transfer and to overcome initial obstacles and persistent barriers to achieve this.
- 5.40 The next chapter looks more closely at how the Government can build on the reforms to the science base and the labour market that have been outlined so far to set the right environment for firms to increase their investment in innovation and technological progress.

Introduction

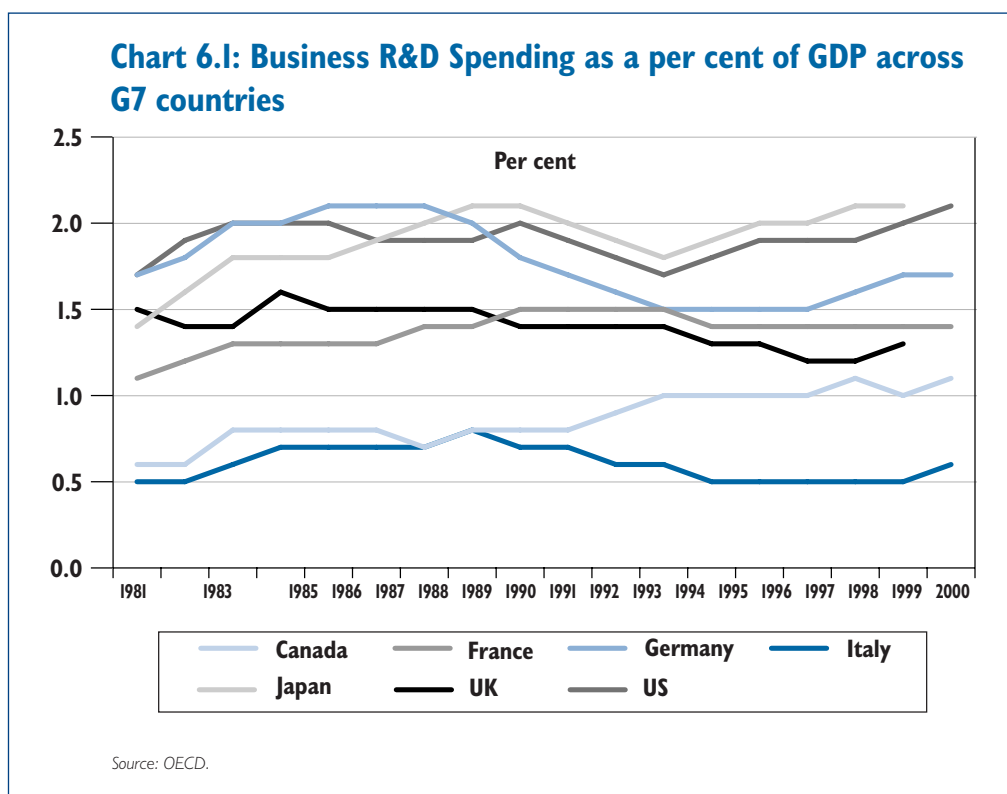
- 6.1 Both the public and the private sectors have vital roles to play in increasing the amount of R&D undertaken in the UK, and thereby raising the technological innovative potential of the economy. Previous chapters have set out the Government's strategy for working in partnership with other stakeholders to ensure that university science research is world class and that there is a sufficient supply of highly skilled scientists and engineers. These measures will ensure that high quality R&D can be undertaken in the UK over the long term.
- 6.2 Ultimately, however, it is businesses that develop new ideas and inventions into new products and services that can deliver economic gains. Their motivation is to deliver value to customers and shareholders. Increasingly, firms in industrialised nations are competing internationally primarily on quality, design and service, to move into higher value added activities: being competitive on price is no longer sufficient to maintain a commercial advantage. Investment in innovation is integral to creating higher value.
- 6.3 To move onto a virtuous circle of increased investment in innovation leading to value creation and re-investment, it is important that the Government takes a holistic approach to innovation as a system across the whole economy. It was for this reason that the Government published its Manufacturing Strategy in May 2002, setting a strategic framework for working in partnership with industry, industry bodies, trades unions, Regional Development Agencies, other Government departments and all key stakeholders, to ensure that Government addresses the commercial needs of business in driving forward the manufacturing agenda. As well as ensuring that university research is world-class, connected to business needs, and that the UK has a sufficient supply of highly skilled scientists, Government has responsibility for setting the framework conditions for competition and investment, knowledge creation and R&D.
- 6.4 This chapter sets out the Government's approach to fostering innovation by UK businesses.

Private sector research performance

- 6.5 As Chapter 2 has shown, the private sector carries out most of the R&D undertaken in all G7 countries. In quantitative terms these businesses therefore have a critical role in driving national innovation performance. But beyond this, business R&D is the prime route for ensuring that value is derived from research undertaken by public sector and higher education institutions, through creating marketable outputs from the skills and ideas developed in these institutions. If this channel for converting knowledge into added value is functioning effectively, it will draw out the benefits of public research; evidence³⁴ suggests that government-funded R&D has a greater impact on productivity growth in countries with a high intensity of business-funded R&D.

³⁴ Guellec and van Pottelsberghe de la Potterie, (2001) R&D and productivity growth: Panel data analysis of 16 OECD countries.

6.6 R&D carried out by businesses in the UK fell as a proportion of UK GDP, from 1.5 per cent in 1981 to 1.2 per cent in 1997. As a result, the UK performs significantly worse than the US, Germany, and France in terms of the amount of R&D performed and funded by the private sector measured as a percentage of GDP (see chart 6.1). However, Chapter 2 also showed that there has been a recent upturn in business-financed R&D, which suggests that more businesses are recognising the importance of R&D and innovation for future performance.

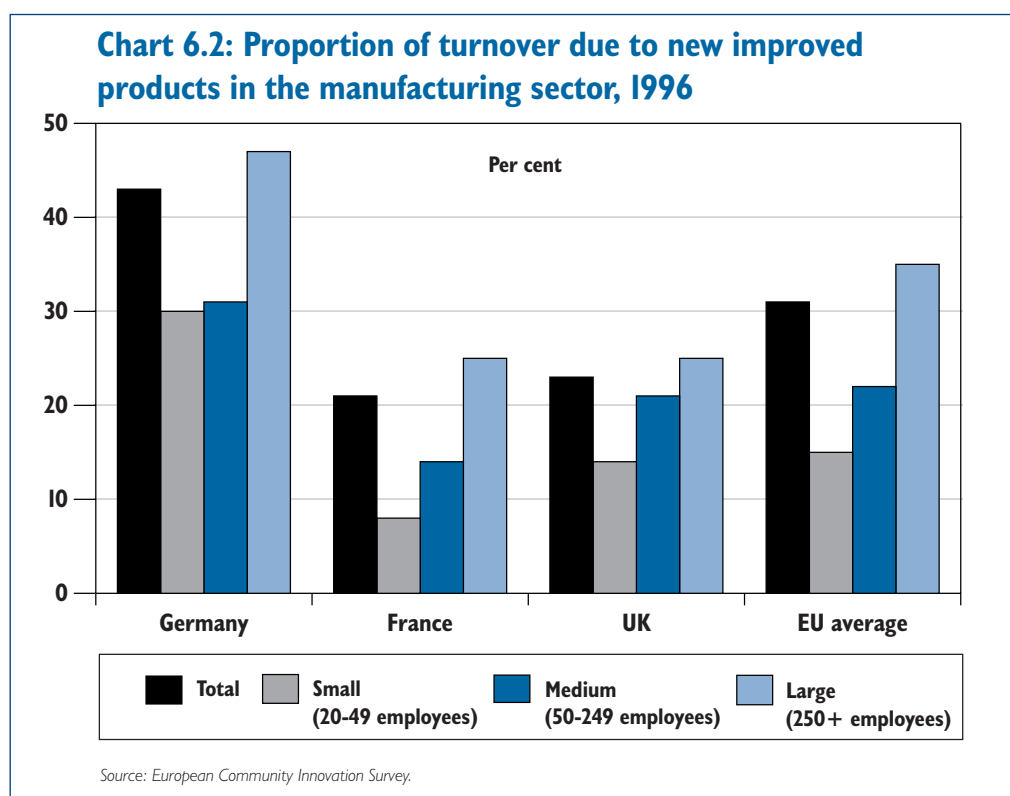


6.7 The R&D Scoreboard³⁵ shows that R&D undertaken by large firms is dominated by pharmaceuticals and aerospace which together account for 48 per cent of total UK R&D (compared to 19 per cent internationally) in 2001. UK companies in both sectors and the health care industry have an average R&D intensity³⁶ above that of their foreign counterparts. However, the UK scores poorly in all other sectors (for example, IT and automotive – the top two sectors for R&D outside the UK) where its R&D intensity lags behind competitor countries. For example, average UK R&D intensity for all sectors in 2001 was 2.1 per cent, representing half the level of the US (4.3 per cent), Japan (4.2 per cent) and the international average (4.2 per cent).

³⁵ DTI (2001), R&D Scoreboard.

³⁶ R&D intensity refers to the ratio of R&D expenditure as a proportion of total sales.

- 6.8 Recent research by the OECD on business R&D intensity has investigated whether industry composition effects partly explain business R&D intensity³⁷: for example, whether the UK has a poor R&D record because it is weak in sectors that are traditionally very R&D-intensive. However, the OECD found that these composition effects were not the most significant factor in explaining the UK's poor record; instead differences in R&D intensity across most sectors were seen to explain the differences in the overall R&D intensity.
- 6.9 The UK business sector's low spend on R&D relative to countries such as the USA, France, and Germany would be expected to translate into a relatively weaker innovation performance. Although innovation as an output is inherently difficult to measure, the available evidence does indeed suggest that UK firms are in practice less innovative than those in countries in which business expenditure on R&D is greater. The UK's larger manufacturing companies, in particular, fall behind the European average in the extent to which their sales are based on innovative or improved products (see chart 6.2 below).



Setting the right environment for private sector investment

- 6.10 The Government recognises that businesses will only invest in R&D and innovation when there are good commercial reasons for doing so, the incentives are right, and when they are likely to see returns from that investment. In the UK in recent decades, these framework conditions have

³⁷ OECD (2002), Productivity and Innovation: The Impact of Product and Labour Market Policies, Economic Outlook 71.

not been as supportive of business investment as they could have been. As argued in Chapter 2, it is partly for this reason that even when the UK's total spend on R&D was the second highest in the G7 as a share of GDP (in around 1980), this investment did not translate into outstanding economic performance.

6.11 The Government's science and innovation strategy is designed to ensure that the overall environment is supportive of business investment in R&D and innovation. This requires the Government to ensure that:

- the supply conditions are right. This involves ensuring there is a steady flow of ideas from the science and engineering base and a sufficient supply of appropriately skilled scientists and technologists to carry out R&D;
- the demand conditions match this with high levels of university and business interaction and incentives for businesses to invest in R&D via a sound intellectual property regime and a favourable tax treatment of R&D investment; and
- wider economic conditions also encourage investment. Macroeconomic stability, a favourable general tax regime and a strong competition policy will all encourage businesses to invest in R&D.

6.12 On the supply of research ideas and skills, Chapters 3 and 4 have set out the Government's strategy for ensuring that universities can fund their research departments on a sustainable basis and that they can continue to develop new areas of research. They also highlight proposals to improve the supply of skilled scientists and engineers.

6.13 On the demand side, Chapter 5 outlines the Government's strategy for encouraging more interaction between universities and businesses. It is also important to create direct incentives for firms to invest in R&D. The substantial reforms to the UK tax system for businesses, investors and entrepreneurs in recent years (highlighted below) have helped improve both general and targeted fiscal support for corporate innovation investment in the UK.

6.14 Finally, the Government is committed to ensuring that intellectual property regime in the UK and Europe continues to provide incentives to research and innovation, through protection of original ideas. Scientific gains in new areas of human genome research, and the continued growth in the importance of information technology raise challenges for intellectual property rights policy. These scientific and technological advances place a premium on ensuring that the creation and protection of intellectual property rights support and sustain a vibrant innovation system.

Creating a favourable economic environment

6.15 Specific demand and supply measures are important to ensuring that businesses have the capacity and motivation to invest further in innovation. However, for the economic gains to flow from this it is crucial that the wider economic framework is conducive to capitalising on R&D and innovation. The Government's approach to achieving this involves:

- creating a stable macroeconomic environment in which firms can invest for the future;
- establishing a strong competition regime that provides powerful incentives for firms to innovate and reduces the costs of, and barriers to, entry to markets;
- reducing barriers to entrepreneurship to encourage new innovative businesses to emerge. New entrants to markets increase competitive pressures on market incumbents, thereby further encouraging firms to innovate;
- developing a general tax regime that is favourable to growth businesses; and
- assisting the development of efficient and sophisticated capital markets that are attuned to the needs of R&D intensive undertakings.

6.16 Creating macroeconomic stability was the primary economic aim of this Government in 1997. Through making the Bank of England independent and the introduction of the fiscal rules, the Government has created greater certainty that interest rates will remain both low and stable. This encourages firms to invest for the long term because returns are more predictable and risks reduced. This situation is radically different from that in preceding years, when instability was partly responsible for low business investment in the UK.

Encouraging innovation through competition

6.17 The UK has historically had a weak competition regime. This may have acted to subdue incentives for investment in R&D and the commercialisation of innovations. In an uncompetitive market, barriers to entry are high, making it difficult for new entrants, often small and medium sized enterprises, to bring innovations to market and thus challenge the power of incumbents. In this environment the pressure to reduce costs is reduced. The result is that incumbent firms themselves may become complacent in exploring new innovations or hold back marketing new generations of products to exploit market power in the current generation.

- 6.18 By contrast, in a vigorously competitive environment firms are forced to adopt best practice techniques, continuously seek to innovate and improve efficiency in order to survive and prosper. And as each firm seeks to innovate to gain advantage over rivals, so those ideas are built on by other competitors, or by potential entrants to the market, thus raising the overall rate of innovation. This benefit can be even greater when firms, toughened by domestic competition, go on to compete effectively on the world stage. A strong domestic competition framework can therefore create benefits for industry as a whole that are greater than the sum of the benefits for each individual firm. This phenomenon is clearly observed in industry clusters, geographic concentrations of a particular industry that can achieve fast productivity growth.
- 6.19 There is substantial evidence on links between strong competition and high productivity growth. Studies³⁸ examining the impact of competition on R&D in the UK conclude that concentration, and other measures of market power, tend to reduce the rate of innovation and hence productivity growth. Wider international studies³⁹ conclude that British industry has long been undermined by monopoly companies and protective regulations with the result that innovation in these industries has been stunted.
- 6.20 The Competition Act 1998 greatly strengthened the domestic competition regime through the introduction of a prohibition against anti-competitive agreements and abuses of dominant market position. This has been augmented by greater resources for the Office of Fair Trading to increase its ability to deter, detect and punish anti-competitive behaviour. The Enterprise Bill, currently before Parliament, will take reforms further by introducing full independence for the UK competition authorities, and criminal sanctions against individuals who engage in cartels.
- 6.21 Whilst a competitive environment will provide the best general incentive for firms to innovate, firms need to be confident that they can reap the rewards of their innovation. This is why the intellectual property regime allows firms to prevent, for a limited period, their competitors from copying their innovations. This is a necessary reward for the costs of research and development, and helps to encourage innovation. Given the natural tension between these objectives, it is critical that Government policies strike the right balance between encouraging competition and rewarding innovation.
- 6.22 Beyond the macroeconomic and competition frameworks, the Government has taken forward a range of policy reforms to enhance the financial incentives to invest at the business level, and the efficiency of capital markets in supplying business finance.

³⁸ Geroski (1990), Innovation, Technological Opportunity and Market Structure, Oxford Economics Papers 42.

³⁹ Porter (1990), The Competitive Advantage of Nations.

Reducing financial barriers to innovation

- 6.23 The bulk of business innovation is conducted by major companies. It is therefore important that the tax regime for such companies supports investment decision-making. However, new entrants also have an important role to play in commercialising new ideas and challenging incumbents. In some sectors, such as biotechnology, whole market niches are populated by new ventures, which have the advantages of focus over larger companies. Weaknesses in the external financing of smaller and start-up enterprises provide the starting point for the Government's reforms to improve the returns to investment by, and in, SMEs. These have been supported by improvements in venture capital and access to public equity markets in recent years.
- 6.24 For established larger corporations, the Government has reformed the business tax regime to encourage investment and remove distortions that would otherwise have impacted on financial planning. This encourages investment by increasing the returns available to the investor. The Government has also used the tax framework to create positive incentives to invest in innovative high growth companies:
- Corporate tax rates have been reduced across the board – from 33 per cent to 30 per cent for large companies, and from 23 per cent to 19 per cent for companies with lower levels of profits.
 - The tax system has been reformed to reduce tax impediments to businesses' innovation activities. In the past, the tax system has not allowed all of the costs of innovation to be written off against taxable profits. To remove this distortion and further align tax with commercial accounting, reforms introduced in this year's Budget allow companies tax deductions for the cost of acquiring intellectual property, including patents, trademarks, brands, copyrights and a range of intangible rights, commercial information and goodwill.
- 6.25 For smaller companies facing greater financing hurdles, the Government has implemented a comprehensive set of measures to encourage enterprise start-up and growth:
- A new starting rate for companies with low profits has been introduced, and this year reduced from 10 per cent to zero.
 - Investors in high growth companies look for returns in capital growth, rather than dividends, and so mitigation of capital gains on corporate shares represents a targeted tax incentive for investment in growth-oriented companies. Government has reduced the effective tax rate on unquoted shares held for two or more years from 40 per cent to 10 per cent.

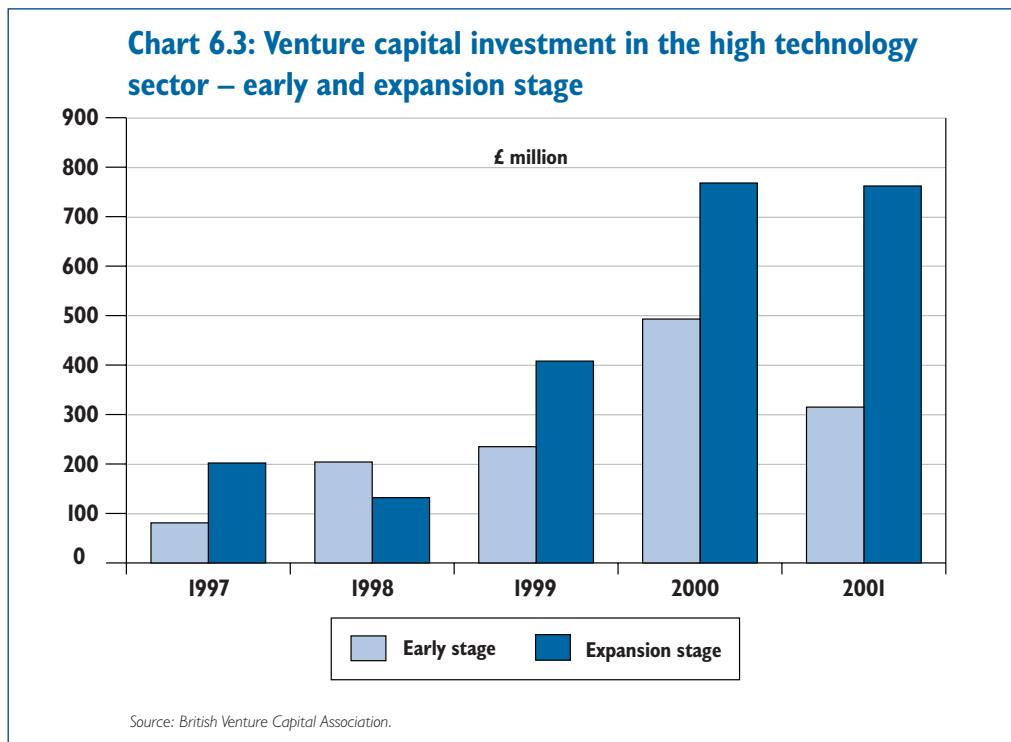
- Further incentives for venture capital investment by individuals in smaller higher risk companies are provided by improved tax incentives via Venture Capital Trusts, the Enterprise Investment Scheme and the Community Investment Tax Credit.
- Small high growth companies can find it difficult to offer the competitive salaries needed to attract the right employees, but may use share options to reward employees for the growth the company achieves. The Government has introduced a tax favoured share option scheme for smaller companies (Enterprise Management Incentives), which allows them to give up to £3 million of share options tax free, across the company, to help recruit and retain personnel.
- The Small Firms Loan Guarantee Scheme assists firms to access debt finance where they do not have sufficient collateral or track record to do so unaided.

6.26 In addition to these tax measures, the Government has further increased access to risk capital through the Regional Venture Capital Funds programme. Funds are being set up in every English region which will provide up to £270 million of investment in businesses with growth potential, backed by up to £80 million of Government funding and £53.5 million from the European Investment Fund. The funds are targeted at the 'equity gap', for injections of risk capital below £500,000, where private sector venture capital funds are reluctant to offer finance. The Government is also making available up to £50 million of Early Growth Funding, to help innovative businesses in their early stages through provision of small amounts of finance. Furthermore, as a result of a £20 million Government cornerstone investment, over £100 million of investment will be targeted at early stage high technology businesses through the UK High Technology Fund.

6.27 Government measures have contributed to an improvement in the supply of risk capital in the UK in recent years. While larger management buy-outs of established businesses continue to dominate market volumes, risk capital is increasingly available for smaller technology-based firms. As the chart below shows, private equity investment in high technology firms⁴⁰ in the early and expansion stage has increased threefold between 1997 and 2001. This marked trend increase in investment indicates the healthy underlying attitude toward investing in the technology sector, despite the recent downturn in capital markets. The UK now accounts for around one quarter of all European investments in early stage venture capital for technology companies⁴¹.

⁴⁰ The high technology category includes communications e.g. computer hardware and software other electronics related technology and biotechnology.

⁴¹ PricewaterhouseCoopers (2002), Money for growth – The European Technology Investment Report 2001.



- 6.28 To complement and reinforce venture capital investment in innovative firms, there are now easier entry routes onto the public equity markets for technology-based firms which are yet to reach profit. This is supported by the increasing number of companies entering the unlisted AIM and OFEX markets. Despite the downturn in the technology sector, the number of companies registered on AIM more than doubled from 308 in 1997 to 629 in 2001 and the number of companies registered on OFEX increased from 138 in 1997 to 195 in 2001.
- 6.29 As well as helping to stimulate an increase in the effective supply of finance for SMEs, the Government is also acting to increase the effective demand. The Small Business Service has announced successful bidders to run six pilot projects operating in different parts of the country. These will help inform small businesses about their financing options and offer a programme of support to help them become investment ready.
- 6.30 These relatively new programmes complement existing measures such as the SMART awards (see Chapter 5) that offer grants to small businesses developing new products or processes.
- 6.31 To complement generic tax measures, the Government has also introduced direct incentives for companies to increase investment in R&D through the R&D tax credits, which recognise and respond to the additional financing hurdles which both large and small firms face in committing long term capital towards research.
- 6.32 In 2000, the Government introduced an R&D tax credit for small and medium sized companies, increasing the tax deduction for current R&D expenditure to 150 per cent, in place of the usual 100 per cent. And because technology-based early stage companies undertaking R&D often face cash flow constraints, loss-making companies can obtain immediate benefit from the credit by converting it into a cash payment worth up to one quarter of their R&D spend.

- 6.33 In Budget 2002, R&D tax credits were extended to all companies with the introduction of a 125 per cent tax credit for larger companies, which undertake around 90 per cent of all business R&D in the UK. The large companies credit reduces the cost of R&D by 7.5 per cent for most large companies, and the two tax credits together represent £500 million support from Government for business R&D investment.
- 6.34 The tax credits have been designed to be transparent and predictable, delivering a flat rate of subsidy that companies can incorporate into their investment decisions. Evidence⁴² suggests that firms show a strong response to a reduction in the cost of R&D – increasing their expenditure pound for pound in line with the tax support.
- 6.35 A large proportion of R&D is undertaken by very large multinational groups of companies, who have considerable choice about where they locate their R&D activity. The large companies credit also targets R&D undertaken in the UK, which will encourage both inward investment of R&D by foreign multinationals and UK based multinationals to locate their R&D here.
- 6.36 While not a substitute for well targeted grant funding, the advantages of a tax credit are that it allows investment decisions to remain with companies, and is cheaper to administer, for both companies and Government. However, to deliver these advantages it is essential that companies are confident about the scope of the credit and their ability to realise the tax advantage it offers. The Inland Revenue is therefore working with industry to promote the tax credits to companies of all sizes and to clarify the R&D definition.

Creating a conducive regulatory environment

- 6.37 Regulation of science reflects society's demands for an ethical approach to research. By designing and implementing regulations sensitively, the Government can encourage rather than deter innovation in the UK by creating confidence for firms and research organisations to undertake science. For example, biotechnological innovation has been stimulated whilst protecting human health and the environment through a pragmatic and transparent regulatory framework that ensures cutting edge research aimed at developing new treatments can proceed. The Human Fertilisation and Embryology Act 1990 and the Human Fertilisation and Embryology (Research Purposes) Regulations 2001 have enabled the UK to encourage innovative research on stem cells while balancing ethical concerns. Such research is now attracting world class scientists to work in the UK, and demonstrating that the UK remains a favourable location for science and investment. Similarly, the UK's approach to regulation of gene therapy has helped the UK to become the European leader and close the gap on the USA in terms of new clinical trials over the last two years.

⁴² Bloom, Griffith & Van Reenen (2000), Do R&D tax credits work? Evidence from an international panel of countries, 1979-94.

The challenge to the private sector

- 6.38 Reaping the rising productivity gains and subsequent economic benefits of innovation is a long term process, requiring sustained investment throughout the innovation system and effective mechanisms for diffusion and exploitation of scientific knowledge. The Government recognises its responsibility for implementing a range of interlinked structural policies to provide credible long term incentives for all partners in the UK's innovation system to play their part. Building on the macroeconomic benefits already delivered through reforms to monetary and fiscal policy, and the structural benefits which should flow from competition policy and business tax reforms, the Government is now tackling the challenge of putting science research funding on a more sustainable long term footing. This should deliver greater confidence for all those engaged in the UK's innovation endeavour that the underpinning investment in production of research knowledge and skills will continue to grow. This in turn should reinforce wider reforms to encourage long term investment in R&D and innovation across the economy.
- 6.39 Ultimately, however, it is up to individual businesses to make the most of the opportunities that are provided as a result of the reforms set out in this strategy. Only business can generate tangible economic value for the knowledge economy from science and technology inputs. Only business faces the growing competitive challenge to be more innovative in boosting their value added.
- 6.40 Businesses are best placed to identify their needs for science and technology inputs, absorbing the skills and ideas emerging from a vibrant UK science base. To attract the skills they need in an increasingly international labour market, companies need to improve the attractiveness of careers in R&D, rewarding and motivating new generations of scientists and engineers who will enable the next generation of innovation. There is now a real opportunity for business to shift the perception of science, engineering and technology in the minds of young people, through engaging with schools, colleges and universities, to inspire the industrial researchers and innovators of the future.
- 6.41 Businesses are also well placed to exploit the growing effort by universities and public sector research establishments to transfer research into the market place. As they increase their interaction with the science and engineering base, business will benefit from the investment by Government in putting the research infrastructure onto a sustainable footing over this decade. In return, commercially-funded research will play its part in ensuring that research in higher education is fully funded across the range of public and private sector partners.
- 6.42 Innovation is at the heart of the UK's future productivity growth and is a key part of the Government's Manufacturing Strategy. Through investing now in research, skills, and knowledge transformation, businesses can provide the impetus for real and lasting economic gains for the country as a whole. There is now the opportunity for joint action: public and private capital, combined with reforms to public policy and commercial practice, to move the UK economy back onto a virtuous circle where innovation and productivity growth reinforce each other, creating the platform for future prosperity.

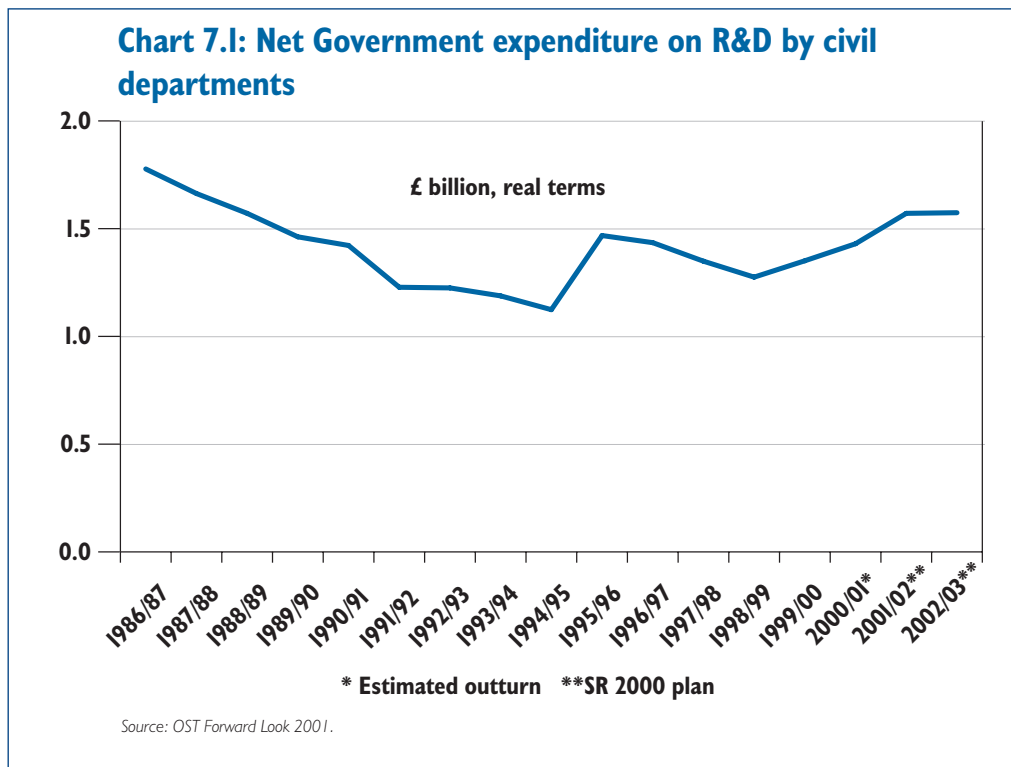
Introduction

- 7.1 Government needs to use high quality science, including social science, and the most appropriate new technologies in order to deliver evidence based policies and excellent public services. To this end, Government departments spend significant sums of money on research and development. Total spending, not including surveillance and testing, was nearly £4 billion in 1999-2000, with £1.35 billion being spent by civil departments. Science base funding by Research and Funding Councils, by comparison, was of the order of £2.5 billion in the same year. In addition, Government obtains scientific advice, often from independent scientists, on a wide range of functions, including policy development, regulation and service delivery.
- 7.2 The importance of high quality science has come into increasing focus in recent years. The Phillips Report on the BSE Inquiry, published in October 2000, and the Government's response to it emphasised the need for rigorous scientific advice and for Government to have the competence to act as an intelligent customer. More recently, during the outbreak of foot and mouth disease, scientific advice based on sophisticated epidemiological models delivered in real time helped to inform decision making and determine policy as events unfolded.
- 7.3 The following criteria are critical for success in using science and managing research:
- effective horizon scanning so that issues involving science, or where science could be involved, are identified in advance;
 - effective arrangements for deciding what current or potential science could benefit the needs of the department and hence whether new research is needed;
 - strong procurement process, run by expert research programme managers;
 - commitment to excellence in research, which is fit for purpose, and carried out to high standards;
 - critical use of the results of research and scientific advice in policy formulation;
 - open approach to publication of results and debate about implications; and
 - effective knowledge sharing and transfer.

- 7.4 The Government has taken a series of measures in recent years to strengthen the use of science. In particular:
- departments have published science and innovation strategies, setting out the broad framework within which research programmes and other scientific activities are carried out, and showing how these help to deliver objectives and priorities;
 - the Chief Scientific Adviser's Guidelines on scientific advice in policy making, revised July 2000, set out the key principles applying to the development and presentation of scientific advice; and
 - the Code of Practice for Scientific Advisory Committees, published in December 2001, promotes good practice in the operation of scientific advisory committees and their relationship with Government.
- 7.5 Most departments can now demonstrate that many of the features essential for success are in place. More needs to be done, with the aim of creating a dynamic for improvement in the use of science by Government, analogous to the improvements in university research delivered following the introduction of an external driver in the form of the Research Assessment Exercise.
- 7.6 The Government is now introducing a package of measures to strengthen the use of science and management of research, covering physical, life and social sciences, and technology. These are designed to:
- ensure that science priorities are carefully considered and given proper weight alongside other priorities in spending decisions, so that there are adequate inputs for science and research;
 - improve the competence of departments to act as an intelligent customer and manager;
 - improve arrangements for knowledge transfer; and
 - increase external scrutiny and benchmarking, led by the Government's Chief Scientific Adviser, to facilitate the exchange of good practice and to encourage a dynamic for improvement.

Budgets

- 7.7 High quality outputs require adequate inputs invested in research. Spending on civil research and development by Government departments tended to decline through the 1980s and 1990s (see chart 7.1 below). This trend has now been reversed. The decision in the 2000 Spending Review that the research spend of the main civil departments should at least be maintained in real terms has made a significant contribution. This improvement needs to be sustained.



7.7 Research spend typically represents a very small proportion of departmental budgets (1 or 2 per cent). As such a small proportion of the overall budget, research spending can be vulnerable to urgent pressures because its outputs are less tangible and more uncertain than other forms of investment, although the outcome is often of major long term importance.

7.8 To encourage a more strategic approach to setting R&D budgets, and to identify clearly the resources needed, future science and innovation strategies will be costed, taking account of the need to make an appropriate contribution to the real costs of work commissioned from universities, as set out in Chapter 3. These costings will enable early identification of the investment needed. Changes in agreed spending plans for departments with major research programmes will be monitored by the Treasury and the Government's Chief Scientific Adviser.

Scientific expertise

7.9 Departments must have the capability to commission the right research, assess its quality, and use it effectively. To do so, they need in-house scientific expertise. A number of developments in the management of the Civil Service in the last quarter of the twentieth century have weakened traditional arrangements for supply of such expertise:

- the privatisation of scientific research establishments, and the development of an arms-length relationship between departments and the remaining public sector establishments, has eroded what was previously the main base for the supply of practising scientists to departments;

- successful implementation of reform programmes designed to facilitate interchange between scientists and the generalist Civil Service, together with the decentralisation of personnel management, means that there is no longer a separate science group in the Civil Service, and arrangements for career management and continuing professional development for scientists have become fragmented.

7.10 A strategic approach is required. Departments need to take a systematic view of the areas that need scientific input, and the critical mass of scientists needed at the interface between science and policy. While maintaining opportunities for movement between specialist and generalist posts, they must ensure that there are adequate opportunities and resources for professional development and career progression for practising scientists working in Government. This will involve exposure to the latest science in their area of work, enhancing the professional status of research management within Government, secondments, and better arrangements for scientists to move freely into related scientific areas in other departments.

7.11 Departments must have the capability to consider science issues at an appropriately senior level in the wider context of the department's work. This requires representation and strategic direction at the top end of the department. **Departments which use or commission an appreciable amount of science research will need to appoint a Chief Scientific Adviser, who can ensure that the department's scientific activities are well directed and that policy is soundly based on good science, and to be the department's scientific spokesman to the outside world.** Such a person will need active experience at the cutting edge of science, in order to ensure they have the appropriate credibility both within and outside the department. The individual concerned will also need to operate at the appropriately senior policy making and operational level in the department.

Knowledge transfer

7.12 In recent years there has been a drive, prompted by the recommendations of the Baker Report⁴³, for commercialisation of the research outputs of Public Sector Research Establishments (PSREs), to promote more effective exploitation of publicly funded research, including that commissioned by Government departments.

7.13 Departments and agencies involved in delivering the knowledge transfer agenda have often been hampered by a lack of appropriate incentives, skills and expertise for this area. To address these barriers, there have been a number of changes in policy, as well as new measures to assist and encourage knowledge and technology transfer.

⁴³ Creating knowledge, creating wealth: realising the economic potential of public sector research establishments - A report to DTI/HMT (1999)

- 7.14 The main initiatives have focused on delivering the agenda set out in the Government's response to the Baker Report. These include the Patent Office guidelines, Intellectual Property in Government Research Contracts; the OST's guidance on good practice for PSREs on staff incentives and the management of conflicts of interest; the establishment of a Science and Technology Commercialisation Unit within Partnerships UK; and the Small Business Research Initiative (SBRI), making research procurement accessible for smaller companies. The 2000 Spending Review also launched the £10m PSRE Fund, which provided £6m for the development of knowledge transfer capacity, and created a £4m seed corn fund to invest in early stage ideas emerging from the PSREs.
- 7.15 There is still some way to go for Government to embed knowledge transfer into the goals and practice of public sector research establishments. Departments will now include knowledge transfer objectives in their science and innovation strategies and in their research programmes. A senior official will be responsible for delivery, by the department and the PSREs for which it is responsible, of knowledge transfer goals and targets, and for ensuring that the department's PSREs are given the financial and other freedoms recommended by the Baker Report. **And as set out in Chapter 5, the Government will provide a further £15 million to continue the PSRE Fund in support of new knowledge transfer activities.**

Cross-cutting issues

- 7.16 Research needs often cut across departmental - and disciplinary - boundaries. Arrangements for co-operation and communication vary according to need. Generally, the arrangements are informal. Although there are some examples of cross-cutting research areas where stronger co-ordinating arrangements are used, procedures for allocating and accounting for budgets have not always facilitated such an approach.
- 7.17 Merged budgets, with departments contributing to a single pot under the leadership of a single department and with shared steering arrangements, provide a more robust basis for strategic direction and are already in use. Research co-ordination of this type generally follows policy and programme co-ordination. A good example is the interdepartmental Research and Information Working Group in the drugs research area, chaired by the Home Office, which monitors the progress of the research programmes and manages a ring fenced budget. The Government's Chief Scientific Adviser will explore the scope for increased use of merged research budgets in cross-cutting areas of research.

External review

- 7.18 The Government's Chief Scientific Adviser is responsible for advising the Prime Minister and the Cabinet on the overall health of science and scientific research funded by Government departments. He needs to be in a position to provide assurance on the quality and rigour of the systems which departments have in place for using science and managing research. **The Government's Chief Scientific Adviser will work closely with departments and their CSAs to introduce a new rolling programme of external scrutiny and benchmarking supported by a new team in OST, so that there is an external dynamic for improvement in the ways that departments use science and manage research.** The programme will work with the grain of existing arrangements for scrutiny and audit, reinforcing best practice and encouraging consistently high standards.

ANNEX A: THE GOVERNMENT'S RESPONSE TO THE ROBERTS REVIEW

Recommendation 2.1: The participation of women in science and engineering

The Review notes that, despite recent progress, the proportion of girls studying mathematics and the physical sciences post-16 is still considerably lower than that of boys, which contributes to the under-representation of women in science and engineering more generally. The Review is clear that the under-participation of women in SET is damaging the UK's supply of scientists and engineers, and a number of the recommendations set out in this report should have an important influence on the participation of women in science and engineering.

The Review is aware of a separate study, led by Baroness Susan Greenfield, who has been asked by the Government to recommend how to achieve a step change in the effectiveness of measures being used to increase the participation of women in science and engineering. This Review has therefore sought not to duplicate the work of that study but firmly believes that action is required.

The Government shares the desire to see more women participating in science (particularly physical science) and engineering, and agrees that implementing a number of the Review's recommendations should help in this regard. The Government will also encourage participation by women through considering the findings of the study led by Baroness Greenfield and through the work of the Promoting Science, Engineering and Technology for Women (PSETW) unit in the Office of Science and Technology. Furthermore, the Government believes that existing measures, such as the Science and Engineering Ambassadors Programme can play a role in this process (in the case of the Ambassadors Programme by providing positive role models for girls).

Recommendation 2.2: The participation of ethnic minority groups in science and engineering

The Review is disappointed by the lack of awareness and analysis of differences in achievement and participation in science and engineering between ethnic groups. It is difficult to establish the root causes of these differences, based on the evidence available. However, the Review believes that they are significant and therefore recommends that the Government investigate this issue fully in schools, further education and higher education.

The Government is alive to the concerns expressed on the participation and achievement of ethnic minority pupils in science and engineering, and in education more generally. The Government is committed to working with key partners – such as the Commission for Racial Equality and representatives from community groups – to develop a coherent national strategy for raising the achievement of ethnic minority pupils. As part of Science Year the Government is working with the

organisation Black Parents in Education in creating a website celebrating the achievements of black scientists past and present. The aim is to raise the self-esteem of African Caribbean pupils and encourage them to consider careers in science and engineering.

As with recommendation 2.1, the Government believes that implementation of a number of the Review's recommendations, coupled with existing initiatives such as the Science and Engineering Ambassadors programme, will encourage participation and achievement in science and engineering by ethnic minority pupils. And in light of this specific recommendation the Government will also take steps to improve data available on the achievement and participation of ethnic minority groups in science and engineering.

Recommendation 2.3: Primary school teachers

The Review recommends that the Government ensure that primary school teachers receive greater subject specific training (in particular, in relation to the physical sciences and mathematics) both in their initial training and through Continuing Professional Development to enable primary teachers to build on the progress they have made so far. Furthermore, the Government should review, in three years' time, the progress made in improving primary school teachers' confidence in teaching all areas of the mathematics and science curricula, and take further action as necessary.

The Government is committed to ensuring that all primary school teachers are able to teach all areas of science and mathematics as well as they can teach other subjects. New standards and requirements for initial teacher training were published in January 2002. These define the skills and knowledge that new teachers are expected to have upon completing their initial teacher training, and allow flexibility to tailor training to meet individual trainees' needs. They specify that all primary trainees must be trained to teach science and mathematics so that they can effectively deliver the National Curriculum in these subjects.

Through the accompanying guidance handbook the Government will focus the attention of teacher training providers on ensuring that all primary teachers are trained and able to teach all areas of science and mathematics to a high standard. The Government will also continue to review the content and standards of initial teacher training and the effectiveness of different routes into teaching.

Through the Learning and Teaching strategy, and in particular through the National Centre for Excellence in Science Teaching (referred to in the response to recommendation 2.6), the Government will also ensure that all those existing primary school teachers who need to do so can, and are encouraged to, improve their understanding and teaching of science.

The Government is also committed to further improving primary teachers' mathematics subject knowledge. Around 40,000 teachers have already attended a National Numeracy Strategy five day intensive mathematics course and by next April the number attending will have risen to around 60,000. This year the Government is also funding training for all mathematics coordinators and leading mathematics teachers.

Recommendation 2.4: Secondary school science teachers' training

The Review recommends that in order to enhance the quality of teaching across the sciences – and in the physical sciences in particular – the Government should act to improve significantly the subject-specific training and support given to science trainee teachers on initial teacher training and other teacher entry programmes. Furthermore, the Government should review, in three years' time, the progress in improving secondary school teachers' confidence in teaching all areas of the science curriculum, and take further action as necessary.

The Review also recommends that in recruiting science graduates the Government should pay more attention to their areas of specialism (*e.g.* physics, chemistry or biology) in order to ensure an adequate supply of teachers able to teach the individual sciences (particularly physics and chemistry) at higher levels.

Currently, where a student's degree does not cover the spectrum of knowledge required to teach a particular subject, a scheme called Pre and In Course Study (PICS) is available to help bridge the gap.

In order to ensure that the aims of Review's recommendation are met, the Government will make it a clear expectation that all science trainee teachers should undertake science-specific training to provide them with a good knowledge base to teach all areas of science up to the end of Key Stage 4. (Although trainees would not be required to undertake this training if they can demonstrate that their recent education has provided them with a sufficient spectrum of knowledge.) In developing this, the Government will draw upon an evaluation of the PICS scheme by the Teacher Training Agency.

The Government will also develop explicit targets for the numbers of teachers needed to teach different areas of science post-16, and will use these targets to influence its strategy for recruiting to initial teacher training.

Recommendation 2.5: Teachers' remuneration

The Review recommends that, to solve the serious shortages in mathematics, science, ICT and D&T teachers, more must be done to address the pay and other incentives offered to teachers in these subjects. The Government, schools and colleges must compete for graduates in these disciplines in the labour market by, amongst other measures, providing more attractive remuneration for teachers in these subjects to better enable schools to attract graduates who can earn higher salaries in other sectors of the economy. This will require head teachers and governing bodies to pay teachers in shortage subjects more than other teachers, which is the economically efficient response to specific shortage in supply.

The Review therefore recommends that the Government tackle such recruitment and retention problems through increasing the remuneration offered to teachers of these shortage subjects – and also that head teachers and governing bodies use all the pay flexibility at their disposal. Furthermore, the Review recommends that this additional pay be linked – wherever possible – to teachers’ take-up of CPD activities and opportunities, thereby rewarding those teachers who make particular efforts to further improve their subject knowledge and teaching style.

Teachers’ pay in England and Wales is based on recommendations made by the independent School Teachers’ Review Body (STRB). The settlement for 2002–03 gives all teachers a 3.5% increase and a radically shortened main pay scale, which will help to improve the attractiveness of teaching as a profession.

Nevertheless, the Government accepts that an employment market operates, and that teachers of shortage subjects have higher value in that market than other teachers. The Government acknowledges the difficulty that this brings in recruiting the required numbers of science and mathematics graduates to teaching. That is why the Government has introduced a range of measures, including golden hellos, differentiated training grants and paying-off teachers’ student loans over a period of time. The Government has also put in place scope for local pay flexibility to address particular recruitment and retention issues, including recruitment and retention allowances of up to £5,262 pa, and management allowances, which recognise particular responsibilities, of up to £10,275 pa. Schools may also help with housing, travel and relocation costs.

These and other measures (such as tackling workload) to improve teaching as a profession have had an effect. For example, vacancy rates are falling and recruitment to ITT courses in 2001/02 was up by 20% in mathematics; 8% in science; and 15% in technology.

Although these measures have begun to have a positive effect, difficulties remain. Over the Spending Review period, the Government is determined to enhance pupils’ science, mathematics and technology education by improving prospects for the recruitment and retention of science and mathematics teachers, including through paying more to good science and mathematics teachers. Therefore, the Government will consider further targeted incentives, building on student loan write-offs and the flexibilities already available to schools, and will be asking the School Teachers’ Review Body to consider how the teachers’ pay and conditions system might be adapted over the Spending Review period to enable schools to offer more targeted incentive packages to tackle problems with the recruitment and retention of science and mathematics teachers. Further details will be announced later this year.

The Government will also work with the Teacher Training Agency to publicise the profession in a positive way and to highlight the various measures that are in place to stimulate recruitment. Recruitment marketing is already integrated under the *“Those who can, teach”* campaign, which has attracted great interest and which seeks to raise awareness of improvements to the profession, in areas of pay, training bursaries, golden hellos and the proposed scheme to pay off student loans. This scheme, to repay the student loans of new teachers in shortage subjects will be at the core of a major publicity initiative this autumn.

Recommendation 2.6: Secondary school teachers' Continuing Professional Development (CPD)

The Review recommends that the Government improve science teachers' access to, and take up of, subject related CPD, which will benefit their teaching and also act to improve retention. In particular, the Review recommends that all science teachers be incentivised to undertake CPD, and that the range of recognised CPD activities be as broad as possible. For example, it should include the possibility of participating in scientific research carried out in industry and universities. The Review welcomes the Government's commitment to a National Centre for Excellence in Science Teaching. It also notes the interest of the Wellcome Trust and hopes that the Government and the Trust can form the sort of partnership that has been so fruitful in other areas of science policy.

The Government welcomes the Review's support for the idea of a National Centre for Excellence in Science Teaching. The Government consulted widely with all interested parties earlier this year and following a positive response to the consultation is now in a position to set out the design of the National Centre.

The Wellcome Trust is a strong advocate of a National Centre for Excellence in Science Teaching and the Government is delighted that the Trust has agreed to enter a partnership to deliver the concept of a National Centre. The Centre will consist of one National Centre and up to 10 regional centres, connected to each other, and to teachers in schools, by a virtual network. It will be funded jointly between the Government and the Wellcome Trust, with the Trust providing up to £25m. The Government and the Wellcome Trust are currently developing detailed specifications for the centre, and further information will be made available later in the year. The Government is keen to involve the Association for Science Education and the Astra Zeneca Teaching Trust Science Forum (which brings together leading employers, academics and school education professionals) in the running of the centre.

When it is up and running in 2004 the Centre will drive the quality, accessibility and relevance of Continuing Professional Development for teachers. It will offer a range of experiences to teachers, including short residential, day or half-day CPD opportunities, together with support, advice and web-based resources. The Government will ensure that teachers and schools are encouraged to make use of the Centre through subsidising participants' travel costs, as well as the costs of supply teacher cover.

The National Centre for Excellence in Science Teaching will complement the national strategy for continuing professional development launched in March 2001. The national strategy is designed to give all teachers greatly increased opportunities for relevant, focused, effective professional development, and to place professional development at the heart of school improvement. It complements specific policy initiatives, such as early professional development pilots, best practice scholarships and science specialist schools.

Recommendation 2.7: School laboratories

School science and D&T laboratories are a vital part of students' learning experiences in these subjects, and should play an important role in encouraging students to study these subjects at higher levels. However, it is clear that for many pupils this is not the case. To address this, the Review recommends that the Government and Local Education Authorities prioritise school science and D&T laboratories, and ensure that investment is made available to bring all such laboratories up to a satisfactory standard (as measured by OFSTED) by 2005. Furthermore, the Review recommends that these laboratories should be brought up to a good or excellent standard (again, as measured by OFSTED) by 2010; a standard which is representative of the world of science and technology today and will help to inspire and motivate students to study these subjects further. The Government should take all appropriate steps to ensure that these targets are met.

The Government agrees that well-equipped, modern laboratories are critical to pupils' learning experiences. For this reason the Government has already set aside £60 million specifically for school laboratories over the last two years, in addition to the significant increase in capital expenditure in schools since 1997. And in this year's capital funding guidance, school science and design and technology accommodation is highlighted as a priority for Local Education Authorities.

In this Spending Review, therefore, the Government will provide funds within the overall increase of over £1 billion for capital investment in education to improve significantly the quality of school science and technology laboratories and equipment. The Government will also prioritise investment in school laboratories from all sources of capital funding, and will include progress on improving the quality of science laboratories in its appraisal of local education authorities' Asset Management Plans. The Government's aim is to meet the initial modernisation target set in the Roberts report by the end of the Spending Review period, and to be on track to meet the 2010 modernisation target set in the report.

Recommendation 2.8: Teaching assistants

The Review is convinced that the high pupil-to-staff ratios in schools in England – particularly in practical classes – is having an adverse effect on the quality of pupils’ science and D&T education, and in turn on the supply of science and engineering skills. The Review believes these high pupil-to-staff ratios in practical classes are best addressed through the employment of skilled teaching assistants acting to support the teacher, and that science and engineering undergraduates and postgraduates are well placed to support teachers in this way, since they have a good recent understanding not only of the subject but also of the school environment. They can also provide important role models for pupils.

The Review therefore recommends that the Government establish a major new programme, paying undergraduate and postgraduate students to support science and D&T teachers. The scheme should be implemented alongside the Researchers in Residence scheme, and should be open to postgraduates as well as undergraduates. The Government should pay students on a competitive footing with other sources of employment open to them. The Government should set an ambitious target for the number of science and engineering students participating in such a scheme by 2005.

The precise role of the teaching assistants should be for schools, universities and the students to decide locally, on the basis of guidance from the Government. Examples of possible roles could be direct support to teachers in supervising practical work, giving demonstrations or supporting science and D&T technicians. Naturally, it will be important to ensure that those participating have the skills and training to work in these capacities.

The Government agrees that teaching assistants and support staff, including undergraduates and postgraduate students, can play an important role in supporting the teaching of design and technology and science, as well as other subjects in schools – particularly in practical classes where pupil-to-staff ratios are an important factor in pupils’ learning experiences.

To further improve schools’ ability to provide high-quality teaching in science, the Government is providing resources in the Spending Review to introduce a major programme that will pay science, mathematics, IT and engineering undergraduates and postgraduates to return to schools during their studies and support teachers in the classroom and laboratory, with appropriate support and training to equip them to be effective. This will operate as part of an initiative covering other subjects as well and will act to improve the support to teachers and pupils – particularly in practical classes – and provide pupils with excellent role models. The Government will build on the teacher associate scheme – which pays participants up to £40 a day – to deliver this programme. The Government’s aim is to ensure that, as quickly as possible, all secondary schools within easy reach of a university are covered by the programme. The Government will seek to work with the organisers of the Researchers in Residence Scheme, SETNET, the pilot Undergraduate Ambassadors Programme and the new initiative developed in collaboration with Imperial College and GlaxoSmithKline in taking forward this programme.

Recommendation 2.9: The science curriculum

The science curriculum – particularly in the physical sciences – is not, at present, sufficiently approachable nor appealing to all pupils between the ages of 11 and 16. This is a significant factor in the declining numbers of pupils taking these subjects at higher levels, and is widely thought to be a particularly important factor in discouraging girls.

The Review therefore welcomes both the QCA's ongoing work to modernise the science curriculum and the Government's Key Stage 3 strategy. These are important elements in making the study of science more attractive to pupils, and, in turn, helping to enthuse pupils to study science and related subjects at a higher level. The Review recommends that the Government ensure that these changes deliver significant improvements to the way that the sciences (particularly the physical sciences) are taught. In particular:

- improving the ability of all pupils to relate the science they study to the world around them and to potential career opportunities;
- encouraging appropriate links to be made with other subjects (particularly D&T);
- ensuring that, whilst pupils continue to study the fundamental principles of science, the curricula and assessments are not dominated unhealthily by reliance on the overall volume of scientific knowledge.

The Review notes that modernising the curriculum must go hand-in-hand with providing teachers with the necessary support and training to teach the new curriculum in a way that appeals to all pupils (especially girls).

The Review further recommends that the Government should review, in three years' time, the progress in improving the attractiveness and relevance of the mathematics and science curriculum, and take further action as necessary.

Finally, the Review welcomes the QCA's proposals for reforming GCSE science, which are a necessary and positive step in increasing the appeal of science to pupils. However, it will be important to support schools and colleges to deal with what is likely to be a more varied intake to A- and AS-level courses, and enable students to successfully make the transition to A- and AS-level science.

The Government welcomes the Review's support for its attempts to make the science curriculum relevant to the 21st century. The Government agrees with the Roberts Review that this will be crucial in increasing interest in the physical sciences, especially among girls and ethnic minorities, who are often under-represented in such subjects. The Government is piloting a new GCSE science programme and will review it in this context as soon as possible.

The QCA and the Government will also be considering the findings of the Young People's review of the Science Curriculum (a Science Year initiative conducted by the Science Museum). Some of the young people involved in the review presented their initial findings to the Government in April and also gave evidence to the House of Commons Science and Technology Committee.

The Government also recognises the need to support teachers in delivering these new developments in course design, and will draw on successful elements of the Key Stage 2 and 3 strategies in providing this support. The National Centre of Excellence will also have an important role to play in supporting teachers in introducing new teaching approaches.

Recommendation 2.10: Transition from GCSE to A-level

The Review welcomes the proactive approach of the QCA in considering the transition from GCSE science and mathematics to AS- and A-levels in these subjects. However, the consultation process revealed that the issue may not yet have been fully addressed and the Review therefore recommends that the Government give it further consideration, and take suitable action to allow pupils to make the transition from GCSE to AS- and A-level study – particular in the physical sciences and mathematics – smoothly.

The Government recognises that the transition from GCSE to AS- and A-level needs to be as smooth as possible. Improving this transition was one of the goals of the Curriculum 2000 reforms. As part of the summer 2003 review of the Curriculum 2000 reforms, the Government will ask the QCA to advise on how effective the recent changes to A-level science have been, and on whether further changes are needed to ease the transition.

In the case of the AS mathematics course, because there have been immediate problems, students will also be able to sit examinations in the autumn of their second year (in addition to the summer of their first year). This 're-phasing' will assist pupils in making the transition to AS mathematics. Additional funding is being made available for the extra teaching involved. In the meantime, re-sit opportunities are available for those who wish to improve their AS and subsequent A level results.

More generally, the Government believes there is a need to hold an inquiry into mathematics, focusing on the requirements of employers, professional bodies and education institutions at each key point of entry through education from age 14 to employment at all levels. The aim of the Review will be to ensure that the UK has a strong supply of young people with good mathematical skills and knowledge that meets the needs of employers and further and higher education. The Review will make recommendations to Government on changes to the curriculum, qualifications and pedagogy in schools, colleges and HEIs. It will include major employers with a particular demand for higher mathematical skills; members of a range of relevant professional institutions, educationalists in mathematics, engineering, physics and other related subjects, mathematics teachers in HE and schools and general educationalists.

Recommendation 2.11: Difficulty of subjects

The Review welcomes the attention that the QCA has given to the issue of inter-subject standards, and urges the Government to undertake definitive research into the greater apparent difficulty of science and mathematics A-levels and to take appropriate subsequent action. It is essential that pupils have a broadly equal chance to achieve high grades in science and mathematics as they would in other subjects. Without this, fewer pupils will choose to study science and mathematics at higher levels. The Review is firm that arguments about the merits of 'levelling up' or 'dumbing down' are a distraction – if pupils generally find it more difficult to achieve high marks in science and mathematics, this needs to be corrected. The Review believes that this can and should be done without compromising the core knowledge and skills needed for studying science and engineering courses in higher education.

Comparing inter-subject standards is extremely difficult as true comparisons can only be made between subjects that assess similar skills (for example, any two science subjects). Studies, such as the ALIS work referred to by the Review, are available, although none is without problems. (For example, the ALIS system has been criticised for adopting an over simplistic approach.) Nevertheless, the Government and the QCA accept the conclusion of the review and will investigate the issue as part of the review of Curriculum 2000 next year. As before, necessary changes could then be made in 2004.

More immediately, the QCA will report to Ministers the outcomes of their review of post-16 mathematics later this year, which may also have a bearing on this issue.

Recommendation 2.12: Enhancing the curriculum

The profusion of independent schemes aimed at enthusing and educating pupils in science and engineering (for example, the Industrial Trust Scheme and CREST), and the lack of support that schools and teachers have in identifying those most suited to their pupils, is inhibiting the collective effect of these schemes. The Review therefore recommends that the Government establish a single recognised channel through which schools access these independently-provided schemes. This will help schools and teachers to identify the schemes most suited to pupils at different ages in different subjects, thereby lowering the burden on teachers. Without better co-ordination (and rationalisation) of the existing schemes, important opportunities and resources will continue to be wasted.

The Review recommends that SETNET and its network of SETPoints, be given this responsibility in the areas of science technology, engineering and mathematics, while still recognising the wider role of the Education Business Links Consortia in England. However, if SETNET is to fulfil this function (and deserve the additional funding that this Review recommends the Government provide), it is important that it emphasises all areas of science and engineering equally, and also that those in the science, engineering, IT, technology and mathematics communities (particularly the scientific community) accept SETNET as the channel of communication. SETNET should work with the proposed idea of a National Centre for Excellence in Science Teaching in delivering this.

The Government agrees on the value of a single recognised channel for the delivery of independent and government schemes, awards and competitions aimed at enthusing and educating pupils in Science, Technology, Engineering and Mathematics. The Government will therefore, through significantly increasing its support for SETNET, ensure that SETNET works with the Education Business Links Consortia in England to be this channel. In particular, SETNET will need to extend its outreach into schools and act to improve and rationalise the number of schemes, awards and competitions. The Government will also take steps to ensure that SETNET works more closely with the scientific and mathematical communities, as well as the engineering and technology communities. The Science and Engineering Ambassadors Programme, coordinated by SETNET, will play an important role in all these improvements. Work will also continue on ensuring SETNET has clear measures of success and on the evaluation of the existing network to identify and disseminate best practice.

Recommendation 2.13: Improving the perception of careers

The Review believes that further action is needed from the Government, but also from businesses and others in scientific and technical fields, to ensure that pupils (especially girls) receive accurate and positive advice about the rewards (and the breadth of careers arising) from studying science and engineering. Specifically, the Review recommends that the Government establish a small central team of advisors (possibly within the new Connexions service, but working closely with SETNET) to support existing advisers, teachers and parents in advising pupils. Furthermore, the Government should review, in three years' time, the progress in improving pupils' knowledge of the rewards and the breadth of careers arising from studying science and engineering, and take further action as necessary.

in science and engineering

The Government notes the Review's conclusion that more should be done to improve the quality of advice offered on the opportunities arising from the study of science and engineering related courses. As recommended by the Review the Government will establish a team that can help Connexions personal advisers and teachers in offering such careers advice. In doing so, the Government will look to draw upon the expertise of those in the scientific, engineering, technological and mathematical communities. The Government will consult with Sector Skills Councils and the Connexions Service National Unit to establish whether this team is best based within the Connexions service or whether it is best placed in the relevant Sector Skills Councils but closely linked to the Connexions service advisers.

Recommendation 3.1: Quality of SET A-level students as degree-level entrants

Students sometimes struggle to make the transition from A-level study to degree level study in science, engineering and mathematics, since undergraduate courses often do not pick up where the students' A-level courses ended. Furthermore, the increasing modularisation of A-level courses has led to students entering higher education with wider variation in subject knowledge (differences in the mathematical knowledge of students are seen to cause particular problems in mathematics, physical science and engineering degrees). The Review recommends that to help students – particularly those in the past least likely to participate in higher education – make the transition from A-level study to degree level study in science, engineering and mathematics:

- A-level awarding bodies and the HE sector should review science, engineering and (in particular) mathematics education at the boundary between school / further education and higher education, and adjust their courses accordingly to ensure that this transition can be made smoothly; and
- the Government should fund HEIs to use new 'entry support courses' and e-learning programmes to 'bridge' any gaps between students' A-level courses and their degree courses.

Furthermore, the Government should in three years' time review progress in reducing the gaps between A-level and degree-level courses – to ensure that students are not discouraged from studying these subjects, and retain interest in them – and take action as necessary.

The Government is keen to ensure that progression between stages of education and training is as seamless as possible. The move from post-16 education to higher education is a key step, and the Review has identified an important issue around A levels and degrees. This was also a consideration in the recent consultation document "14–19: extending opportunities, raising standards".

Responsibility for designing and delivering degree courses lies of course with HEIs, and it is ultimately for individual institutions to make sure that they teach students what they need to know in order to progress in science, engineering and mathematics courses.

This is sometimes a challenge for institutions. On some courses students can have quite a range of previous experience in maths and science – some with relevant A levels, some with access course experience, some with GCSE level maths. Many non-traditional students in particular need extra support in technical skills. Institutions already put a good deal of effort into supporting new students, bringing them up to speed, and providing on-going specialist support with important underpinning skills like maths.

Responsibility for designing and delivering courses lies with institutions and it is ultimately for them to make sure that they teach students what they need to know in order to progress in science, engineering and mathematics courses. The Roberts Review identified though that the variation in the prior knowledge and skills of students can be a challenge to institutions in delivering science and engineering degrees in particular. Mathematics skills can be a particular issue and, as mentioned

earlier, the Government is launching an inquiry into post-14 mathematics. Furthermore, in order to improve the transition into science and engineering at HE the Government will work with the HE sector to pilot and evaluate different approaches to bridging the gap between students' prior knowledge and the requirements of higher education study.

The Government will keep under review students' progress between A-level and degree courses.

Recommendation 3.2: Undergraduate course structure

Updating the nature and content of undergraduate courses to reflect the latest developments in science and engineering (through having lecturers who can draw on recent experience of work environments other than HEIs, and through explicit changes in course content) has the benefit of improving the attractiveness and relevance of the course to both students and employers. Accordingly, the Review recommends that employers and HEIs work closer together, for example, through:

- increasing the number of industrial placements offered to academic staff;
- encouraging industrialists to spend time in universities;
- encouraging greater engagement between businesses and careers services and, in turn, between careers services and science and engineering departments; and
- encouraging universities to be more innovative in course design in science and engineering.

These actions by HEIs and employers must be supported by those bodies that accredit science and engineering courses – for example, the Engineering and Technology Board and professional bodies which are members of the Science Council – who must work with universities to drive forward innovation in course design, and not allow the accrediting processes inadvertently to inhibit it. The Government should facilitate these types of HEI / employer interactions through 'third stream' funding such as the Higher Education Innovation Fund (HEIF). Furthermore, the Government should in three years' time review progress in this area and take action as necessary to further improve HEI / employer interactions.

The Government agrees that interactions of this sort are important elements to providing innovative courses that appeal to students and educate and train them in knowledge and skills relevant to business. This type of interaction should be encouraged through teaching funding and the permanent 'third stream' of funding. To address the Review's recommendations the Government will further promote this type of activity further through the guidance notes issued to HEIs in respect of 'third stream' and other funding.

The Government will keep progress in 'third stream' activities under review, taking into account both the views of employers, through its group of R&D employers (see Recommendation 6.2), and the views of HEIs.

The Government is working in partnership with key stakeholders to develop vocational education aimed at better preparing students for work, and discusses these issues with employers, employer bodies and the higher education sector. Follow-up work to the Harris review report 'Developing Modern Higher Education Careers Services' (January 2001) will prompt institutions and careers services to consider greater engagement between businesses and careers services and careers services and academic departments.

The Government has also actively involved employers in working in partnership with HE institutions in the design of foundation degrees. The qualification also involves work-based learning, thereby involving employers in the delivery. Foundation degrees have been designed specifically to ensure that students develop the combination of technical skills, academic knowledge and transferable skills that are needed in the labour market. Science and engineering occupations are well represented amongst the first courses to come on stream. The Government is looking now to generate growth in both the number of courses and students to meet current and projected skills shortages at the associate professional and higher technical level.

Recommendation 3.3: University teaching laboratories

The Review recommends that the Government should introduce a major new stream of additional capital expenditure to tackle the backlog in the equipping and refurbishment of university teaching laboratories. The priority should be to ensure the availability of up-to-date equipment and that then, by 2010, all science and engineering laboratories should be classed as at a good standard or better, as measured by HEFCE. In delivering this recommendation, the Review believes it is important that the teaching infrastructure capital stream complements existing research infrastructure funding to facilitate the building, refurbishment or equipping of joint research and teaching facilities, where appropriate.

The Government agrees with the aim of the Roberts report that by 2010 all university science and engineering teaching laboratories should be of a good standard or better (as measured by HEFCE). Resources to start to improve laboratories and move towards this target are included within the overall increase of capital funding for higher education.

This teaching laboratory capital stream will be closely linked with parallel funding for research capital, with flexibility built in to enable institutions to manage them sensibly together. Institutions will be able to vire between the two streams without limit so long as the original balance is recovered over time.

Recommendation 3.4: Recurrent funding for teaching

In order to ensure that in future higher education institutions can and do invest properly in science and engineering teaching laboratories, the Review recommends that HEFCE should formally review, and revise appropriately, the subject teaching premia for science and engineering subjects. The revisions should ensure that the funding of undergraduate study accurately reflects the costs – including paying the market rate for staff, as well as the capital costs – involved in teaching science and engineering subjects.

As recommended by the Roberts Review, HEFCE is examining the detailed funding formulae for teaching different subjects. Through this review the Government and HEFCE can ensure that in the longer term, teaching funding for different subjects accurately reflects the costs involved in modernising their teaching environments (for example, science and engineering teaching laboratories) in line with technological progress. The Human Resources strategies and associated funding provide a mechanism for institutions to recruit and retain teaching staff in competitive markets, but HEFCE will also consider whether and, if so, how, the teaching funding for different subjects should reflect differing recruitment and retention costs.

Recommendation 3.5: Undergraduate student funding

Whilst student debt does not appear to be deterring potential students from undergraduate education, at the margin some undergraduates may be deterred from science and engineering courses, as they involve longer hours than other courses and as a result students find it more difficult to supplement their income by working part-time. In order for this not to deter the most disadvantaged students from studying science and engineering (and other courses with long 'contact hours'), and to assist with widening participation, the Review recommends that the Government (through its guidance to HEIs) should ensure that the Access Funds and Hardship Funds adequately provide for students on courses involving a high number of contact hours. The Review recommends that additional funding should be provided to accommodate this, and that HEFCE monitor the targeting of this additional funding to ensure it reaches those most in need.

The Review also recommends that the Government closely monitor the impact that an additional year of student debt has on students' choices of course, to ensure that the student funding system at undergraduate level is not discouraging students from studying (the longer) physical science and engineering courses.

Access and hardship funds can be important in helping to retain students in higher education when they encounter financial difficulties. Distribution of the funds is a matter for institutions, but Government does provide guidance on how these funds should be used. Following this recommendation, Government will ensure that this guidance recommends that institutions take account of contact hours in considering how to make these funds available.

The Government will also continue to monitor closely the effect of the student funding system on choices between courses.

Recommendation 3.6: University careers advisory services

The Review welcomes the recommendations of the Harris report on improving university careers advisory services. It is important that science and engineering students have accurate, up-to-date careers advice on the rewards and range of opportunities available to them (particularly opportunities in research and development). In particular, the Review endorses the recommendations in his report aimed at improving the links between careers advisory services and businesses, particularly small businesses, which will require action by both HEIs and by businesses.

The Government welcomes the support of the Review for improving the effectiveness of university careers advisory services. The majority of the recommendations of the Harris report were for institutions and other bodies and it is for them to take forward. A number of recommendations were addressed to the sector as a whole, and these have been taken forward by a group representing the sector convened by Universities UK, the Standing Conference of Principals, and the Quality Assurance Agency. The results of their work will be available this autumn. A snapshot survey of progress within institutions has recently been undertaken, and this shows that, generally, good progress has been made although more work could still be done in specific areas.

Recommendation 4.1: PhD Stipends

In order to recruit the best students to PhD courses, it is vital that PhD stipends keep pace with graduates' salary expectations, particularly given the increasing importance of student debt on graduates' career choices. It is also important that stipends better reflect the relative supply of, and market demand for, graduates in different disciplines. The Review therefore recommends that the Government and the Research Councils raise the average stipend paid to the students they fund over time to the tax-free equivalent of the average graduate starting salary (currently equivalent to just over £12,000), with variations in PhDs stipends to encourage recruitment in subjects where this is a problem. Furthermore, the Review recommends that a *minimum* PhD stipend of £10,000 is established, to ensure that HEIs do not use this extra flexibility to attract extra PhD students at the expense of quality.

The Government has already announced significant increases in Research Council PhD stipends for the 2002/03 and 2003/04 academic years. However, the Government accepts the Review's recommendation and appreciates the importance of PhD stipends reflecting the supply of and demand for graduates in different disciplines. In the Spending Review the Government will therefore fund the Research Councils to increase their minimum stipend to £12,000 by 2005-06. The Government will also provide additional funding to ensure that stipends in areas of recruitment difficulty can rise significantly beyond the minimum. Through this additional funding the Government expects the average PhD stipend for Research Council students to exceed £13,000 by 2005/06. The funding provided is consistent with maintaining the current numbers of Research Council PhD students.

Recommendation 4.2: PhD training elements

Despite the welcome current moves by the Funding Councils to improve the quality of PhD training, institutions are not adapting quickly enough to the needs of industry or the expectations of potential students. The Review therefore believes that the training elements of a PhD – particularly training in transferable skills – need to be strengthened considerably. In particular, the Review recommends that HEFCE and the Research Councils, as major funders of PhD students, should make all funding related to PhD students conditional on students' training meeting stringent minimum standards. These minimum standards should include the provision of at least two weeks' dedicated training a year, principally in transferable skills, for which additional funding should be provided and over which the student should be given some control. There should be no requirement on the student to choose training at their host institution. The minimum standards should also include the requirement that HEIs – and other organisations in which PhD students work – reward good supervision of PhD students, and ensure that these principles are reflected in their human resources strategies and staff appraisal processes.

Furthermore, in order to assure employers of the quality of PhD students, as part of these standards the Review recommends that institutions should introduce or tighten their procedures for the transfer of students to the PhD. In particular, the Review believes that HEIs must encourage PhD projects that test or develop the creativity prized by employers.

The Government agrees that there needs to be a new impetus to improve standards of PhD training. To encourage universities to address the skills acquired by PhD students, and to ensure they are relevant to business, the Government expects all universities to meet high quality minimum training standards on their PhD programmes, and agrees that all funding from HEFCE and the Research Councils in respect of PhD students should be made conditional on meeting these standards. The Government has also provided additional funding to the Research Councils in the Spending Review to enable enhanced training for their students, as recommended in the Roberts Report.

Recommendation 4.3: Length and nature of PhD programmes

The Review believes that measures should be put in place to help nurture a diverse range of PhD programmes to train able students in research methods and technical skills, and help them acquire the advanced knowledge and transferable skills they will need in their future careers. This should include encouraging part-time working and the gaining of experience in business R&D. Individual institutions should be given flexibility to offer a range of provision. The Review therefore recommends that:

- the Government and the Research Councils should fund their present numbers of PhD students on the basis that the average full-time student requires funding for 3½ years;
- it should be possible for the institution to use the funding flexibly to run three and four year full-time programmes (and also study of intermediate length) to support longer and more challenging projects, advanced courses and transferable skills training;
- both three- and four-year courses should be examined to the same standards, which should be at least as high as the current standards; and
- students should be able to exit early from PhDs (subject to satisfactory performance) with an MRes or an MPhil.

The Review believes that the EPSRC's doctoral training grants system represents a good way of achieving this flexibility, and urges other Research Councils to implement similar mechanisms.

The Government accepts that it is necessary to provide the flexibility to permit a longer time for PhDs, in order to further enhance students' transferable and technical skills. Funding will therefore be provided to extend the average length of funding for Research Council students to 3½ years. RCUK will consult later this year on detailed implementation issues, including the issue of any additional costs incurred by universities. The Government will also encourage the Research Councils, Funding Councils, HEIs and employers, to continue to work together so that, where appropriate, frameworks are in place to aid flexibility.

Recommendation 4.4: EU PhD students

The Review would welcome the extension of PhD maintenance awards to EU students by the Research Councils as a means of maintaining and improving the quality of research in the UK. The effect of this on the number and quality of UK PhD students should be closely monitored in order to ensure sufficient supply of PhD holders for the needs of the UK economy.

The Government agrees that UK universities need to attract sufficient high-quality PhD students and understands the reasons behind this recommendation. The Government is working with partners to explore how best to achieve this objective. A further announcement will be made in the autumn.

Recommendation 5.1: Academic Fellowships

The Review believes that there should be a clearer path for those who have completed PhDs into academic lectureships. This should be achieved through creating Fellowships that allow those involved to move from principally research-based work towards the role of lecturer, with an added role of reach-out to schools (for example, becoming a Science and Engineering Ambassador) and helping to widen access to Higher Education. The Review therefore recommends that the Government provide funds to establish a significant number (the Review believes 200 a year) of prestigious academic Fellowships to be administered by the Research Councils. The Fellowships should last for five years and should be designed to prepare people explicitly for an academic career, to be distributed and awarded on the basis of academic excellence across the range of subjects considered in this Review. The Research Councils should work with the funders of similar schemes (for example, The Royal Society and the Wellcome Trust) in introducing these Fellowships.

The Government agrees and will therefore provide funds to create 1,000 new academic fellowships (200 a year, each lasting five years) to provide more stable and attractive routes into academia. The Government also agrees that those in these positions should be actively involved in reaching out to schools, thereby helping to widen access and enthuse the next generation of pupils about science and engineering.

These prestigious fellowships will be developed by the Research Councils, in collaboration with organisers of similar existing fellowships, such as the Wellcome Trust and The Royal Society. Further details will be announced later this year. Particular care will be taken to ensure that these Fellowships are accessible to women and under-represented ethnic minorities.

Recommendation 5.2: Industry secondments for postdoctoral researchers

The Review recommends that HEFCE and the Research Councils evaluate schemes such as the Research Assistants Industry Secondments run by the EPSRC as the basis for a wider mechanism for encouraging postdoctoral researchers into industrial careers, and as a mechanism for knowledge transfer.

The Government agrees and will therefore ask the Research Councils to consider how to meet the need for further mechanisms to encourage postdoctoral researchers into industrial careers. As the Review notes, this should also help to promote knowledge transfer.

Recommendation 5.3: A vision for postdoctoral researchers

It is important for postdoctoral researchers to be able to develop individual career paths, reflecting the different career destinations – Industrial, Academic and Research Associate – open to them, and that funding arrangements reflect the development of these career paths. The Review believes that enabling the individual to establish a clear career path, and a development plan to take them along it, is critical to improving the attractiveness of postdoctoral research. The Review therefore recommends that HEIs take responsibility for ensuring that all their postdoctoral researchers have a clear career development plan and have access to appropriate training opportunities – for example, of at least two weeks per year. The Review further recommends that all relevant funding from HEFCE and the Research Councils be made conditional on HEIs implementing these recommendations.

To address these issues the Government will provide funding in this Spending Review to improve the training opportunities available to postdoctoral researchers. The Government will provide additional funding to the Research Councils to deliver additional training for contract researchers and will work with RCUK and HEFCE to ensure that this is put into practice. The Government will ask HEFCE to make clear that support for postdoctoral researchers will be expected to feature in institutions' human resources strategies. This will help ensure that researchers are prepared for future careers in academic or industry.

Recommendation 5.4: Postdoctoral researchers' salaries

In addition to establishing clearer career progression, the Review recommends that the Research Councils should significantly increase salaries – particularly starting salaries – for the science and engineering postdoctoral researchers it funds, and sponsors of research in HEIs and PSREs should expect to follow suit. The Review considers that the starting salary for postdoctoral researchers should move in the near future to at least £20,000, and that further increases should be available to solve recruitment and retention problems in disciplines where there are shortages due to high market demand (for example, mathematics).

To meet this recommendation, the Government will fund the Research Councils in the Spending Review to increase their average postdoctoral salary by £4,000 by 2005-06. These increases will aim to ensure that post-doctoral research is an attractive option to recent PhD graduates. As with the PhD stipend, the Government believes that salaries should be varied to reflect labour market pressures.

Recommendation 5.5: Academic salaries

As with contract researchers, there is a need for universities to improve salaries – particularly starting salaries – for many scientists and engineers. The Review is clear that universities must use all the flexibility at their disposal to differentially increase salaries, especially for those engaged in research of international quality, where market conditions make it necessary for recruitment and retention purposes. The Government should assist by providing additional funding to permit universities to respond to market pressures. As a first step, the HEFCE funding currently dedicated to the human resources strategy should be made permanent. Further additional funding for recruitment and retention, which will vary between institutions, should initially be part of a separate stream linked to the existing human resources strategy fund and appropriately focussed towards research excellence. However, once more market-based systems have been embedded, the funds should be incorporated into core funding for research and also into revised subject teaching premia.

The Government recognises the importance of effective pay and human resources development in higher education. That is why £330m was made available over three years in the 2000 Spending Review for higher education pay, including recruitment and retention of high academic quality staff in strategically important disciplines. This funding was allocated by HEFCE to institutions, which were required to submit human resources strategies setting out how it would be used to achieve institutions' priorities.

The Government agrees with Sir Gareth's conclusion that more, permanent, funding is needed and will therefore allocate further funding in the 2002 Spending Review for pay increases targeted on the recruitment and retention of staff in disciplines (including, but not only, those in science and technology) where there is the greatest competition.

Recommendation 6.1: Attractiveness of careers in R&D

Responding to the challenge of improving the attractiveness of jobs in R&D to match or surpass all other opportunities open to the best science and engineering graduates and postgraduates is crucial to individual businesses' future success – since their R&D underpins their future products, services and, ultimately, their future sales and profits.

Through consultation with businesses and scientists and engineers themselves, the Review has identified a number of issues related to work in R&D that employers must address in order to be able to attract the best science and engineering graduates and postgraduates.

- **Initial pay.** Starting salaries are an increasingly important factor in students' career choices, in part due to the effect of student debt and students' increasing commercial awareness. The starting salaries and bonuses paid to scientists and engineers working in R&D are often not as high as they could receive in other sectors or occupations. While it may not be necessary to match the highest salaries paid elsewhere, the Review is clear that businesses will ultimately need to raise the salaries and other financial rewards they offer if they are to compete for the best scientists and engineers (particularly those with an entrepreneurial spark or good commercial awareness). This goes hand-in-hand with the need for businesses to look at R&D not as a cost, but as an investment in their future survival and growth.
- **Salary progression.** Similarly, retention in an increasingly mobile workforce relies upon salary progression that compares well with the other opportunities available. Evidence suggests that the salary progression for scientists and engineers in R&D does not compare favourably with that for their counterparts in other sectors.
- **Career Structure.** Science and engineering graduates and postgraduates can be put off entering R&D due to unattractive career structures – with short-term contracts, low levels of responsibility, few chances for progression within R&D and poor job design (e.g. jobs that do not use their skills to the full). It is clear from the Review's consultation that many employers can do more to improve the career structures of scientists and engineers, through addressing these and other influential factors.
- **Training and professional development.** Scientists and engineers working in research do so partly because of their interest in the subject, and it is therefore key that they can stay in touch with the latest developments in their field. Employers should do all they can to provide time and resources to allow them to do this, and partake in CPD activities, which will also bring benefits in terms of recruitment and retention. There is a role for the Government and for trades unions in helping to make sure that smaller businesses are able to provide sufficient training and CPD to research employees.
- **Recruitment mechanisms.** The Review believes that many R&D businesses must improve their recruitment mechanisms to compete better with other employers. For most R&D businesses, especially the smaller ones, increasing marketing efforts and taking opportunities to widen the number of students they make contact with should improve their ability to recruit the scientists and engineers they need. R&D businesses must also take responsibility for improving the perception of jobs in R&D.

The Review is clear that the response of R&D employers to these challenges is crucial in providing an adequate supply of scientists and engineers for R&D. Without improved and more attractive opportunities to work in R&D, the UK's best scientists and engineers will doubtless be tempted elsewhere, since the demand for their skills – and the rewards offered – will only grow over time.

The Government's responses to recommendations 6.1, 6.2 and 6.3 are grouped together at the end of these three recommendations.

Recommendation 6.2: The challenge to employers

The Review recommends that the Government should establish a group of R&D employers to support and monitor employers' responses to the challenge of improving the pay, career structures and working experiences for scientists and engineers in R&D. The group should include representatives from businesses (large, medium and small) and others that employ scientists and engineers in an R&D capacity.

The Review believes the group must act as a driving force in taking the recommendations in this report forward, and should publish a report, before the next public spending review, setting out the response of employers to the challenges identified by this Review. The group might also play a key role in considering cross-regional and national R&D skills needs, referred to in Recommendation 6.4.

The Government's responses to recommendations 6.1, 6.2 and 6.3 are grouped together at the end of these three recommendations.

Recommendation 6.3: Skills planning

It is clear that although many businesses may plan their R&D projects a number of years in advance, they often do not plan their skills needs for this research more than a year ahead. Although there are difficulties in detailed skills planning, the Review believes that R&D businesses must do more to establish what future science and engineering skills they will need for future research projects in order for them to be able to recruit the skilled scientists and engineers they need with less difficulty.

The Government agrees with the Review's conclusion that sustained action by employers is vital in securing a strong supply of highly skilled scientists and engineers who are keen to work in R&D. The specific areas identified by the Review are all important in providing attractive opportunities in R&D, particularly given the increasingly broad range of opportunities available to the best scientists and engineers. The Government can and will play a part through, for example, helping to disseminate best practice, but ultimately the challenge of improving conditions of employment is one that employers must rise to.

The Government agrees that an employers group could play an important role in improving the attractiveness of careers in R&D. Through working in partnership with the CBI and other employers organisations the Government will assist in ensuring that a group of R&D employers is established, as recommended.

Recommendation 6.4: Skills dialogue

The Review believes that the supply of skills to R&D businesses can be improved through more coherent skills dialogue between these businesses and universities. The Regional Development Agencies (RDAs) should take a leading role in the coordination of regional dialogue between businesses and HEIs through the new FRESAs (Frameworks for Regional Employment and Skills Action) to ensure that demand for higher level skills at a regional level can be met.

Furthermore, the Review recommends that the sector skills councils (which the Review believes, should be represented in FRESAs) work with the Learning and Skills Council, trade associations and other business groups to identify – based on the regional skills discussions – evolving supra-regional and national R&D-related skills needs.

The Government agrees that the coherence of the skills dialogue between R&D businesses and HEIs must be improved. It will, accordingly, ensure that RDAs, through FRESAs, undertake the action recommended by the Review.

The Government will also work with the employers group referred to in recommendation 6.2 and the sectors skills councils, FRESAs, employers groups and higher education organisation to ensure that national and supra-regional skills trends can be identified and responded to.

Recommendation 6.5: Business involvement in higher education

Although universities need to be proactive in ensuring that courses are as relevant to business as possible, the Review believes that businesses must become more actively involved in university course design. In particular, the Review recommends that employers' bodies – for example, the CBI and trade associations – and the Government work to encourage more R&D businesses to participate in providing work placements for SET graduates and postgraduates (for example, in sandwich year courses).

The Government agrees that the input of businesses and other employers into university course design is vital if the skills and knowledge of students is to be of most relevance to the employers. The Government is already working to promote this kind of partnership between HEIs and employers, and funding is available to HEIs to put in place arrangements to embed work-related skills in higher education, through HEFCE's Learning and Teaching Support Network.

The new foundation degrees promote this kind of partnership working between HE institutions and employers. The Government is however keen to ensure that all higher education delivers the skills and attributes that individuals need in the workplace and that employers require if their businesses are to grow. In November 2001, the Government announced that £1m is being made available to HEFCE over 2002-04 to put in place a Work-Related Skills Co-Ordination Team to work with established networks of subject specialists to spread and embed good practice in developing graduate employability.

The aim is to make work-related skills a feature of mainstream higher education provision. Employer involvement and establishing links between the subject networks and the relevant Sectors Skills Councils and professional bodies is an important part of that process. An Advisory Group is being established to oversee this work which will include employer representation. We are also considering arrangements for engaging with a wider range of employers to advise us on all aspects of higher education. R&D employers will feature in these arrangements.

Recommendation 6.6: Research collaboration between business and higher education

There are a number of Government sponsored schemes that act to encourage research collaboration between businesses and HEIs. However, the Review feels that the collective impact of these schemes is not as great as it should be. The Review therefore recommends that the Department of Trade and Industry, as part of its increased focus on innovation and skills, and more effective delivery of business support, should evaluate the success of existing initiatives in this area – in particular, paying attention to whether the training elements of these schemes are sufficiently supported and prioritised and the extent to which they play a strong role in employer-university communication and collaboration.

The Government is keen to improve research and development collaboration between businesses and HEIs and to improve the effectiveness of its existing policy measures in this area. Therefore, all parts of the Government that seek to encourage research collaboration between businesses and HEIs will evaluate the success of their initiatives in this area by 2003. Necessary changes will then be developed as soon as practical. The Department of Trade and Industry is considering this issue in taking forward its review of business support activities.

Recommendation 6.7: Innovation Partnerships for collaborative research

The Review recommends that the Government, while retaining successful initiatives, should develop stronger, more coherent and more substantial “Innovation Partnerships” to boost research collaboration between universities and businesses. The Review believes that these should incorporate the following principles:

- that the research be business-led and focussed on commercially-oriented R&D;
- that the partnerships be based on clusters of businesses with particular research interests, either nationally or regionally;
- that the Government invest in each partnership alongside the prime funders (business and higher education and RDAs);
- that each partnership could be virtual or could have a physical centre, depending on the nature of the research and the participants in the partnership; and
- that each partnership should have an explicit, core aim of prioritising skills training for SET students and graduates, building a critical mass of SET students and graduates with experience in commercial R&D, and encouraging the interchange of people and technology between business and academia.

The Government welcomes and agrees with the Review's principles for innovation partnerships, which are consistent with those that guide the existing Faraday Partnerships. The Government will therefore seek to develop activity in line with these principles. Further decisions on the nature and scale of these activities will depend on the outcome of the Department of Trade and Industry's ongoing review of business support activities.

Recommendation 6.8: Migration and work permits

The Review welcomes the Government's campaign to raise HEIs' and overseas students' awareness of the recent improvements to the work permits scheme. However, given the lack of knowledge of these changes shown by businesses during the course of its consultation the Review recommends that this campaign be extended to cover the business community, including smaller and medium sized businesses engaged in R&D. Through this, more UK businesses will be able to draw upon worldwide scientific expertise in driving forward their R&D.

To address this recommendation the Government will step up the provision of information about these changes. In particular, Work Permits UK will develop concise and tailored information for smaller employers, and will work with the Small Business Service and employers groups to target the advice towards those who might benefit. Work Permits UK will also consult employers and others on the merits of adding more fields of science and engineering to the list of areas of national skills shortage. This would further ease recruitment of scientists and engineers from abroad. Furthermore, the Government will take steps to improve awareness of the options and routes into employment available to foreign students in UK universities.

Final remarks (repeated from the executive summary)

The recommendations set out in this report, which represent challenges for the Government, for employers and for the education system, are designed to help secure a strong supply of people with science and engineering skills. The Review believes that implementing these recommendations will be a crucial element in achieving the Government's agenda for raising the R&D and innovation performance of the UK to match the world's best.

The Review is clear that progress towards the goals set out in the report must be reviewed regularly in order to ensure that the UK's R&D and innovation performance can grow as intended. In particular, the Review recommends that the Government should review progress on improving the supply of scientists and engineers, encompassing all the areas identified by this Review, in three years' time, and take any further necessary action to continue the process of improvement.

The Government agrees, and will review progress accordingly in three years.