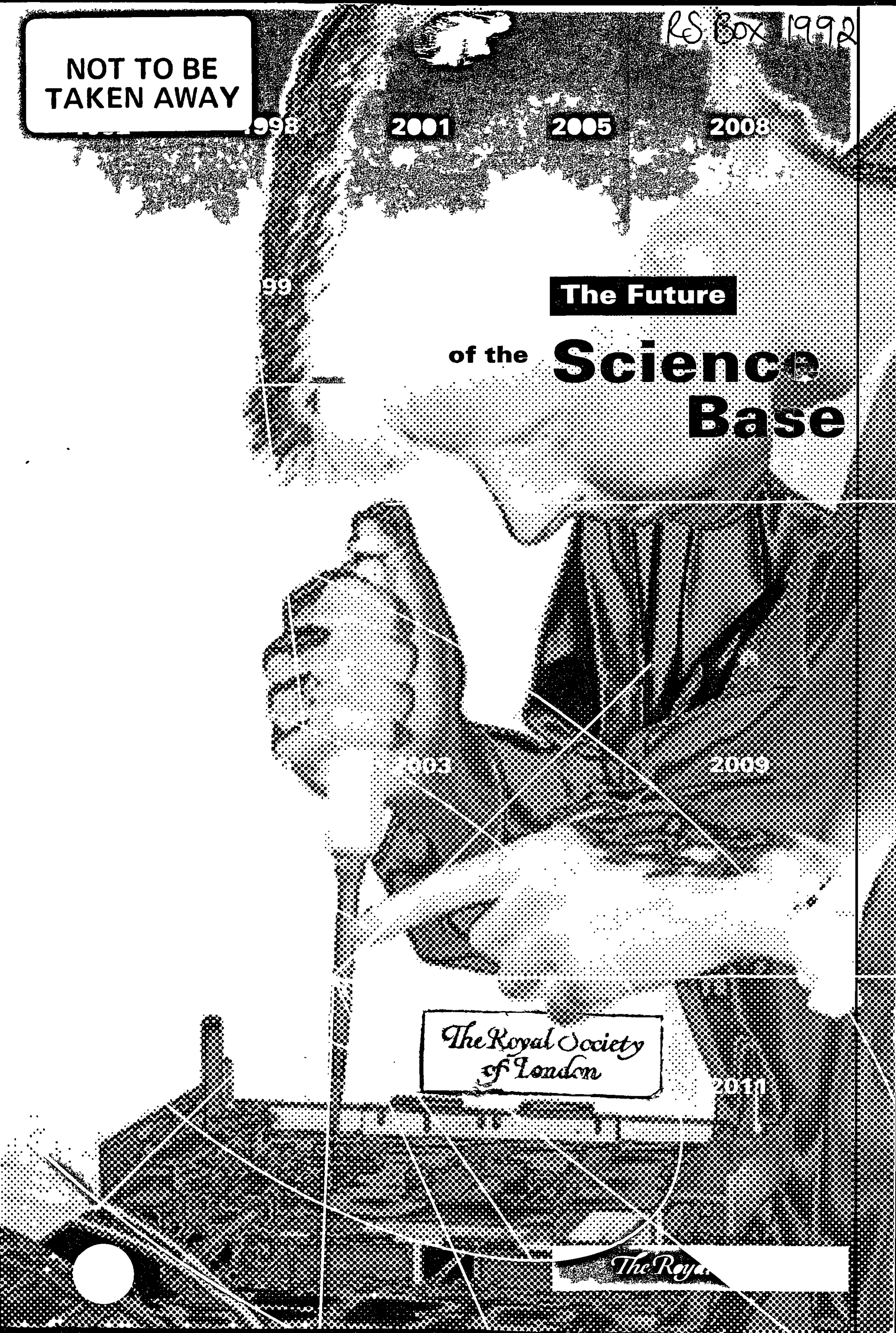
The Future of the Science Base



THE FUTURE OF THE SCIENCE BASE

September 1992

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FOREWORD

Over the past few years concern about the state of science in this country has been expressed in many quarters. Major changes have been taking place affecting all aspects of scientific training and research, with uncertain implications for the future. Given the vital role which science plays in modern life the Council of the Royal Society felt the time had come for an in-depth inquiry into "The Future of the Science Base".

The Science Inquiry started in January 1991 and has consulted widely. I would like to thank all those who, by contributing to its discussions, have ensured that the views and experience of the scientific community have been fully utilized.

"The Future of the Science Base" is published as a statement of the Council of the Royal Society. It analyses the current situation and puts forward ideas on how the vigour of the UK Science Base may be maintained and enhanced.

I hope that all who are concerned about science in this country will read and consider the report. The responsibility for action lies with many individuals, institutions and organizations: all have a part to play, and I hope that this report will act as a stimulus to all involved.

Sir Michael Atiyah
President
The Royal Society

ACKNOWLEDGEMENTS

An exercise of this sort depends on contributions from large numbers of people. Over 300 individuals and organizations went to often considerable lengths to respond to our request for evidence. Oral evidence was taken from the five Research Councils and a number of other organizations and individuals. Several bodies invited the Science Inquiry Steering Committee to visit them; in the end practical constraints restricted formal external visits to three—the Cambridge Institute of Animal Physiology and Genetics Research, Imperial Cancer Research Fund and ICI. These varied inputs both confirmed our sense of the timeliness of our undertaking and contributed greatly to our understanding of the issues. We are grateful to all who helped us in these ways. It is clear that the process of conducting this Inquiry has of itself served to stimulate long-term strategic thinking within the scientific community.

The work of preparing this report was entrusted by Council to the Science Inquiry Steering Committee; Council acknowledges gratefully the work put in by individual members of SISC.

CONTENTS

SUMMARY AND KEY RECOMMENDATIONS

1. Science is one of the principal forces structuring modern life. Its ethos, its thought processes, its practice and culture lie at the heart of our society.

2. In many fields, UK science is in the forefront of international research. Nonetheless, there are causes for concern and there is no room for complacency. In this report, drawing on widespread consultation, the Royal Society sets out practicable recommendations for maintaining and enhancing the excellence of the nation's Science Base over the next decade.

PEOPLE

3. The Science Base must attract sufficient people to allow enough with real aptitude for research to emerge by competition. The number that can be supported adequately is limited by what the country can afford.

4. Research students should be paid grants and/or salaries sufficient to enable them to concentrate on their research. It may sometimes be advantageous for career development to allow research students to take on significant amounts of properly rewarded teaching or administrative work. This may have the added benefit for the university of reducing the non-research workload of academics. Funding agencies may need to accept correspondingly longer PhD completion times.

5. Postgraduate training necessitates specialisation. Many research students, however, would benefit from more flexible and versatile training that included non science-specific elements such as communication skills and the management of human, material and financial resources.

6. Securing a career in Science Base research is a long and uncertain process, marked for most researchers by a series of short-term appointments. While individuals bear the prime responsibility for their own careers, employers too have a serious responsibility to advise their short-term staff about their long-term prospects. They should find ways of helping individuals unsuited to a continued career in scientific research, or seeking a non-academic career, to transfer to different employment.

7. Able researchers, identified after one or two short-term contracts, should be rewarded by long-term support. Salary and research expenses guaranteed for at least five years, coupled with rigorous review, would be appropriate. They should be allowed to carry their resources to any approved academic institution, thereby providing more genuine competition for resources, greater independence for individuals, giving abler scientists the chance to demonstrate their talents and secure long-term appointments, and making HEIs compete for good researchers.

8. A system of secure appointments is more likely to succeed in attracting proven independent researchers than a more mobile system of "rolling tenure". However, "permanent" academic appointments should be given at later stages, and through a more deliberate process of review than has typically been the case in British HEIs and some Research Council and other similar establishments. Holders of long-term appointments can benefit from being able to spread their efforts between research, teaching, administration and professional activities.

9. Progress in science depends on many differently skilled people. For many purposes the professional grade of 'Research Officer' can provide a valuable and satisfying career path. The

Research Officer, already present in certain institutions, is a competent postdoctoral scientist, though not a team leader. ROs and technicians (qualified to HNC/D or graduate level) should form a core group that is skilled, versatile and employed on a long-term basis. Continuity would depend on an appropriate ratio of core to independent researcher staff reflecting the research work being done. It would be proper to achieve some flexibility across the spectrum of posts.

EUROPEAN AND INTERNATIONAL ISSUES

10. The UK has a special relationship with other European countries through its membership of the European Community (EC). There are close economic, cultural and, increasingly, political relations between the EC Member States. Science is part of this growing convergence of ideas and purpose.

11. If the UK is to derive the maximum benefit from scientific collaboration in Europe, it will require a long-term strategy. Such a strategy must include the strengthening of UK representation in European fora both politically and scientifically. It must also include a constructive intermeshing of national and EC science policies over such matters as scale of funding, setting of priorities, mechanisms for funding and the means of achieving beneficial interactions between the Science Base and wealth-creating sectors.

12. The Treasury practice of attribution should be scrapped. It penalizes success in participating in EC initiatives. It also impedes the achievement of a proper balance between national and EC policies. A constructive financial approach towards the EC dimension in science policy would, by contrast, provide matching funds for EC-supported projects, so that Science Base institutions that competed successfully in EC schemes could avoid the penalty of inadequately covered overheads.

13. Some international collaborations are established by inter-governmental agreement. These cannot be amended or cancelled by the (non-political) managers of the Science Base. Nevertheless it is they who are required to provide the requisite funds. In such cases, the subscriptions should constitute a distinct, ear-marked element within the total package of Government expenditure on R&D.

14. No individual nation can support research in all areas. Europe as a whole should, however, maintain expertise in all disciplines, and to that end needs to turn to an independent, non-governmental European body to provide a strategic overview of European Science Base Research.

ORGANIZATION AND FUNDING

15. External funding demonstrates that the Science Base is of value to a variety of customers: we welcome it. But such funding is vulnerable to fluctuations in the economic situation. Science Base institutions must have a clear sense of long-term purpose so that externally funded research does not seriously distort their mission. External funds should not replace Government funds. Using public funds to lever private funds is more constructive than cutting public funds in the hope of coercing private funds.

16. One of the strengths of UK academic research is the dual support approach to funding (with the Universities Funding Council financing the research infrastructure and the Research Councils financing specific projects or programmes). The UFC (now

the various HEFCs) funds are crucial to the well- found laboratory and to the ability of individual researchers to pursue new ideas in their early stages. It is critical to the future of the Science Base that these funds should be distributed in a way, and on a scale, that allows individual universities to establish and maintain high quality departments able to compete for external funds as required.

17. The optimum balance between 'responsive' and 'directed' modes of funding will depend on circumstances, and neither category is clear cut. The objectives of the research are a key consideration: detailed priorities should not be formalized for basic research. There must be flexibility to accommodate unexpected opportunities. A significant proportion of Research Councils' funds should, therefore, be retained outside 'directed' programmes for distribution on purely scientific criteria in the responsive mode.

18. The Society believes that most fundamental research should be associated with teaching, particularly at the postgraduate level. We therefore welcome the continuation of the block grant system, by which the grant to universities can be used at their discretion for the joint support of teaching and research in the most economical and effective manner.

19. A major issue that has affected the future of science in the UK has been the nature and location of political responsibility. The appointment of the Chancellor of the Duchy of Lancaster, acting on behalf of the Prime Minister and assisted by the Chief Scientific Adviser, to take central responsibility within Government for science and technology policy, plus the creation of the Office of Science and Technology (OST), will resolve many of the shortcomings in previous arrangements.

20. The Chancellor's new responsibilities include, or could include, the following:

* representing the UK at EC Councils of Ministers of Science;
* coordinating UK R&D activities, particularly maintaining an adequate infrastructure and promoting new fields of applicable S & T;
* reviewing annually UK Government expenditure on R&D and advising the Cabinet on how to achieve best value for money;
* identifying trends for UK science, with particular reference to enlarged international activity.

21. As well as responsibility for the former DES Science Budget, the OST should have charge of a separately identifiable budget to meet:

* subscriptions to international facilities and programmes, established by intergovernmental agreement, where continued involvement needs to be viewed in a broader context than the functional responsibilities of any one Department/ Agency;
* activities transcending the responsibilities of individual Departments that nonetheless are, actually or potentially, vital components of the national R&D infrastructure;
* complementary funding for certain EC-supported research projects.

22. The new structures will need new advisory mechanisms. One key requirement is for a body able to advise the Chancellor, and (either through him or directly) the Prime Minister, on the S & T aspects of strategic issues of national importance, including particularly those affecting science-based industry. This body must be able to connect with all elements of UK S & T. It should focus its work primarily on the major strategic issues.

23. To complement this, consideration should be given to developing a single advisory mechanism that can address the full range of the OST's direct responsibilities for the nation's science and technology. This includes in particular the OST's financial responsibilities — the former DES Science Budget, additional monies voted to the OST (paragraph 21 above), and the OST's role in advising on the S & T expenditure of other Departments. This advice function must be demonstrably disinterested.

24. The OST should address the issues of:

* coordination between the Research Councils and the Higher Education Funding Councils;
* coordination between activities in the same or related disciplines;
* the balance of support at national level between expensive and less expensive fields of research; and between institutes, major facilities, research grants and research Fellowships;
* integration of Research Council central facilities with their customer communities (for example, establishing facilities as agencies deriving some or all of their income from fees paid by users).

25. A healthy Science Base is vital to the long-term well-being of the UK. The Society welcomes signs that the Government recognizes this, and urges all involved to work towards policies that will enable the Science Base to make a full contribution to national life.

I. INTRODUCTION

It has been perfectly evident, since the Great Exhibition of 1851, that the prosperity of these islands depends on industry and agriculture and that these stand on technology; technology stands on science and science stands on the education of the general population.
FRS–Crystallography

The need continually to reorganise the Science Base to try to make the best use of inadequate funds, combined with rapid switches in government objectives and priorities, has produced a decade of unprecedented upheaval and discontinuity in the institutional framework for managing and delivering research and development in the UK.
Institution of Professionals, Managers and Specialists

Why The Inquiry Was Carried Out

1.1 The last decade has been a turbulent one for the Science Base, with many far-reaching changes. Yet these changes seem often to have arisen piecemeal, the accidental outcome of policies implemented for other reasons. The rapid rate of change is likely to continue over the next decade.

1.2 At the outset we wish to emphasize that, in many fields, UK science is in the forefront of international research. There are however causes for concern and there is no room for complacency. Our aim must be to maintain and enhance scientific excellence over the next decade.

1.3 In this report, the Council of the Royal Society takes stock of the present situation and sets out its views on:

* the purposes of the Science Base;
* the form it should take over the next decade if it is to fulfil its national roles;
* the problems to be overcome in achieving that form;
* some possible solutions to those problems.

1.4 By the Science Base, we mean scientific and technological research within Higher Education Institutions (HEIs) and the various research institutes, facilities and other activities supported by the Research Councils, the Royal Society and the Royal Academy of Engineering. We include within our definition research carried out in Science Base bodies but funded by sources other than the former Department of Education and Science (DES) or its successors, including for example the medical research charities. We are not addressing the whole of UK civil R&D; expenditure in the Science Base as just defined constitutes only about one quarter of total UK expenditure on civil R&D, though it does constitute the majority of expenditure on the R portion.

1.5 Our audience is all who care about the long-term health of the Science Base: those who work in it, those who hope to work in it, those who look to it to provide particular services, those who carry political or managerial responsibility for it. We hope all will find something in this report to catalyse long-term thought and action.

How The Inquiry Was Carried Out

1.6 The Inquiry was launched early in 1991, with the appointment of the Science Inquiry Steering Committee

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(SISC) (for membership see Annex A). SISC met on ten occasions between January 1991 and May 1992. Its report was presented to the Council of the Royal Society in May and July 1992 and was adopted as a statement of Council.

1.7 The Inquiry began with an invitation to all Fellows of the Society and all holders of the Society's research appointments (including about 160 young University Research Fellows) to comment on a series of policy issues and to draw other issues to the Committee's attention. The Committee later contacted many organizations, and published several short articles in different journals, inviting evidence. Over three hundred individuals and organizations wrote to us (Annex B); their contributions provide a most valuable insight into the state of the UK Science Base in the first half of 1991 and into possible future directions. We are most grateful to those who went to often considerable lengths to respond to the Inquiry. The Committee took oral evidence from the five Research Councils and several other bodies (Annex C); again, we are most grateful to the individuals concerned.

POINTS RAISED IN EVIDENCE

1.8 The evidence we received ranged widely. The issues that were raised most frequently included:

* the pattern of careers in science
* morale
* funding mechanisms, notably responsive funding
* the structure of the Science Base
* the case for a Minister of Science
* total levels of funding
* European Community issues
* international aspects of research policy

STRUCTURE OF THE REPORT

1.9 In the light of the evidence received and of our own deliberations, we have structured our report around the following five key areas:

* the roles of the Science Base — in wealth creation, creation and dissemination of skills, enrichment of culture;
* people in the Science Base — the principles that should guide the management of scientific careers;
* science policy issues arising from the UK's membership of the European Community and, over the long term, the process of convergence towards a European identity;
* the structure and funding of the Science Base, including the representation of science at the highest levels of government;
* international issues.

The final chapter draws together the conclusions and recommendations developed earlier in the report.

At the head of each chapter are quotations selected to illustrate the opinions received from respondents to the Inquiry.

II. THE ROLE OF THE SCIENCE BASE

The Association is deeply concerned that the Government does not appear to appreciate the relationship between expenditure on Research and Development and the national economic performance. The successful performance of the pharmaceutical industry has long been based on this relationship. Unless the Government accepts that this relationship applies to all aspects of the Science Base it will not realise its economic objectives for the nation.
Association of British Pharmaceutical Industry

Scientific achievements, like artistic and sporting achievements, can contribute to the overall sense of well-being of the country. Money spent on them is an investment in the strength of the country, which can pay off indirectly in very different fields.
Smith Associates Limited

We view the UK Science Base as an educational resource, as a warehouse for scholarship, and as part of the international mainspring of scientific progress.
ICI plc

INTRODUCTION

2.1 Science is one of the principal forces structuring modern life. Its ethos, its thought-processes, its practice and culture lie at the heart of our society.

2.2 In this chapter we describe some of the roles of the Science Base that make it central to modern society. Although the roles are described below individually, they are strongly interdependent. National policy priorities may highlight different roles at different times, but to be effective in the long term the Science Base has to be able to accomplish the full set of roles and to accommodate the varying motivations of funders, performers and beneficiaries.

SCIENCE AS PURSUIT OF KNOWLEDGE

2.3 **The primary purpose of scientific research is the pursuit of knowledge in its own right, in the well-founded expectation that knowledge brings rewards.** It is not necessary to define the rewards in advance in order to give value to this pursuit of knowledge. A desire for knowledge is fundamental to human existence. The idealism inherent in this view is one underlying stimulus for the individual scientist.

2.4 The scientific enterprise is based on the assumption that knowledge of the material world can be gained by a process of rational thought based on experimental and observational evidence. An important cultural function of science is to emphasize the legitimacy and value of this route to knowledge.

2.5 A key feature of science as pursuit of knowledge is that its outcome is unpredictable and full of surprises. The management of creative scientists must recognize this.

WEALTH CREATION

2.6 **Science is central to wealth creation in an advanced industrial nation.** In her September 1988 speech to the Royal Society, the then Prime Minister endorsed the wealth creation role of the Science Base:

"Science and the pursuit of knowledge are given high priority by successful countries,

not because they are a luxury which the prosperous can afford; but because experience has taught us that knowledge and its effective use are vital to national prosperity and international standing ... This country will be judged by its contribution to knowledge and its capacity to turn that knowledge to advantage".

THE ROLE OF THE SCIENCE BASE

2.7 Major sectors of British industry depend upon science to maintain their position in an increasingly competitive world market. In 1989 UK industry spent nearly £5Bn of its own funds on civil R&D.

2.8 Industry's own R&D effort is closely tied with the Science Base at several points. During the 1980s, funding by UK industry of research grants and contracts in universities —one part of the Science Base—grew at 15% p.a. in real terms; by 1989/90 it stood at £105M. Industry looks to the Science Base both as a source of new concepts, ideas and challenges and as a source of new people trained in research.

2.9 **The role of the Science Base, and indeed of industrial R&D, in wealth creation is not a simple linear one: it is a complex, iterative process whose outcome is affected by the intervention of many factors. Moreover, if investment in research can contribute to the creation of wealth, the creation of wealth can also facilitate investment in research. There is a virtuous circle here; the starting point may not always be self-evident.**

2.10 The processes of wealth creation in the UK draw necessarily not only on the UK Science Base but also on the Science Base supported by all other countries. The UK Science Base accounts for only 5% of the world total. However, the UK could not dispense with its own Science Base and rely on exploiting everyone else's. Good science is accessible only to good, active scientists, whose own work ensures immediate access to international scientific networks and who have the ability to recognize and exploit potential opportunities when they see them. Scientific or technological capability cannot simply be imported into an otherwise barren landscape.

2.11 There is a real danger that excessive emphasis on wealth creation could impede the natural quality assurance processes of basic research — publication, verification, repetition, peer review. The pressures of commercialism and secrecy must not be allowed to erode the ability of the scientific community to separate out genuine advances from false observations or misleading interpretations.

QUALITY OF LIFE

2.12 Science plays a central role in satisfying social pressures for improved quality of life. These pressures are manifested in many ways: expectations about length of life; searches for cures to increasingly complex diseases; demands for avoidance of man-made pollution; hopes for mitigation of natural environmental disasters; requirements for security and predictability, e.g. of supplies of food and energy. Over the next decade, an essential part of the social function of the Science Base will continue to be generating the knowledge needed to meet such pressures.

2.13 This argument applies also to any role the UK may seek to play in helping other countries to meet analogous pressures. Indeed, scientific research is a major element in the UK's contribution to improving the quality of life in other parts of the world.

TRAINED WORKFORCE

2.14 It is sometimes argued that the Science

Base contributes more to society through disseminating skills than through creating and disseminating knowledge. What skills, and for what purpose? The skills are broader than straight technical knowledge, and are relevant to many situations. They include skills in:

* particular modes of thought, as a contribution to the cultural needs of society;
* particular modes of thought, for use throughout the economy (including the public service);
* the fundamentals of the core scientific disciplines, for use in a variety of occupations both scientific and non-scientific;
* the frontiers of scientific disciplines, for use in particular research environments;
* critical, independent, creative thought, as a reservoir of wisdom to which society can turn for advice.

These are not mutually exclusive. While some can be imparted to an adequate level by school or undergraduate teaching, others need personal experience of conducting research.

2.15 Many of the skills are valuable in careers outside scientific research: the UK would benefit greatly from having more decision-makers with some direct experience of science. The relative importance attached to the various training functions of the Science Base will have implications for other long- term policy issues, such as career structure and the linkages between research and teaching.

PRIORITIES

2.16 Recognition of these several dimensions of the social role of science opens up the question of criteria for setting priorities. The dimensions often overlap: a company (or a government) may fund a particular piece of research in the hope of solving a specific problem, a scientist may undertake the work out of intrinsic interest, one outcome may be an insight of cultural significance, another may be acquisition of particular skills. Much expenditure is motivated by the wish to achieve specific goals, e.g. to create wealth or to improve the quality of life. But the direct approach is not always the most effective way of meeting these objectives. Speculative research in one area may provide the key to solving problems in a completely different area. A science policy able to meet the competitive needs of the UK, both short-term and long-term, must accommodate the many-sidedness of the scientific enterprise.

III. PEOPLE IN THE SCIENCE BASE

Good career progression in the HEIs is the engine for good scientists and engineers to be developed for industry.
Unilever plc

As professional scientists we believe that an inadequate number are being trained for the next generation ... the majority of lively, young people, with the necessary intellectual gifts, seek training in other careers from an early age, and we have difficulty in persuading young science graduates to embark on a research career.
FRS–Biophysics

Young researchers are the lifeblood of UK science; urgent action should be taken to ensure that they are nurtured and sustained.
British Medical Association

INTRODUCTION

3.1 In this chapter we examine the resource on which all else in the Science Base depends—the scientists—both current researchers and the next generation.

3.2 Concerns over the quality and quantity of scientists figured highly in the list of issues raised by the respondents. A majority thought that, one way or another, scientists were being treated poorly and, as a result:

* the current population of researchers was not working as effectively as it could;
* the new generation, seeing and not wishing to experience the tribulations of the old, was being discouraged from embarking on a career in academic research.

3.3 Five root causes were suggested:

* a large increase in fixed-term contracts that offer no long-term security, and the subsequent difficulty of getting a permanent post;
* the increasing constraints on research, due to time spent on resourcing, teaching and administration and to uncertainties over funding;
* the comparative reduction in scientists' salaries over recent years and the low levels of research student stipends;
* the perceived reduction in the prestige of science and scientists;
* the reported lowering of morale (to which all the above contribute).

3.4 Underlying all these perceptions, is the rapid growth in commissioned and short-term funded research that has led to a dramatic increase in the number of short-term appointments, coupled with lack of corresponding growth in long- term appointments.

3.5 Between 1977/78 and 1990/91, short-term researchers in science and engineering disciplines in universities increased by 6000, rising from 22% to 44% of total academic staff in these disciplines. Many of these are employed as research assistants. They may be graduates, graduates pursuing a PhD in addition to their normal work, or postdoctorates on 2 or 3-year contracts.

There was a loss of over 1100 permanent science and engineering posts in universities between 1979/80 (the peak year) and 1989/90; nearly 300 posts were restored in 1990/91.

PEOPLE IN THE SCIENCE BASE

TABLE 3.1 NUMBERS OF FULL-TIME ACADEMIC STAFF IN UNIVERSITIES

	1977/78			1989/90			1990/91		
	Long-term	Short-term	Total	Long-term	Short-term	Total	Long-term	Short-term	Total
Engineering	4107	1186	5293	4024	2956	6980			
Agriculture	733	352	1085	641	523	1164	12716	9930	22646
Science	8611	2367	10978	7779	5610	13389			
All disciplines	32986	7568	40554	31340	18050	49390	31861	19400	51261

Source: ACOST, *The Science Base: research in universities* (1992);
1992 *Annual Review of Government Funded R&D*, table 3.7.3

3.6 **Sufficient people must be attracted into the Science Base to allow enough with real aptitude for research to emerge by competition. Ultimately, the number of individuals that can be supported adequately is limited by what the country can afford. At current levels of support, only a modest proportion of those on short-term appointments can realistically expect to obtain a long-term career in scientific research within the Science Base.**

POSTGRADUATE RESEARCH

3.7 Substantial numbers of research students registered for PhDs now choose to support themselves by taking salaried research assistant posts rather than by accepting Research Council studentships. This can provide a major improvement in their net income as compared with a conventional studentship grant. Given constant studentship budgets, the Research Councils are caught between ignoring the situation or increasing the value and reducing the number of studentships awarded.

3.8 **Research students should have grants or salaries sufficient to enable them to concentrate on their research.** However, in some circumstances it may be advantageous for some to engage in activities outside their research training. Giving them the opportunity to take on properly rewarded teaching or administrative work would improve student finances and offer experience in additional skills. In the long term it could help reduce the number of full-time research assistants as academics' teaching and administrative loads were reduced and they had less need for extra pairs of hands.

3.9 **There should be more flexibility and choice in the way research postgraduates are able to obtain finance. This may require Research Councils to accept longer PhD completion times and allow postgraduates sufficient time to complete their PhDs *and* permit them a tolerable standard of living.**

3.10 **Postgraduate training varies widely according to discipline. Research demands specialisation, but some degree of flexibility and versatility should be incorporated into PhD training and continue also for postdoctorates. This should include elements of non science-specific training and at the very least should include communication skills and, where appropriate, the management of human, material and financial resources.**

POSTDOCTORAL RESEARCH

3.11 Before embarking on postdoctoral research individuals should be made aware of what that career choice might mean. One problem that many experience is that they are funded by one organisation and employed by another, with neither taking an interest in their careers.

3.12 Short-term contracts of two or three years are appropriate for early-career researchers, but should be accompanied by rigorous review. **Scientists should accept that they are embarking on a career that may not take them to retirement and, like everyone else, that they have to compete for the career of their choice. Employers must be wary about allowing the more mature to continue in a career that is dependent upon gaining short-term contracts and must, in accepting a grant, undertake to advise short-term staff on a formal and regular basis. An agreed code of practice should be put in place. The AUT/CVCP "good employer agreement" could form a basis for this.**

3.13 Five or six years, after a PhD, should provide adequate time to judge whether a person has a good chance of a successful research career. "High flyers" may be identified after one or two short-term contracts. Those who show a marked aptitude for scientific research should be rewarded by long-term support. This should include benefits good enough to compete with careers in other sectors. **A contract guaranteeing salary and research expenses for at least five years, coupled with rigorous review, would be appropriate.**

3.14 **We also advocate that the contract be granted to the individual and allow him/her to carry their resources to any approved academic institution.** We would like to see a significant shift in research support towards the talented individual for the following reasons.

* more resources would be allocated by genuine competition;
* researchers so funded would have more independence;
* this mode of support would give the abler research assistants the chance to leave the "pool" of short-term researchers;
* universities would have to compete to attract good researchers.

The consequences of such an arrangement for management of overheads would need to be considered (see also paragraph 5.21).

3.15 This is the principle on which the Royal Society University Research Fellowships (URF) scheme works. Currently the amount spent on URFs and similar Research Council Fellowships compared to that spent on "recruited" postdoctoral research assistants is small. A 2 to 3-fold increase in the funding of individuals would give 500-750 independent researchers the freedom to follow their own interests rather than those of established departments. We would expect many of these to achieve permanent Science Base posts.

3.16 Central to the objective of these medium-term Fellowships is that they are allocated to individuals, primarily on the basis of individual talent. They should therefore be administered, in consultation with the UFC and its successors, by an organization or organizations covering the full breadth of scientific research. They are complementary to, and quite distinct from, the short-term assistantships of various sorts that are properly allocated by Research Councils to projects, primarily in order to support particular disciplines.

PEOPLE IN THE SCIENCE BASE

Expanding Opportunities

3.17 **In order to meet the need of those postdoctorates unsuited to continue in a scientific research career, mechanisms should be introduced to help individuals transfer to a different employment sector.** This process would be facilitated by:

* employers seeking to identify such persons at as early a stage as possible;
* training: giving skills and capabilities other than the purely scientific;
* constructive guidance by the employer;
* a better understanding both outside and inside academia of the value and nature of skills acquired during postgraduate/postdoctoral training.

3.18 We use the word "stage" deliberately. The entrance of mature students into science and the return of women into scientific careers should not be deterred by arbitrary age limits: "stage" relates to time in research since PhD, and not simply to age.

3.19 In recent years academia/industry relations have much improved. Many good interactions have been established through Teaching Company Schemes, CASE studentships, Cooperative Research Grants, etc. However, one aspect which could have great benefits for both sectors is still largely undeveloped and that is mobility between them. **An expansion of the use of visiting professors and wider development of cooperative schemes should be encouraged and would educate further each sector about the other. Financial and administrative problems should be addressed to facilitate mobility.**

Appropriate Career Grades

3.20 **Many scientists will not become leaders in their field. Progress in science depends on many differently skilled people. Those who have not demonstrated a particular aptitude for original or independent research may still make an important contribution.**

3.21 To counter the personal difficulties implicit in sequential short-term contracts and the discontinuity in research projects produced by rapid staff turnover, a career researcher path may be required different from that which leads the "high-flyer" to an independent research career. We may call this the Research Officer path.

3.22 The Research Officer, or equivalent, already exists in certain institutions. S/he is a competent postdoctoral scientist, though not a team leader. Research Officers should form part of a core group that is skilled, versatile and employed on a long-term* basis. The other part of the core would be technical staff, qualified to HNC/D or graduate level. The key to the successful deployment and continuity of the core group would be to have an appropriate ratio of core to independent researcher staff in any institution, reflecting the research work being done. The skills and versatility of the core would be maintained through regular training/retraining coupled with a more flexible vision of a career in science. There would be a spectrum of posts ranging from technician through Research Officer to independent researcher. It would be proper to achieve some flexibility between them.

3.23 The vision of a scientific career should embrace the notion of mobility within institutions and between institutions

*[Long-term as used here need *not* mean tenured, and periodic adjustments in personnel levels may be necessary as in any other employment sector.]

so that shifts of staff between Universities, Research Council institutes, industrial research establishments and other bodies might happen more easily. Artificial impediments such as pension rights differences should be removed.

FLEXIBILITY

3.24 **To give greater opportunity to scientists, flexible mechanisms should be introduced to allow shifts between research/teaching and administration. The aptitudes and desires of the individual should be identified by senior staff. Each person may then be slotted into the role or combination of roles to which they are most suited at a particular time, or guided into employment elsewhere.**

3.25 A system of secure appointments following proven independent research ability is still to be preferred over a more mobile system of "rolling tenure" for the following reasons.

i) Fixed-term appointments can cause discontinuity and can seriously interfere with the fundamental long-term thinking that researchers should be pursuing.
ii) The system is well tried and in general has produced excellent results.
iii) The world is a highly competitive place and current practice elsewhere, such as the availability of tenured positions in the USA, cannot be ignored. Inferior conditions in the UK could lead to the loss of talented scientists overseas.

3.26 However it must be acknowledged that the old system of awarding tenure was imperfect; very few respondents to the Inquiry advocated continuing it. Therefore "permanent" academic appointments should be given at later stages, and through a more deliberate process than has typically been the case in British HEIs and some Research Council and other similar establishments.

IV. THE UK SCIENCE BASE AND THE EUROPEAN COMMUNITY

Economically and culturally, the UK is becoming more closely linked with the countries of the EC. In spite of obvious difficulties in such links it is quite clear that the success of co-operation in Europe is one of the main causes for hope that humanity might be capable of living constructively and in peace. Research scientists have been in the vanguard of international co-operation. Our links with Europe are especially strong.
Professor of Physics

Clearly we must be involved in important European projects but the terms must be right and the funding arrangement controlled such that major adverse effects do not result elsewhere in the system.
The Royal Academy of Engineering

Closer ties with other Community members should be seen as a positive benefit. It should result in some of the better practices and particularly the high esteem in which engineers and scientists are held in most other European countries, influencing our conduct and attitudes. The danger is that when the UK finally sees the light we will be so far behind that it will be difficult to catch up. The harmonisation activities in the EC as a result of the single European market are throwing up many areas of research which should sensibly be tackled on a pan-European basis.
Ove Arup

INTRODUCTION

4.1 The UK has developed a special relationship with other European countries through its membership of the European Community (EC). There are close economic, cultural and, increasingly, political relations between the EC Member States. Science is part of this growing convergence of ideas and purpose.

4.2 The UK has been a successful partner with other EC countries in collaborative projects and facilities. British project proposals have a comparatively good record for attracting European funding. However, it appears that instead of the UK playing a major (some have suggested a lead) role in setting R&D priorities, developing productive partnerships and participating in a major way in large projects, it is perceived as becoming a less popular and a less willing partner in European scientific programmes.

4.3 **If UK science is to derive the maximum benefit from collaboration in Europe it will require a long-term strategy.** This should include the following elements.

i) **Potential collaborators and funders of research should be aware of the benefits and consequences of European collaboration.** (The benefits and consequences of international collaboration described in chapter VI apply equally here).
ii) **UK representation in European fora must be strengthened both scientifically and politically.**
iii) **Funding of UK scientific research should at least be comparable in volume to that of our major European partners/competitors, so that the UK is able to engage in international agreements as an equal partner.**

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iv) **There should be harmonisation between the way the UK funds its participants in international programmes and that of the other major European countries. UK Treasury practices that disadvantage British researchers should be changed.**

v) **Successful participation in international research depends on a strong domestic science base. There must be mechanisms in place to ensure that international research priorities complement rather than distort domestic priorities.**

vi) **Adequate governmental advice and support must be available to UK scientists wishing to engage in European collaboration. A higher proportion of those with responsibility for science should have scientific training and they should consult more with senior scientists.**

vii) **Communication and mobility must be encouraged and mechanisms introduced to facilitate them.**

Decision Making And Promotion Of UK Science

4.4 The UK cannot afford to meet its scientific needs in all areas by going it alone, but it does retain sufficient expertise in all areas to join with and/or build on European work. **The UK should aim to maintain a leading role in the scientific development of Europe and, in areas where the UK has particular interest and strength, government representatives should push harder for well-funded inclusion of those areas in programmes such as Framework.** Leaders of the S & T community at all levels should actively promote UK interests within the EC and seek opportunities for fostering initiatives relevant to the UK's long-term priorities.

4.5 The situation with regard to advice and decision making has previously been unsatisfactory. We welcome the establishment of the new Cabinet post for science and the creation of the Office of Science and Technology within the Cabinet Office. How we expect this move to resolve some of the shortcomings in previous arrangements is discussed in chapter V.

Funding Issues*

4.6 The UK both competes and collaborates with other European countries. Accordingly, it is important to monitor how the size and shape of the UK Science Base compare with other, similar Member States. From the data given in table 4.1, the UK's GDP was a little below Italy and France and some way below Germany in 1990. In terms of gross expenditure on R&D (GERD) and GERD as a percentage of GDP, the UK was fairly close to France, considerably above Italy and considerably below Germany. The UK's ratio of public to private spending on R&D is much closer to Germany than to France and Italy, while its commitment to publicly funded defence R&D, as a proportion of total public R&D expenditure, exceeds that of any other European country. Government expenditure on civil R&D exceeds UK expenditure by 41% in Italy, 84% in France and 129% in Germany.

4.7 Trend data are given in figures 4.2 and 4.3. The UK stands out from the comparator countries in several respects. It is the only country to record a real-terms cut in absolute volume of Government expenditure on R&D (during 1985-89; comparative data not availa-

* [In this section figures are for total R&D not just that in the Science Base, as these are the most reliable figures for international comparisons.]

TABLE 4.1 SIZE AND SHAPE OF EUROPEAN NATIONAL R&D SPENDS, 1990 (IN 1990 POUNDS)*

	France	Germany	Italy	UK
Population (millions)**	54.0	78.0	56.5	56.0
GDP (£bn)	598.5	703.8	562.0	549.2
Gross Expenditure on R&D (GERD) (£bn)	14.4	19.8	7.6	12.1
GERD/GDP %	2.4	2.8	1.4	2.2
% GERD financed by Government	48.1**	34.1	51.3	35.8
Total Government spend on R&D (£M)***	8527	7352	4163	4963
Government spend on civil R&D (£M)	5112	6361	3908	2780
Government defence spend as % total Gov. R&D spend	40.0	13.5	6.1	44.0
Government spend on civil R&D as % of total Gov. expenditure	3.7	4.0**	3.6	2.2

Source: 1992 *Annual Review of Government Funded R&D*, tables 2.6.1, 2.6.2, 2.6.5
* Data for France, Germany and Italy converted to pounds at OECD purchasing power parities
** Data for 1989
*** Total excludes contribution to EC R&D expenditure, estimated at £217M for the UK in 1990.

TABLE 4.2 REAL GROWTH RATES OF R&D EXPENDITURE, 1985-1989*

	France	Germany	Italy	UK
Government	n/a	1.15	5.43	-0.94
Industry	3.88	4.55	5.07	4.42
Other	n/a	11.28	10.60	7.14
Total	2.92	3.47	5.48	2.55

* Annualized percentage growth rate over the period. Covers both civil and defence R&D.
Source: 1991 *Annual Review of Government Funded R&D*, table 1.4.4

TABLE 4.3 SOURCES OF R&D FUNDING, AS % OF GDP

	Italy	France	Germany	UK
Average 1981-85				
Government	0.49	1.14	0.99	1.10
Industry	0.45	0.88	1.52	1.00
Other	0.03	0.10	0.03	0.22
Total	0.97	2.12	2.54	2.32
Average 1986-90				
Government	0.64	1.16	0.98	0.85
Industry	0.53	0.97	1.79	1.12
Other	0.05	0.15	0.06	0.28
Total	1.23	2.28	2.83	2.25
1990				
Government	0.69	n/a	0.96	0.79
Industry	0.60	n/a	1.78	1.09
Other	0.06	n/a	0.07	0.33
Total	1.35	2.40	2.81	2.21

Source: 1992 *Annual Review of Government Funded R&D*, table 2.6.7.
Includes both civil and defence R&D. Of the 2.21% of GDP spend in the UK in 1990 on R&D, 1.71% was for civil R&D and 0.50% was for defence.

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ble for 1990). Its growth rate in R&D expenditure from all sources is the slowest of the countries shown. It is the only country to show a cut in total R&D expenditure as a percentage of GDP.

4.8 These trends are not healthy. The UK has cut public support for R&D to German levels in GDP terms but, unlike Germany, nearly half the support goes to defence rather than civil R&D. Industrial investment in R&D, despite substantial growth, remains at French rather than German levels. France has overtaken the UK in terms of gross expenditure on R&D, and Italy is beginning to close the gap. **Such trends, if allowed to continue over the next ten years, would weaken the contribution the UK can make to shaping the future of European science and technology.**

ADDITIONALITY AND ATTRIBUTION

4.9 The principle of additionality is enshrined in EC law. It means that EC funds gained for a project should be additional to national public expenditure on that project and should not be a substitute for it — EC funds should not subsidise underfunding. However, the UK Treasury insists that funds received by UK Departments through EC R&D programmes are attributed against their budgets. Attribution is applied only to EC funding. Funding of all other international collaboration is treated differently. These departments' budgets are then adjusted downwards by the attributed amounts in the following annual public expenditure round. This accounting practice is now a major disincentive to increased involvement in EC scientific programmes.

4.10 Another consequence of attribution on European collaboration is the way it determines priorities within the UK Science Base. In effect the cost of EC projects are met first by deduction from budgets. As this process continues, more success in gaining EC funding means more EC research priorities replace UK priorities.

4.11 Both Houses of Parliament have criticised the attribution system. **The obscurity with which attribution is in practice implemented is a major problem. We agree with the statement of the House of Lords Select Committee on European Communities that the system operates against the national interest and needs of industry as it only exacerbates the underfunding of R&D in the UK.**

4.12 EC R&D funds are granted on the assumption that 50% of industry's total costs in a project, and 100% of HEIs' non-marginal costs, will be met by non-EC sources. The UK Government does *not* explicitly contribute matching funds, so by engaging in EC funded research the HEIs have suffered a net loss. Select committees of both Houses of Parliament have recommended that a government fund be established to make contributions towards overheads on EC research contracts secured by UK HEIs. **Without this, or some similar fund, EC projects merely become another major example of the propensity of UK HEIs *not* to recover overheads, and the UK remains "the odd man out" in Europe — the only one whose Science Base loses money by doing collaborative work. This cannot be in the interest of the UK.**

EUROPEAN COMMUNITY PRACTICES

4.13 Collaboration and understanding within Europe are improving. Cultural and linguistic differences will remain. Agreements and procedures have been developed by compromise and national practices differ. However, certain aspects of EC practice are of concern to the UK scientific community, notably time-consuming and complicated procedures, and the ways in which programmes are created and resources allocated.

4.14 The UK cannot expect to effect change without full involvement. **We therefore reaffirm our statement of paragraph 4.3(ii), that UK representation must be strong both scientifically and politically. This must be coupled with a greater effort to build and maintain relationships in the European scientific community.**

Coordination Of European Scientific Research

4.15 National Science Bases should remain strong, but resource constraints will dictate that no individual nation can support research in all areas. Europe as a whole should aim to maintain expertise in all disciplines. **To ensure this there is a need for an independent non-governmental European body to provide a strategic overview of all European Science Base Research.**

V. FUNDING AND ORGANIZATION OF THE SCIENCE BASE

While it is acknowledged that there is often a case for the concentration of resources in large institutes, the creation of a diverse range of scientific research organisations from large institutes through research teams in HEIs to individual researchers, creates the best environment for scientific research by providing the flexibility for research activities to grow or decline according to the ideas and vigour of scientific thought in a particular institution.
University Vice-Chancellor

Many departments that we have close relationships with have sought funds from commercial contract work in order to survive. This trend is leading academics away from the pursuit of knowledge and the expansion of the frontiers of science and engineering which this company will need in the future. They are engaging in commercial activities for which they are untrained and unsuited and this is a highly unfortunate state of affairs.
British Gas plc

The current weak representation of British science at international level by junior ministers in the DTI or the DES should be bolstered by appointment of a senior minister of cabinet rank to represent British science.
FRS–Medical Research

SCIENCE BASE FUNDING

5.1 Total UK expenditure on civil and defence R&D is shown in figure 5.1. In real terms, government expenditure, particularly on defence R&D, declined between 1981 and 1991. Industrial investment in R&D, however, more than offset this, growing by 41% in real terms between 1981 and 1990. As a percentage of GDP, total Government expenditure on R&D dropped from 1.33% in 1981 to 0.87% in 1991; industrial expenditure rose from 0.91% in 1981 to 0.99% in 1990.

5.2 Trends in the funding of the Science Base over the last ten years are shown in figures 5.2 and 5.3. The key points to emerge are:

* The Science Budget grew between 1981/82 and 1991/92, by a total of 18% in real terms.
* Expenditure on research in universities from UGC/UFC sources and from fee income dropped between 1981/82 and 1991/92, by 8% in real terms. [Reliable trend data on research expenditure are not readily available for the polytechnic and college sector].
* Total Science Base income from DES sources grew between 1981/82 and 1991/92, by 5% in real terms. However, the national wealth grew by 27% in the same period. Core public funding of the Science Base therefore dropped from 0.34% to 0.28% of GDP.
* There was a marked increase in research income from non-DES sources, up from 20% of total Science Base research income in 1981/82 to 30% in 1989/90. Total Science Base income from all sources, as a percentage of GDP, was about the same in 1989/90 as it had been in 1981/82.

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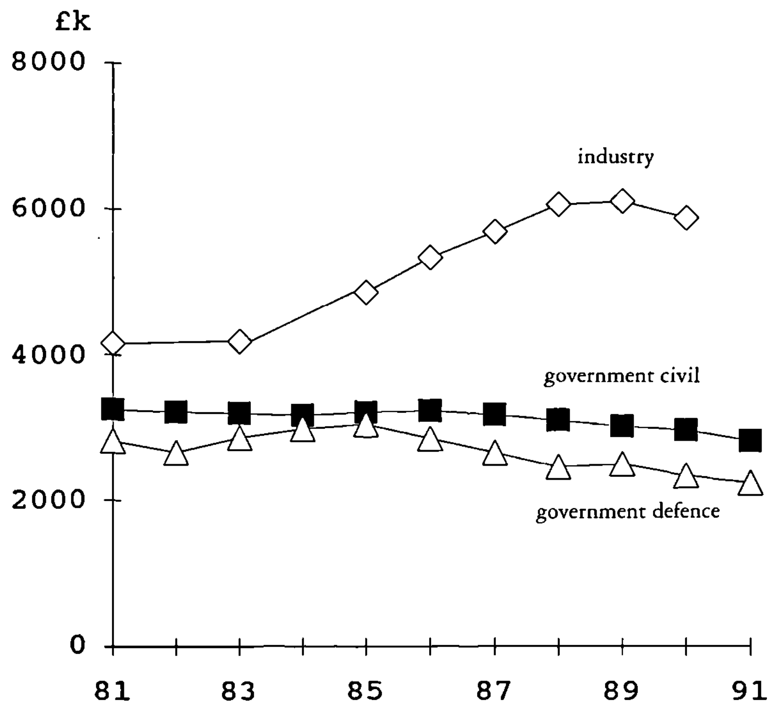
FIGURE 5.1 TOTAL UK EXPENDITURE ON R&D (1991/92 POUNDS)



Source: 1992 *Annual Review of Government Funded R&D*, tables 2.3.1, 2.4.2, 2.4.3. Treasury GDP data 10 March 1992.

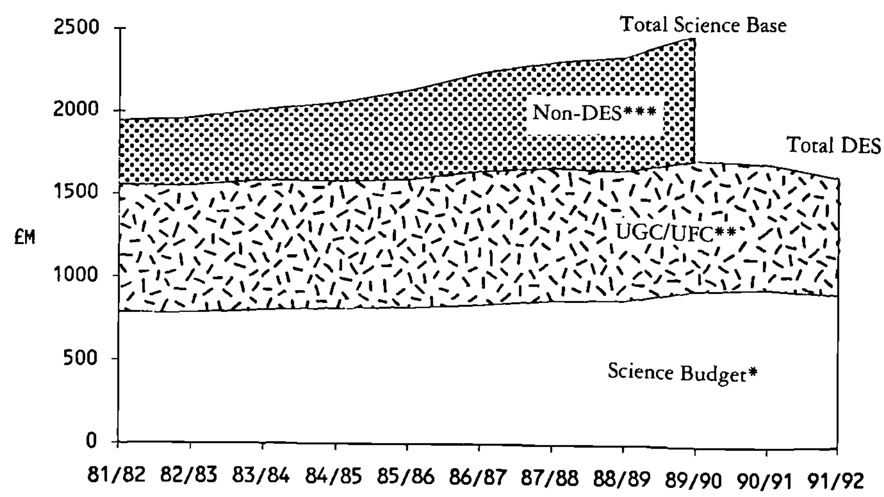
Note: Data for expenditure by industry on R&D includes both civil and defence. In 1990, 92% of the industry total was for civil R&D. The industry data do *not* include expenditure in industry of Government funds for R&D or of funds from overseas sources.

5.3 A striking feature of the past decade is the rapid growth of external (i.e. non-DES) funding of HEI research (detailed further in figure 5.4). In 1981/82, Research Councils provided 46.2% of university income for research grants and contracts (excluding the UGC/UFC component). By 1989/90, despite real terms absolute growth of 6.4% p.a., this had dropped to 34.7%, the remainder being provided by charities (20.5%), Government sources other than the DES (15.7%), UK industry (13.8%) and 'other' (15.3%) (including £38.6M, or 4.4%, from the European Community). The rapid growth of funding from the medical research charities is particularly notable. The Research Councils have also secured significant external funding, though it dropped slightly from 17.8% (£94.4M) of their total income in 1981/82 to 14.0% (£144.3M) in 1990/91. These trends have profound implications for the Science Base.

5.4 The rapid growth of external funding has generated a corresponding growth of short-term contract staff. The consequences are addressed in chapter III.

5.5 External funding demonstrates the value of university research to a variety of customers. The trend towards external funding can go some way further without harming the Science Base. However, industrial funding of Science Base research is inherently vulnerable to fluctuations in the

FIGURE 5.2 FUNDING OF THE UK SCIENCE BASE (1991/92 POUNDS) ****



Notes:

* Science Budget covers expenditure by the five Research Councils, the Royal Society and the Fellowship of Engineering of Parliamentary-Grant-in Aid via the DES. Allocations for the British Museum (Natural History) are omitted in all years. Source: ACOST, *The Science Base: research in universities (1992)*

** UGC/UFC figures for research expenditure given here include social science, exclude humanities and exclude medical science directed toward clinical ends ('primary purpose'7). Sources: UGC/UFC, *Annual Review of Government Funded R&D.*

*** Non-DES means income for research earned by the Research Councils and the universities from sources other than the former DES Science Budget and the UGC/UFC.

****Adjusted GDP deflator at market prices based on the 1992 Financial Statement and Budget Report.

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economic situation. Moreover, the further the external work is from the broad mission of the Science Base, the greater the risk that it will distort that mission in ways that individual Science Base institutions will be unable or unwilling to resist.

5.6 Science Base institutions must have a clear sense of purpose when undertaking externally funded research. We welcome the funding, but external funds should not replace Government funds. **Using public funds to lever private funds is more constructive than cutting public funds in the hope of coercing private funds.**

5.7 Both the volume and the sourcing of Science Base funding, then, have changed markedly in the last ten years. The trend towards greater diversity of sources has advantages for the Science Base. But a high level of core Government funding will remain essential if the Science Base is to discharge all its roles in a balanced manner, and if it is to nurture its capacity for truly creative research.

USE OF SCIENCE BASE FUNDS

(i) SELECTIVITY

5.8 Science is an international activity. The UK cannot expect to take the lead in every field. With the ever increas-

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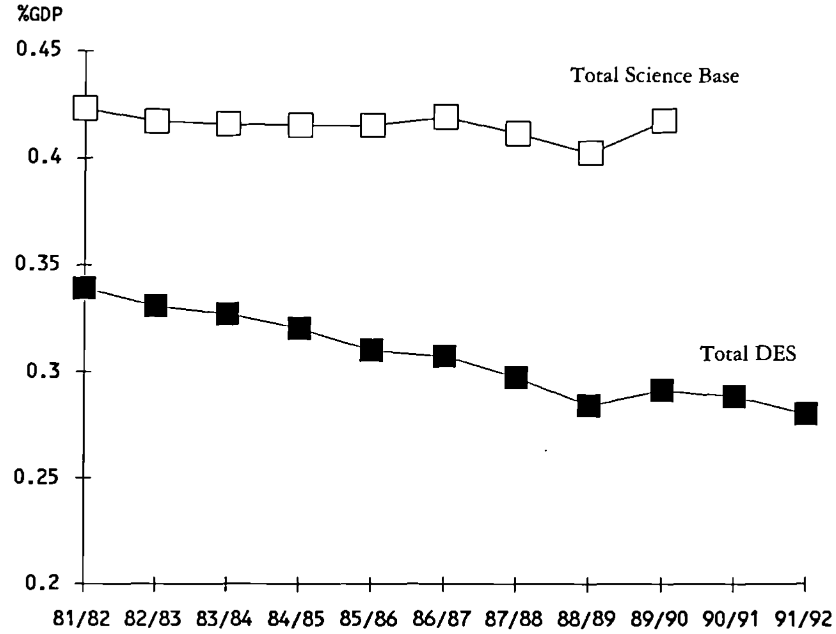
FIGURE 5.3 FUNDING OF THE UK SCIENCE BASE % GDP



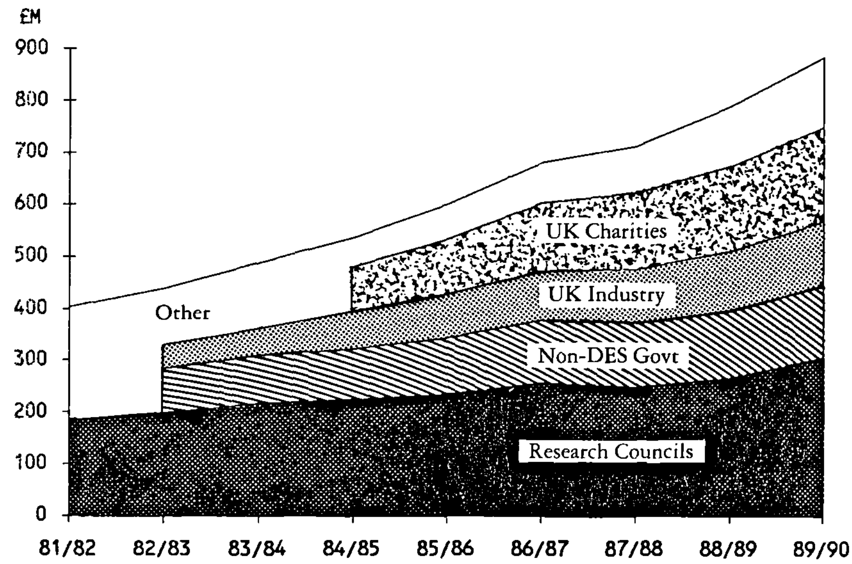
Note: See figure 5.2

ing pressures imposed by the growing sophistication and cost of modern science, decisions have to be taken about which areas to support and where to give lower priority. But, apart from relatively prosaic goals, a narrow focus on the obviously 'relevant' is rarely the most effective way to achieve progress. The best research is full of surprises. Priority-setting must allow scope for the unexpected.

5.9 The following set of criteria should be taken into account when determining the pattern of effort across the Science Base of the future.

* Balanced contribution to all the functions of the Science Base described in chapter II.
* Balance between basic and strategic research, insofar as these are distinguishable.
* Inherent cost: expensive disciplines should not be supported so generously as to weaken relatively cheap disciplines. Where costs per researcher or per increment of knowledge vary by several orders of magnitude, this must be a relevant consideration.
* Maturity: a rapidly advancing discipline has different needs from a relatively mature one.
* For the objective of contributing to wealth creation, the relative strengths of the different wealth-creating sectors of the UK economy must play some part in influencing the overall pattern of activity in the Science Base. This applies equally to the likelihood of generating exploitable ideas and to the production of an appropriately skilled workforce.
* Previous capital investment should not, of itself, be unduly influential in determining priorities: that way lies long-term inflexibility.
* Finally, of course, scientific excellence is essential. There is no point in prioritizing a field of research if there are no front-rank researchers to advance it.

FIGURE 5.4 UNIVERSITY RESEARCH INCOME FROM SOURCES OTHER THAN THE UGC/UFC (1991/92 POUNDS)



Source: USR University Statistics volume III.

Note: Data cover all disciplines, including humanities and clinical medicine; separate income data for science and technology are not readily available. 'Total' includes other sources not shown separately. In 1989/90 these included £36.8M from the European Community and £43.1M from other overseas sources.

(ii) Ring-Fencing

5.10 Efficient and effective management of Science Base funds is hindered by large international subscriptions whose cost to the UK can fluctuate suddenly, particularly if defined in a non-ERM currency. Since most Science Base expenditure is committed some time in advance, the impact of these fluctuations is borne almost entirely on the small element of the budget that is flexible in any one year. Moreover, some international collaborations are established by inter-governmental agreement and therefore cannot be amended or cancelled by the (non-political) managers of the Science Base, who nevertheless are required to provide the requisite funds. **We therefore recommend that major international subscriptions established by inter-governmental agreement be a distinct, isolated element within the remit of the Office of Science and Technology.**

Support Of Academic Research

(i) The Dual Support System And The Binary Line

5.11 One of the strengths of the UK system is the dual support approach to funding academic research. The UFC (HEFCs) provides the basic research infrastructure (salaries of permanent staff, premises, libraries, routine consumables and equipment — the 'well found' laboratory), while the Research Councils provide additional project money to support specific disciplines and their related missions.

5.12 The UFC (HEFCs) funds are crucial to university research. As well as underpinning the entire structure, these funds provide:

* resources with which to do exploratory work in advance of undertaking specific projects;

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* scope for developing tangential ideas arising from projects;
* freedom to do work that cannot be fitted into the normal run of grant- funded projects;
* ability to support externally-funded staff in the gaps between projects;
* ability to support promising young staff in the early stages of their careers.

The well found university laboratory lies at the heart of the Science Base: without it, the Research Councils would be unable efficiently to invest in research projects outside their own institutes.

5.13 The dual support system is under increasing pressure. The money going from Research Councils to universities to support research grants and contracts grew at more than 6% p.a. in real terms between 1981/82 and 1989/90; UFC support for research grew by just 2% over the whole of these eight years (and dropped by 10% in the following two years). **This has brought damaging inflexibility to university research. It is critical to the future of the Science Base that the UFC/HEFCs leg of the dual support system is large enough to meet all of the above demands.**

5.14 **UFC/HEFCs funds for research should not be distributed according to a top-down discipline-based selectivity. They should be distributed in a way, and on a scale, that allows individual universities to establish and maintain high quality departments able to compete for external funds as required.**

5.15 The UFC block grant is calculated according to research-based and teaching- based criteria. However, it remains a single block grant, and universities account for it as such. We believe that most fundamental research should be associated with teaching, and therefore welcome the continuation of the block grant system. This will allow universities to use their grants, at their own discretion, for the joint support of teaching and research in the most economical and effective manner. This flexibility is the key to preserving the beneficial interactions of research and teaching, the well found laboratory and the ability of universities to determine their own mission and strategy.

5.16 **HEIs cannot all be funded as internationally competitive research centres. Each HEI must establish its own individual mission, combining local, regional, national and international perspectives.** Many HEIs had their origins in local civic ambition and local industrial need. Building on this foundation, many HEIs will also achieve regional or national pre-eminence in particular fields, and some will achieve international pre-eminence. The key to a healthy HEI sector will be diversity and flexibility.

5.17 **From the national perspective, these principles amount to policies of selectivity and concentration, but implemented in an evolutionary manner through local institutional decisions. This is the best way of achieving a strong HEI sector. But removing the binary line and inviting a greatly increased number of HEIs to bid for core research funding, while making no extra core money available for research, is going to have drastic consequences for the dual support system and for the research ambitions of HEIs at institutional and at departmental level.**

(ii) TYPES OF GRANT

5.18 Although there are many variants, the principal vehicle for distributing Research Council money to HEIs is the individual research grant. This is based on a detailed application, subjected to a detailed process of peer review, and typically lasts not more than three years.

5.19 For researchers pursuing a line of inquiry over a period of years, it makes little sense to package ideas into discrete project-sized portions and seek funding portion by portion. We therefore envisage in the Science Base of the future much greater use of programme grants or Fellowships, where a team or an individual is supported for five years or longer, with quality being assured by expert review of actual progress rather than by detailed statements of intent. This would accord more closely with the real nature of scientific research, as well as reducing the heavy burden of reviewing that the present system imposes.

5.20 **We would also like to see a significant shift towards funding more independent researchers.** This could be a particularly effective way of launching young scientists of outstanding promise on their careers as independent researchers: the offer of, say, five years' support would provide both opportunity and incentive to demonstrate aptitude for a career in independent research. Such an approach would encourage more adventurous research than is possible under a regime of continual application for short-term grants. Detailed proposals along these lines are set out in chapter III.

5.21 **The present system for calculating indirect research overheads relates them to the salaries of short-term staff engaged for a given project. This makes it advantageous to the departments to maximise the number of short-term assistants — which in the long term is in the interests neither of the Science Base as a whole nor of the assistants themselves. A different basis is needed for calculating overheads.**

(iii) Responsive And Directed Funding

5.22 Perceptions about responsive and directed funding depend on which way one is looking along the cascade of decisions from national expenditure plans to individual grants. In particular, there may seem to be a conflict of interests between the individual researcher and the funding agency facing pressure to demonstrate relevance, performance and value for money. The funding agency is caught between the legitimate expectations of its clients (researchers wanting to pursue particular lines of inquiry) and the equally legitimate demands of its paymasters (tax-payers, public and private companies, Government agencies etc. wanting certain outcomes from public expenditure). Ultimately, this becomes a conflict about who sets the agenda for the Science Base and about whether this agenda can best be met by relying on researchers following their scientific instincts: a conflict between the 'internal' and the 'external' criteria for scientific choice. The conflict needs to be worked through at each level in the decision-making process; the optimum balance point is likely to tend towards the internal criteria as one moves down to the level of the individual researcher, or as one moves towards the basic end of the research spectrum.

5.23 Within the Science Base, and in varying degrees within any research organization, it is essential to allow space for the unexpected, and for individuals of proven quality to pursue their own ideas. **This means that significant Research Council funds must be retained outside 'directed' programmes for distribution on purely scientific criteria in the responsive mode.** Detailed priorities should not be formalized for basic research. All science

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that we now regard as mainstream was once peripheral and unorthodox. New fields — the mainstream science of the future — will emerge most readily if the most innovative scientists are given maximum scope to pursue their hunches, without having artificially to peg their work to directed priorities.

TEACHING AND RESEARCH

5.24 **It is to the advantage of the Science Base as a whole that most fundamental research should be conducted in institutions that are also active in undergraduate and/or postgraduate teaching. Both the teaching and the research benefit.**

* Lecturers benefit from the continual challenge of peer review in research as a stimulus to rigour in teaching.
* Exposure to top-level thinkers allows able undergraduates to see what research involves and to consider whether they wish to pursue a career in research themselves.
* An atmosphere of research helps students to realise that science is not a set of dogmatic truths but, at least at the frontiers, is full of unknowns and conflicting views: it helps inculcate an appreciation of the need to weigh evidence and form sound judgements.
* Given the rapidity of scientific advance, it is vital that lecturers (through personal research or in other ways) are able constantly to update their material so that students come into contact with the latest ideas.
* Researchers benefit from the challenge of constantly having to present their ideas to a lively audience.
* Since few researchers are capable of sustaining front rank research for their whole careers, it is beneficial for them to have the option of taking on other responsibilities such as teaching.

5.25 **All undergraduate teaching must at least be informed by acquaintance with recent research findings (i.e. 'scholarship'). Undergraduate teaching will benefit by being conducted at least in part by staff actively engaged in research and in the development of their professions. All postgraduate teaching should, and postgraduate research supervision must, be conducted by active researchers.**

MINISTER FOR SCIENCE, TECHNOLOGY AND RESEARCH

5.26 One of the most important, and difficult, issues affecting the future of science in the UK is the nature and location of political responsibility. In recent years the arrangements have been weak in four key aspects:

* inadequate oversight of publicly funded research as a whole;
* lack of effective representation at Cabinet level;
* inadequate representation of UK interests in international fora, notably the European Community;
* unsatisfactory arrangements for handling major international subscriptions.

5.27 Since the 1981 House of Lords report on "Science and Government" there has been a progressive strengthening of the oversight role at the centre of UK Government. The first step was the reappointment of a Chief Scientific Adviser and the re-creation, and subsequent growth, of a Science Secretariat in the Cabinet Office. At the same time an Annual Review of Government-funded R&D was introduced. The second step was transformation of the role of the Advisory Council for Applied R&D (ACARD) into the much broader remit of the

Advisory Council on Science and Technology (ACOST) with the Prime Minister as Chairman. The third was the institution of an Annual Report from ACOST on progress and priorities in UK S & T. It is, of course, vital that S & T play an integral role in the policies of each individual department in relation to its specific functional area. Departments should continue to seek advice and to support research to satisfy their own remits and priorities. At the same time, however, there is growing recognition that the advance of science and technology must also itself be a central objective of UK government policy. **Initiatives need to be focused centrally and strategically; in the recent past they have been held back by the UK's strongly sectoralized approach to S & T.**

5.28 Much less progress had, until the recent changes, been made towards resolving the second of the four problems listed above, namely that of achieving adequate political representation for science at Cabinet level. Other leading scientific countries have either a Cabinet minister with full-time responsibility for science (France, Germany) or a top-ranking science official who attends all Cabinet meetings and committees (USA). Such people are able to develop and defend policy for science at national level and, no less important, to comment on the scientific aspects of other areas of national policy. **Both the scientific enterprise itself and other areas of policy-making with a scientific component have been disadvantaged in the UK by the lack of an effective scientific presence at Cabinet level.**

5.29 The processes of science policy in the European Community starkly show up the third problem. Negotiations are inevitably political; they involve trade-offs both across science, technology and research, and more broadly. Other countries have a single Cabinet Minister to focus their national effort and to express a collective position at EC Councils of Ministers. The UK, however, has been represented by a junior Minister from the Department against which happened to be attributed the largest single element of the Framework Programme. Although that Minister was able to draw on the Chief Scientific Adviser in the Cabinet Office and on other cross-departmental resources, it was inevitably hard for him to be as effective as some of his opposite numbers.

5.30 Finally, problems can arise with international collaborations if diplomatic priorities differ from scientific ones, particularly if this results in the Science Budget having to bear the cost of a collaboration where continued participation is justified primarily on extra-scientific grounds. In addition, sudden fluctuations in the cost of collaboration can cause severe difficulties for the Science Base.

5.31 We therefore warmly welcome the appointment of the Chancellor of the Duchy of Lancaster, acting on behalf of the Prime Minister and assisted by the Parliamentary Under-Secretary of State, to take central responsibility within Government for science and technology policy. This move, and the creation of the Office of Science and Technology (OST), will resolve many of the shortcomings in the previous arrangements as just outlined. The new arrangements must be given time to evolve out of the previous situation: the new relationships that will be needed cannot be forged overnight. We shall follow this process closely and offer our part in ensuring its successful outcome.

5.32 The Chancellor's new responsibilities include, or could include, the following:

* representing the UK at EC Coun-

FUNDING AND ORGANIZATION OF THE SCIENCE BASE

cils of Ministers of Science;

* coordinating UK R&D activities, particularly maintaining an adequate infrastructure and promoting new fields of applicable S & T;
* reviewing annually UK Government expenditure on R&D and advising the Cabinet on how to achieve best value for money;
* identifying trends for UK science, with particular reference to enlarged international activity.

5.33 In addition, **as well as responsibility for the former DES Science Budget, we recommend that the Chancellor should be given oversight of the expenditure of a small separately identifiable budget** to meet:

(a) subscriptions to international facilities and programmes, established by intergovernmental agreement, where continued involvement needs to be viewed in a broader context than the functional responsibilities of any one Department/Agency (international collaborations entered into by Research Councils at their own initiative should remain a charge on their own budgets);
(b) activities transcending the responsibilities of individual Departments that nonetheless are, actually or potentially, vital components of the national R&D infrastructure;
(c) complementary funding for certain EC-supported research projects.

5.34 The scale of such a budget should, by analogy with the French situation, be around 2% of total Government R&D, say £100M, to cover points (b) and (c) above. To this should be added such international subscriptions as may be derived from other Departments/Agencies by PES transfers, to cover point (a). Expenditure from the budget should, in general, be arranged through an appropriate Agency or Department, but might be direct from the Cabinet Office vote. The impact of such a budget, decided in the light of broad consultation within and outside Whitehall, would be altogether greater than its mere scale might suggest. We believe it would help the UK gain a substantially better total return from EC research, in particular, and international science more generally, and better promote S & T within the UK to the benefit of wealth creation.

Advisory Mechanisms And Research Council Structure

5.35 Two matters that the Chancellor of the Duchy of Lancaster will need to address are the design of new advisory mechanisms and the structure and functioning of the Research Councils.

5.36 In view of the Government's stated intention to raise the profile of science and technology in national policy-making, the structure and functions of the current ACOST need to be revised. **The key requirement is for a body able to advise the Chancellor, and (either through him or directly) the Prime Minister, on the S & T aspects of strategic issues of national importance, including particularly those affecting science-based industry. This body must be able to connect with all elements of UK science and technology. It should focus its work primarily on the major strategic issues.**

5.37 Responsibility for the Science Budget (i.e. Parliamentary-Grant-in-Aid paid directly to the five Research Councils, the Royal Society and the Royal Academy of Engineering) has been moved from the old Department of Education and Science to the new OST. Under the new arrangements, the Science Budget will be only one of the responsibilities falling under the purview of the OST. **Consideration should therefore be given to developing a single advisory mechanism, complementary to that discussed in the previous paragraph, that can address the full range of the OST's direct responsibilities for the nation's science and technology.** This includes: the OST's financial responsibilities - the former DES Science Budget, additional monies voted to OST (paragraphs 5.33 — 5.34 above), and the OST's role in advising on the S & T expenditure of other Departments; review of the overall balance of Government activities in science and technology; and ensuring that effective means are in place for implementing agreed policies. This advice function must be demonstrably disinterested.

5.38 In several respects, the remit of ABRC is no longer satisfactory. Its ability to direct the work or modify the remits of the Research Councils is constrained by the autonomy assured to each Council by its charter. Its independence as an advisory body is impaired by the fact that the heads of the five Research Councils play a dominant role in its quasi-executive work. To have a proper overview of the UK Science Base, it must have proper cross-linkages with the three HEFCs. In establishing the advisory mechanism described in the previous paragraph, the Chancellor of the Duchy of Lancaster, and the OST, will need to take account of these considerations.

5.39 We recommend, further, that they tackle such issues as:

* ensuring proper coordination, including some cross-membership, between the Research Councils and the Higher Education Funding Councils;
* ensuring proper coordination between activities in the same or related disciplines, initiating joint work or even adjusting areas of responsibility where necessary;
* developing coherent policies on, respectively, institutes, major facilities, research grants and research Fellowships, so that sudden problems in one area are not solved at the expense of another;
* ensuring that Research Councils introduce mechanisms for integrating central facilities with their customer communities (for example, establishing facilities as agencies deriving some or all of their income from fees paid by users).

5.40 The three HEFCs will be located within the Department for Education, the Scottish Office and the Welsh Office. This means that the two parts of the dual support system will be the responsibility of four different Government Departments. This underlines the importance of achieving full and formal liaison between them.

Regional Issues

5.41 Recent decisions to create separate Higher Education Funding Councils for England, Scotland and Wales presage a strengthening of the regional element in the structure of the Science Base. This is consistent with what would appear to be an increasingly strong regional element in many areas of the world.

5.42 Regionalism in the Science Base has both benefits and dangers. The benefits relate to a stronger sense of identity at institutional level and to more effective interactions with local industry. The dangers concern narrowly conceived missions, lack of critical mass and duplication that appears wasteful from a UK perspective. A policy that required the UK Science Base to be distributed through the UK pro rata with political boundaries might be appropriate for the training functions of the Science Base, but it would be detrimental to the research functions.

FUNDING AND ORGANIZATION OF THE SCIENCE BASE

ACCOUNTABILITY

5.43 Expenditure of public money rightly entails processes of public accountability. These processes must be tailored to the context. Science Base institutions are not, in the first instance, commercial or industrial organizations. They should not be subjected to accountability regimes designed for such organizations. Inappropriate control mechanisms waste time and energy and may, paradoxically, serve to distort institutions' objectives and hinder them from operating effectively.

5.44 At national level, accountability must reside with those who make decisions. This is particularly important for decisions about international collaboration, where the decision-making process may be separated from the locus of subsequent financial responsibility.

VI. INTERNATIONAL ISSUES

All scientific research is international. This has always been true at some level, however, now increasingly it is becoming so that not only is the research international but the teams are also international.
FRS–Physics

There is clearly a case for making effective use of collaboration but there are also problems to be overcome. The key issues appear to be the prudent choice of partners, ensuring that each has something different to contribute, clear objectives and a need in the case of industrial partners to achieve timely results that are required for onward development or exploitation.
British Telecommunications plc

INTRODUCTION

6.1 Three major geopolitical changes are transforming the world. These are having and will continue to have a profound impact on science.

6.2 The European Community is expanding to accommodate, to varying degrees, the EFTA countries and others. With the dissolution of the Soviet Union and the Warsaw Pact, a "greater" Europe is evolving, eroding the old polarisation between East and West. This heralds possibilities of much greater cooperation. Opportunities exist to build on the "common interest" relationships founded in the "cold war" and to establish new ones. There is also the explosive growth in technological achievement in Japan, which is now accompanied by major investment in basic scientific research. Dramatic changes in themselves, these are being emulated by other Pacific-Rim countries such as Taiwan and South Korea. Thus, South East Asia presents a further major focus for scientific research.

6.3 The Science Base of the future will have an increasingly international dimension, and offers tremendous opportunity for all those involved. The UK competes and collaborates with many countries outside Europe as well as with its European partners. In this chapter we address some international aspects of UK science and technology policy.

CONDITIONS FOR COLLABORATION

6.4 Some research is best carried out by individuals and some benefits from collaboration. What type of collaboration depends on various factors.

(i) Where UK researchers are the leaders in a field **intranational collaboration** might be the most appropriate type. There is excitement and personal fulfilment in discovery, and discoveries not shared with overseas partners/competitors may have greater long-term benefit to the UK.

(ii) **International cooperation** may take a number of forms. Individuals or laboratories may have the same or complementary interests. Nations may wish to combine their expertise to facilitate or hasten research in a certain area. Very large projects may be beyond the reach of individual countries because of the high cost, and therefore be possible only through international cooperation. Some problems such as global warming or AIDS are by their nature international and demand worldwide cooperation.

INTERNATIONAL ISSUES

(iii) There will be some investigations which are not of a high enough priority for UK participation or for which the costs are prohibitive. In these cases a watching brief should be maintained. The reasons for the non-involvement of the UK should be made clear to those involved in the research so that opportunities for future cooperation are not damaged.

BENEFITS AND CONSEQUENCES

6.5 International programmes offer scientists the chance to participate in well-funded and well-equipped research at the leading edge. They enable the establishment of wider contacts and development of new insights, ideas and expertise. Access to pooled scientific data becomes available. **The UK Science Base benefits from the experience and contacts gained by UK scientists and research entities in this way.**

6.6 By involvement in international programmes, the UK may influence the siting of major facilities. **The UK government should recognize the advantages of appropriate international facilities based on British soil in terms of prestige, access, development of expertise and improving morale (through demonstration of excellence by a British run institution).**

INTERNATIONAL COMPARISONS

6.7 How the UK compares with Germany, USA and Japan is shown in table 6.1. Major contrasts emerge. The UK spends a good deal less of its GDP on R&D than any of the three other countries. In the USA, half the national expenditure on R&D is funded by the Government, and of this two-thirds goes on defence rather than civil R&D. In Japan, less than one sixth of national R&D expenditure is funded by the Government, but nearly all this goes on civil R&D, so total Government expenditure on civil R&D is not far short of that in Germany and double that in the UK. The UK spends slightly more on civil R&D as a percentage of total Government expenditure than the USA but lags behind Japan and Germany.

6.8 It is noteworthy, and hardly surprising, that the countries which spend least on defence R&D, namely Germany and Japan, are also those with

TABLE 6.1 INTERNATIONAL COMPARISONS OF R&D SPENDS, 1990 (IN 1990 POUNDS)*

	UK	Germany	USA	Japan
Population (millions)**	56.0	78.0	229.8	117.7
GDP (£bn)	549.2	703.8	3281.8	1325.6
Gross Expenditure on R&D (GERD) (£bn)	12.1	19.8	91.7	38.2
GERD/GDP%	2.2	2.8	2.8	2.8
% GERD financed by Government	35.8	34.1	48.2	16.2
Total Government spend on R&D (£M)	4963	7352	38819	5976
Government spend on civil R&D (£M)	2780	6361	14524	5651
Government defence spend as % total Gov. R&D spend	44.0	13.5	62.6	5.4
Government spend on civil R&D as % of total Gov. expenditure	2.2	4.0**	2.1**	2.9**

Source: 1992 *Annual Review of Government Funded R&D*, tables 2.6.1, 2.6.2, 2.6.5

* Data for Germany, USA and Japan converted to pounds at OECD purchasing power parities. See Table 4.1 for comparable figures for France and Italy

** Data for 1989

the best economic performance. It is to be hoped that the dramatic changes in the geopolitical scene will enable a significant redistribution of R&D resources to take place in the UK, enhancing the civil sector.

VII. CONCLUSION

There should be some realisation that a relatively rich country such as ours has an obligation to the whole of mankind for the continued advance of basic knowledge—of science and other disciplines—simply as a part of its contribution to civilisation. Secondarily, but still crucial, such knowledge gives an edge in the competitive world of international trade and we would, therefore, be exceedingly foolish to fall behind our competitors.
FRS–Biochemistry

7.1 If the UK is to continue to benefit from the contribution that science makes to the life of the country, it needs a strong Science Base. In this report we have set out some thoughts on how that might be achieved.

7.2 We recommend greater flexibility and opportunities for mobility in scientific research careers. Improved guidance, training, planning and support will make it easier, and less risky, for young scientists to get started. Expanding direct funding of outstanding individuals will make it easier for them to establish themselves in long-term careers.

7.3 We envisage the UK as a committed and reliable partner in European science through strong representation, both scientifically and politically, and greater harmonization of its practices with those of its principal partners/competitors. We recommend funding appropriate to the national economy and the objectives of those involved with the Science Base.

7.4 The appointment of the Chancellor of the Duchy of Lancaster to take Cabinet level responsibility for science, and the strengthening of the Office of Science and Technology, are positive steps in the right direction. We hope that they will lead to a better recognition of the central position of science and technology in national affairs and to policies that will maximize the effectiveness of the Science Base.

7.5 We hope that all who care about the UK Science Base will find something in this report to catalyse long-term thought and action. We would welcome comments.

ANNEX A: THE SCIENCE INQUIRY STEERING COMMITTEE

Chairman: *Sir Michael Atiyah*–President of the Royal Society. Director of the Isaac Newton Institute for Mathematical Sciences at the University of Cambridge, and Master of Trinity College, Cambridge.

Members: *Lord Adrian* – Master of Pembroke College, Cambridge, and Professor of Cell Physiology in the University of Cambridge

Sir John Cadogan – Research Director, British Petroleum plc. Visiting Professor at the Imperial College of Science and Technology in the University of London and Professorial Fellow at the University of Swansea in the University of Wales

Professor D. E. N. Davies – Vice-Chancellor and Honorary Professor of Loughborough University of Technology

Professor J. F. Dewey – Professor of Geology and Head of the Department of Earth Sciences in the University of Oxford

Professor J. E. Enderby – H.O. Wills Professor of Physics in the University of Bristol

Professor R. M. May – Royal Society Research Professor at the University of Oxford and at Imperial College, London

Dr J. J. Skehel – Director of the MRC National Institute for Medical Research, Mill Hill, London, and Director of the WHO International Collaborative Centre for Reference and Research on the Influenza Virus

Professor A. W. Wolfendale – Astronomer Royal. Professor of Physics in the University of Durham

Secretariat: *Dr P. T. Warren*
Dr P. M. D. Collins
Mr A. J. Leaney
Dr J. D. Skinner

ANNEX B: LIST OF THOSE SUBMITTING WRITTEN EVIDENCE

AEA Industrial Technology (Dr R Bullough, FRS)
Agricultural and Food Research Council (AFRC) (Prof. T Blundell, FRS)
Dr M Ashburner, FRS
Dr B A Askonas, FRS
Association of British Pharmaceutical Industry (Dr J Kipling)
Association of Researchers in Medicine & Science Ltd (Prof. P N Campbell)
Association of University Teachers (P Cottrell)

Dr W Barford
Dr M T Barlow
Professor A R Battersby, FRS
H. V. Beck
Dr C R Bemrose
Dr R E Benfield
Dr M J Berridge, FRS
Dr G C L Bertram
Bickerdike Allen Partners (Dr W Allen)
Biochemical Society (Dr D Stilwell)
Professor J D Birchall, FRS
Professor R D Blandford, FRS
Professor D M Blow, FRS
Sir Hermann Bondi, FRS
Sir Robert Boyd, FRS
Professor D Bradley, FRS
Professor A D Bradshaw, FRS
Dr Jeremy Bray MP
Dr S Brenner, FRS
Dr K M Brindle
British Aerospace (Mr J Arnall)
British Gas (Mr G Clerehugh)
British Institute of Radiology (Prof. C A F Joslin)
British Medical Association (Sir Christopher Booth)
British Railways Board (G W Buckley)
British Scientists Abroad (M Freeman)
British Technology Group (Mr P Tanner)
British Telecom (Dr A Rudge)
Professor A N Broers, FRS
Dr D W Bruce
Dr P G Bruce
Professor A D Buckingham, FRS
Building Research Establishment (R G Courtney)
Dr N J Bulleid
Professor M Burrows, FRS
Dr L Burton
Dr S J W Busby
Dr R Butlin

Professor F W Campbell, FRS
Cancer Research Campaign (Professor J G McVie)
R J Cashmore
CBI
CEST (Centre for Exploitation of Science & Technology (Mr J Cheese)
Dr M Charlton
Chemical Industries Association (Dr P A Leonard T D Culpin)
Professor B C Clarke, FRS
Professor J F Clarke, FRS
Professor A B Clegg
Committee of Heads of University Chemistry Departments (CHUCD)
(Professor J A McCleverty & R D Langstaff)
Conservation Unit (Dr D Leigh)
Professor E J H Corner, FRS
Sir John Cornforth, FRS
Dr A A Cottey
Council for Awards of Royal Agricultural Societies (J A C Gibb)
Courtaulds (Dr D J Giachardi)
Sir Bernard Crossland, FRS

Professor J F Davidson, FRS
Mr J H Davies
Deans of Science Committee (Professor K H Goulding)
Professor K G Denbigh, FRS
Department of Environment (Dr R J W Saunders)
Department for Trade & Industry (Dr R F Coleman)
R Devenish
Dr R H L Disney
M J Doenhoff
Dr J Doonan
Dr C J Dorman
J D Dowell
Dr P Doyle
Dr B Drobak
Dr M R Duchen
Dr M Duer
Professor M Duff

Professor S W E Earles
Economic & Social Research Council (ESRC) (Professor H J Newby)
Mr D Edgerton
Sir Sam Edwards, FRS
Dr M Elliott, FRS
Sir Roger Elliott, FRS
Dr J R Ellis, FRS
Dr P C Engel
European Environmental Research Organisation (Dr J V Lake)
Dr D E Evans
Mr W M Evans

Professor D S Falconer, FRS
Dr T Farrell

Dr G B R Feilden, FRS
Professor P B Fellgett, FRS
Fellowship of Engineering (Sir Denis Rooke, FRS)
Professor D J Finney, FRS
Dr E Fisher
Martin Flannery, MP
Professor G E Fogg, FRS
Professor Sir Hugh Ford, FRS
Dr A M Fox
Dr P M W French

Professor E Gabathuler, FRS
Professor R L Gardner, FRS
Dr G A Garton, FRS
Dr J M Gaugas
Dr W Gelletly
Geological Society (Professor A L Harris)
Dr A M Glazer
Professor I M Glynn, FRS
Professor P J Goodhew
Professor C F Graham, FRS
Professor P M D Gray
Professor D Greig
Professor M L H Green, FRS
Dr J F Gregg
Professor R W Guillery, FRS

Halcrow (Sir Alan Muir Wood, FRS)
Dr E C Hamlyn
Dr A Harrison
Dr S D Harrison
Professor R D Heap, FRS
Professor V Heine, FRS
Dr J S Heslop-Harrison
Dr D M Heyes
Professor R Hide, FRS
Dr R Hill
Sir Peter Hirsch, FRS
Dr A M Hodge
Professor G Horn, FRS
Professor G A Horridge, FRS
K Hoselitz

IBM (Dr G W Robinson)
ICI (Dr B W Langley)
Imperial Cancer Research Fund (Sir Walter Bodmer, FRS)
Professor D C Imrie
Institute of Mathematics & its Applications (Dr J C R Hunt & Ms H Brown)
Institute of Medical Laboratory Sciences (A R Potter)
Institute of Oceanographic Sciences (Dr R B Whitmarsh)
Institute of Professionals, Managers & Specialists (T M Addiscott & V Ellis))
Institution of Chemical Engineers (Ms D Farrar)

Institution of Civil Engineers (R S Dobson)
Institution of Electrical Engineers (P Secker)
Interdisciplinary Research Centre Surface Science (Prof. P Weightman)
Irish Committee for Basic Science (Prof. P K Carroll)
Professor J M Irvine

Dr H T Jacobs
Dr A T James, FRS
Professor J N R Jeffers
Sir Ewart Jones, FRS
Dr G Jones
Dr T W Jones

Professor G Kalmus, FRS
Professor P I P Kalmus
Dr E W Kellermann
Professor R D Keynes, FRS
Professor T W B Kibble, FRS
Sir John Kingman, FRS
Dr C J Kirk
Professor H Kleinpoppen

Professor M F Land, FRS
Dr A U Larkman
A M Lau
L M Lederman
Dr M H Levitt
Linnean Society (Professor M F Claridge)
Dr C W Lloyd
Sir Bernard Lovell, FRS
Professor J E Lovelock, FRS

Dr I J D MacGregor
Professor A L Mackay, FRS
Dr A E Magurran
Professor P M Maitlis, FRS
Professor J Mallard
Dr E N G Marsh
Sir John Mason, FRS
Dr J N McDonald
Dr M E McIntyre, FRS
Dr T C B McLeish
Medical Research Council (Dr D A Rees, FRS)
Merck Sharp & Dohme (Dr L L Iversen, FRS)
Professor R H Michell, FRS
Dr A Milne
Ministry of Agriculture, Fisheries & Food (Dr P J Bunyan)
Ministry of Defence (Prof. E R Oxburgh, FRS)
Sir William Mitchell, FRS
Dr P J T Morris

Professor F R N Nabarro, FRS

Dr M A Nagarajan
National Physical Laboratory (Dr P B Clapham)
Natural Environment Research Council (NERC) (Prof. J Knill)
Dr M Neal
Professor R M Needham, FRS
W J Nuttall
Mr P H Nye, FRS

Ove Arup Partnership (Sir Jack Zunz)

Dr M R Palmer
Dr M C Payne
Dr D E Pegg
Professor J B Pendry, FRS
Professor C J Pennycuick, FRS
Professor M Pepper, FRS
Professor D H Perkins, FRS
Dr R N Perutz
Professor N J Petch, FRS
Mr R Peto, FRS
Dr J R Philip, FRS
Physiological Society (Prof. R A Chapman)
J M Pick
A T Pickering
Polytechnics & Colleges Funding Council (W H Stubbs)
Professor R K Poole
Dr W C K Poon
Professor J Postgate, FRS
Professor K A Pounds, FRS
Dr H M Prichard

POLYTECHNICS
Brighton (A Simpson)
Bristol (A C Morris)
Coventry (Prof. B Ray)
East London (Prof. F W Gould)
Huddersfield (Prof. M I Page)
Lancashire (B G Booth)
Leeds (C Price)
Liverpool (Prof. W B Rowe)
Manchester (Prof. T S Jewitt)
Middlesex (Dr M M Edwards)
South Bank (Baroness Perry of Southwark)
Staffordshire (Dr G J Gittens)
Sunderland (Dr A Wright)

Professor J R Quayle, FRS

Reckitt Products (Dr R A Cowen)
K M de Reuck
Ricardo International plc (D H C Taylor)
W P Richardson
Dr D H Roberts, FRS
Professor K Roberts

Dr N J Robinson
Rolls-Royce (P C Ruffles)
Sir Denis Rooke, FRS
Royal Astronomical Society (D A Williams)
Royal Society of Chemistry (Dr J S Gow)
Royal Society of Edinburgh (Professor C Kemball, FRS)
Professor I J Russell, FRS

Professor A Salam, FRS
Save British Science (Dr J H Mulvey)
Professor D H Saxon
Professor B F Schutz
Science and Engineering Research Council (SERC) (Sir Mark Richmond, FRS)
Science Policy Support Group (Prof. J M Ziman, FRS)
Dr M Seal
Professor R C Searle
Lord Shackleton, FRS
Professor J F Sharpey-Schafer
Dr P Shaw
Shell Research (E G Masdin)
Professor N Sheppard, FRS
Lord Sherfield, FRS
Professor R V Short, FRS
Professor A C Shotter
Professor R E Smallman, FRS
Smith Associates Ltd (Dr C J Elliott & Dr B G Smith)
Sir David Smith, FRS
Professor S D Smith, FRS
Dr R A Snowdon
Society of Chemical Industry (J Wren)
Dr G H Stafford, FRS
Dr A Stephenson
Professor C J M Stirling, FRS
Dr A M Stoneham, FRS
Sir Peter Swinnerton-Dyer, FRS
T D V Swinscow

T H Thomas
Professor B A Thrush, FRS
Dr M A Tuck
Dr R M Turnball
Professor P U J Twin
Dr D A J Tyrrell, FRS

Unilever (R J Moran)
Universities Funding Council (Sir Peter Swinnerton-Dyer, FRS)

ANNEX B: LIST OF THOSE SUBMITTING WRITTEN EVIDENCE

UNIVERSITIES

Aberdeen (Prof. A R Forrester)
Bath (Prof. J R Quayle, FRS)
Birmingham (Sir Michael Thompson)
Bristol (J Franklin)
Brunel (D Neave)
Buckingham (Dr K L Shephard)
City University (Prof. R N Franklin)
Dundee (Prof. M J Hamlin)
Durham (Dr P D B Collins)
East Anglia (Prof. D C Burke)
Edinburgh (G C Webber)
Essex (Prof. M Harris)
Exeter (Dr D Harrison)
Glasgow (Sir William Fraser)
Goldsmith College (Prof. A Rutherford)
Heriot-Watt (Prof. A G J MacFarlane, FRS)
Hull (Prof. A Pugh)
Kent (Dr D J E Ingram)
London (Prof. S R Sutherland)
Manchester (S A Moore)
Open (J Daniel)
Oxford (A P Weale)
Reading (Dr E S Page)
Sheffield (Prof. G G Roberts, FRS)
Southampton (Dr G Higginson)
St Andrews (Mr D J Corner)
Ulster (Prof. R J Gavin)
UMIST (Professor A C Rose-Innes)
Wales, Bangor (Dr E Sunderland)
Wales, Swansea (Professor B L Clarkson)

Professor A E Vardy

Dr D D Warner
Wellcome Trust (P O Williams)
R M White
Sir Alwyn Williams, FRS
Dr D H Williams, FRS
K R Williams
Professor R J P Williams, FRS
W R Williams
Professor E N Willmer, FRS
Professor L Wolpert, FRS
Professor M M Woolfson, FRS
Dr L R Wyatt

Sir Christopher Zeeman, FRS
Professor J M Ziman, FRS

Note: Some organizations and insitutions have changed their names since they responded to the Inquiry. They are listed here under the names in force at the time evidence was submitted.

ANNEX C: LIST OF THOSE GIVING ORAL EVIDENCE

Agricultural and Food Research Council

Albright and Wilson Ltd.

Economic and Social Research Council

ICI plc

Imperial Cancer Research Fund

Institute of Animal Physiology and Genetics Research, Cambridge

Medical Research Council

Natural Environment Research Council

Science and Engineering Research Council

Sir Peter Swinnerton-Dyer, FRS

Professor J. M. Ziman, FRS