the responses to the Convention on Biological Diversity (CBD). An international working group was established at the third meeting of the Conference of the Parties to the CBD. Work was completed by Botanic Gardens Conservation International on a new version of the International Transfer Format for living plant records maintained by botanic gardens, facilitating the transfer of electronic data. New categories and criteria, developed by the International Union for Conservation of Nature and Natural Resources (IUCN - the World Conservation Union), were used to evaluate the status of the world's wild animal species. The results were published in the IUCN Red List of Threatened Animals at the World Conservation Congress in Montreal.

In India and China, the two most populous countries in the world, rising living standards led to massive expansion of domestic and commercial flower gardens and horticultural suppliers of ornamental plants. In Europe and the eastern side of the USA, the harsh winter of 1995-1996 caused die-back of many perennials, giving fresh opportunities to plant suppliers.

United Kingdom Perspectives

Initial estimates pointed towards a growth of 2.5% in the UK GDP during 1996. Improving consumer confidence was reflected in recovery of the housing market and in related areas of spending. For most of the year, industrial manufacturing output was weak but rebounded towards the end of the year. Overall investment expanded by 3%. At the end of the year, unemployment was about 7.2% of the workforce. Underlying inflation moved to 3.3%, very low by historical standards, but the financial markets expressed concern about the fuelling of inflationary pressures and potential effects on exports of a rise in the value of sterling. Holders of Ecu-denominated EU grants are beginning to suffer the effects of Ecu revaluations, making EU funding unattractive for research linkages.

The Public-Sector Borrowing Requirement remained well above target, severely restricting the scope for tax cuts and/or increases in public spend, even in the politically favoured areas of education, health, and law and order.

Britain sharply improved its competitiveness, according to the World Economic Forum's Global Competitive Report 1997, putting it in seventh place worldwide, below Singapore, Hong Kong, USA, Canada, New Zealand and Switzerland. Acquisitions of UK companies by foreign corporations in 1996 reached $38.5bn, up 8% from 1995. UK-based companies purchased overseas businesses to the value of $34.1bn. Britain received about 40% of the inward direct investment reported by EU members in 1996, almost double its share of a year earlier. In addition, the UK attracted bigger inflows than any industrialised country except the USA. UK inflows, which rose to $31.6bn, were more than double those into France, the next most popular country, according to the OECD. Inward investments into most other EU states fell. The OECD data indicated that Britain was the third-largest country for investment after the USA and China during the period 1991-1995.

A survey by Coopers & Lybrand considered that accounting for tax in line with the newly established global accounting code being developed by the International Accounting Standards Committee, rather than in line with the UK's unique system of partial provisioning, would add 10% to the gearing of the UK's top 90 companies. Gearing is a measure of the extent to which a company is financed by debt rather than equity. This effect on gearing would hit hardest the capital-intensive sector and may influence future UK investments. The UK actuarial approach on pensions also differs from the international current-market-valuation system.

The UK R&D Scoreboard 1997, produced by the Department of Trade and Industry, demonstrated the relatively poor performance of UK companies which continue to have the lowest ratio of R&D to sales of any G7 country. In 1996, company R&D as a percentage of sales was 2.3 in the UK and Italy, compared with 4.0 in France, 4.3 in the USA, 4.7 in Germany, 4.9 in Japan, 6.2 in Switzerland, and 7.4 in Sweden. On a sector-by-sector basis, the UK was, with few exceptions, consistently below the sectoral average. Civil expenditure on R&D has declined in the UK in real terms uniquely among the G7 nations since 1986. According to a survey by the Confederation of British Industry and NatWest Innovation, manufacturers cut 'innovation' spending (which includes market research and training as well as R&D) from 6.2% of turnover to 5.9% in 1996, but non-manufacturers increased their 'innovation' spending from 10.6% to 11.8% of turnover. Clearly, the UK Foresight Programme needs to retain its evangelical mode to address the paucity of R & D investments by UK industry.

Adverse publicity generated by the BSE and *E.coli* crises placed UK agriculture under hostile scrutiny by the public, politicians, overseas customers and competitors. Food safety, quality and traceability; animal welfare and dignity; malcontentment with the costs and processes of the Common Agricultural Policy (CAP); and urban perceptions of agriculture posed special difficulties. Not only was the industry destabilised, but regulatory issues, the rôle of science, food preparation and marketing, and waste disposal systems were examined in great detail. Data for UK agricultural production are readily accessible from the Ministry of Agriculture, Fisheries and Food (MAFF) on http://www.maff.gov.uk/. Yields of wheat, barley, oilseed rape and sugar beet increased markedly in the decade 1986-1996. Wheat production in 1996 increased to 16mmt, barley declined to 7.8mmt, oilseed rape increased to 1.5mmt and sugar beet rose to 1.4mmt. Production data for potatoes, hops, apples, pears, cauliflowers and tomatoes were only available for 1994. Output valuations for 1996 indicate that cereals were £3bn, oilseed rape £419m, sugar beet £360m, beans and peas for stockfeed £140m, potatoes £564m, horticultural vegetables £1.1bn, fruit £260m, and ornamentals £675. Of the input costs in 1996, seeds amounted to £334m, fertilisers and lime £823m, pesticides £459m, and farm maintenance £404m.

The net worth of UK agriculture rose to £60bn but profitability in the context of farm income declined by 7% from 1995 values to less than £46bn. Output rose by £377m, but subsidies to farming (a 52% rise mainly in the form of BSE-related payments) exceeded income, and cost increases rose more rapidly than total output value. Much of the 'profitability' related to currency devaluations since leaving the ERM in 1992, and the improvement in net worth reflected increases in land value. Strengthening of sterling in 1997 will seriously affect the value of Ecu-based subsidies and will put pressure on market prices and competitiveness in export markets. Introduction of the single currency (Euro) would have a direct bearing on agricultural profitability.

Over the last ten years, the total farming labour force in the UK declined by 12.4%, although employment and population levels in the rural areas have grown. The effects of the 1992 MacSharry CAP reforms would indicate that there will be a continuing annual decline in direct employment to give a smaller workforce distinctly skewed to the older age groups.

Scottish farm incomes declined by 18.5% in 1996 to £443m, with the gross output down 3.5% at £2bn. The value of farm crops declined 10.2% to £526m, with potato output at £103m, nearly half the 1995 level. Cereals rose to £369m.

The draft UK Plant Varieties Bill, which seeks to update the 1964 Plant Varieties and Seeds Act in line with UPOV 1991, raised questions about (i) protection afforded to holders of rights to an initial variety (cultivar) compared with the 1994 EC Plant Variety Regulation, (ii) hybrids, (iii) intra-specific-use groups, (iv) alignment of penalties for non-compliance with those agreed under EU legislation, (v) transition arrangements to bring all protected varieties under the farm-saved seed provisions from July 2001, and (vi) GM crops.

According to a report from Strathclyde University, speciality salad products offer the best prospects for the European salads industry. Over-supply of round tomatoes, conventional lettuce, cucumbers and peppers have led to market saturation, forcing out inefficient producers. Diversification into new cultivars offers potential for higher margins. Vine-ripened and specialist tomatoes, specialist lettuce and other salad species, and pre-prepared salad packs are rapidly developing areas of investment. UK consumption of salads was the lowest in Europe at 12kg *per capita*, compared with 20-40kg in most European countries, and 107kg in Spain.

Within the wider scope of the Uruguay round of GATT (see previous Annual Reports), signed in 1994, the EU accepted reductions in the volume of food exports onto the world market in return for retaining its direct support to the agricultural industry, a powerful lobby but largely inefficient industry in continental Europe. Consequently, exports of cereals and animal products from the EU are set to stagnate or fall by 2001, whereas exports of these commodities from Australia, Canada, New Zealand and the USA are projected to increase substantially to meet the needs of expanding populations, particularly in the Far East and Pacific Rim.

Before the end of the six-year transition period for reducing subsidised exports, a new round of negotiations will start in 1999 under the auspices of the

WTO. This will have the express intention of making substantial and progressive reductions in agricultural support and protection, an aim that will force changes in the CAP and Fonds Europeen d'Orientation et Guidance Agricole expenditure. In any case, changes will be essential for eastward enlargement of the EU.

Well in advance of the WTO negotiations, agreement has to be reached by consensus of EU member nations on reshaping the CAP. Questions about the high costs of the CAP; the desirability of redirecting CAP funds to other aspects of the rural economy; intra-EU competition; CAP-related fraud, corruption and anomalies; introduction of technological innovation currently quenched by subsidy; rural employment; maintenance of and access to the rural environment and its resources; and restructuring to achieve development of the agricultural and horticultural industries, cannot remain unanswered for long. In the USA, the 1996 Federal Agricultural Improvement and Reform Act will over 7 years liberalise farm policy, reduce government intervention in production and cut subsidies, thereby aligning many sectors of US agriculture with the requirements of the WTO.

Exposure of UK farm commodities to world markets would bring about a marked decrease in production costs to match those of non-EU competitor nations. Yield efficiency and competitive innovation need to become paramount, as do longer-term relationships with end-users. In the interim, price volatility will provide problems for most growers, but opportunities for the few with foresight or good fortune.

Biotechnology

Biotechnology is the collective noun for the application of organisms, parts of organisms or sub-cellular entities, or biological processes, to manufacturing and service industries, including agriculture, horticulture and forestry, as well as environmental management, pharmaceuticals and diagnostics. The aims of the technology in respect of plants encompass: biomass production; production of chemicals and useful products; decomposition of wastes and recovery of valuable components; generation of new types of organism thereby extending the scope and precision of plant breeding; exploitation of fermentation; diagnosis, prevention and treatment of diseases; unravelling metabolic pathways; selecting parents for breeding lines; checking ownership and origins of cultivars; assessing biodiversity; and propagation of cells and whole organisms.

Recent technological and intellectual advances in molecular genetics, particularly sequencing of genes and proteins, isolation and insertion of genes into receptor organisms, development of marker genes, and gene amplification (notably those techniques based on the polymerase chain reaction) have, within a decade or so, given rise to a highly pervasive multidisciplinary subject - the so-called 'new biotechnology' - such that civilisation might be regarded as entering the age of the biotechnologist. Although technology is usually defined as applied science of commercial value, biotechnology is far more than a straightforward technology, for it can be employed at a basic level to study the most fundamental processes of life.

With the advent of a battery of techniques to overcome barriers to sexual reproduction, as well as to insert genes or sequences into the DNA of receptor organisms and sub-cellular entities containing nucleic acid (this therefore excludes BSE or scrapie-like bodies) to form transgenic organisms (GMOs), the inherent similarity of the genetic language in the major groups of organisms has been unequivocally demonstrated. Exploitation of these discoveries in ways that do not abuse responsibility to safeguard the natural world is a prime concern. Political, public and industrial pressures - especially if ill-informed, prejudiced or conniving - could bias or jeopardise proper scientific advances and consumer acceptance of the technology. Regardless of these pressures, though, biologists are coming to terms with a fundamental reappraisal of the concepts of taxonomy and systematics. Genotypes are assuming as great an importance as phenotypes, with the added realisation that genes as well as money can be banked.

Biotechnology is a major growth industry worldwide, particularly in the USA. The original Technology Foresight and the current Foresight Programmes of the UK (see previous Annual Reports) and those of other nations have highlighted the potential rôle of biotechnology for wealth creation, quality of life and UK competitiveness. SCRI is at the forefront of those areas of plant biotechnology relevant to its mission and aims. The new technology offers novel approaches for the goal of achieving environmentally sustainable development.

Agenda 21, the participatory plan of action jointly formulated and agreed upon by the world community at the Earth Summit in Brazil in June 1992, proposed a number of inter-related actions aimed at environmentally sustainable development. The Inter-Agency Committee on Sustainable Development designated the United Nations Industrial Development Organisation (UNIDO) as the task manager for chapter 16 of Agenda 21, which deals with environmentally sound management of biotechnology.

In 1995, UNIDO reviewed the progress achieved on the implementation of this programme and noted that many of the issues discussed in chapter 16 were also reflected in at least seven chapters of Agenda 21. If properly managed, biotechnology can play an essential rôle in supporting the economic and social development of both MDCs and LDCs. Biotechnology development and applications continue to grow at a rapid rate, leading to an expanding range of products and processes across several sectors that began with pharmaceuticals and health care and now extends to agriculture and the environment.

With respect to biosafety, one provision of the Convention on Biological Diversity, Article 8(g), required contracting parties to: *"establish or maintain means to regulate, manage, or control the risks associated with the use and release of living modified organisms resulting from biotechnology which are likely to have adverse environmental impacts that could affect the conservation and sustainable use of biological diversity, taking also into account the risks to human health."* Another provision, Article 19(3), stipulates that: *"The Parties shall consider the need for, and modalities of, a protocol setting out appropriate procedures, including, in particular, advance informed agreement in the field of the safe transfer, handling, and use of any living modified organism resulting from biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity."*

What of the potential threats to biodiversity from modern biotechnology products, particularly organisms with novel traits? While the term biotechnology is nowhere clearly defined, the way in which it is used suggests it is most commonly meant to refer to plants, animals, and microbes that have been modified with recombinant DNA techniques. The largest category of such organisms is new agricultural varieties of existing crop plants.

The single largest threat to biological diversity arises from the conversion of natural habitats or native lands to urban development or to agriculture, often with monocultures, or their ecological near-equivalents. After this threat comes the dangers from habitat degradation through pollution or unsustainable extractive practices such as clear-cut logging, overfishing and mineral extraction. Against this background, the threat to biological diversity from the products of modern biotechnology is infinitesimal. But what if all the products presently in the R&D pipeline were now on the market?

Nearly all the new crop cultivars being produced with the techniques of modern biotechnology have been modified or selected using biotechnology to sustain or increase yields, whether through imparting to them resistance to pests or diseases or through increasing their ability to withstand competitive pressures (or to eliminate such pressures) from, for example, weeds or other biotic or abiotic stresses. It has been argued that if the genes added to existing cultivars to impart such characteristics were to flow (generally by sexual recombination) into wild or weedy relatives, weed problems could be exacerbated or wild, pristine gene pools could become contaminated. In the vast majority of cases, however, the pests or diseases detrimental to agricultural yields are not the limiting environmental constraints on the wild relative being receptive to out-breeding from the domesticated cultivars. Experience shows that selection pressures found in nature do not favour such gene flow from modified crops to wild relatives.

A far more likely path through which potential characteristics or traits from genetically modified crops could have an impact on biodiversity is, in the absence of constraining population growth, by decreasing the rate of habitat loss through increased yields. The most likely impact on biodiversity from novel crop varieties, therefore, is to alleviate the main threat.

By 1996, the future of biotechnology in the European Union was fast becoming a victim of the very debates surrounding it. For the most part, **food and environmental safety** of GMOs, in tandem with commercial development, occupy the thoughts of the regulatory authorities and the public in the USA, Canada, Japan, Argentina, *etc.* Conversly, the EU is engaged extensively and exhaustively in ethical and moral discussions of the **processes** of biotechnology, operating with an incomplete and inconsistent legal framework, an unclear patent position, indecision over labelling of GMOs and their products, an inadequate investment climate, risk-averse entrepreneurs, and poor public acceptance aided by aggressive antibiotechnology organisations and insensitive biotechnology industries. In appealing for action rather than endless discussion, Sir William D P Stewart, President of the UK BioIndustry Association and former Chief Scientific Adviser to the Government, whose landmark 1993 Science White Paper helped revolutionise and re-focus UK science, forecast the value of the global biotech industry to reach $90bn by the turn of the century. Ernst and Young estimate that by this time the world agricultural and food biotechnology market could reach $46bn.

Concerns about biotechnology relate to nine main areas.

1. Even though genetic modification was the first technology to have a raft of controlling legislation in place to ensure human health, and environmental safety, well before the first products reached the market place, environmentalists have expressed concern at the lack of statutory post-approval monitoring when GM crops move from field trials to commercial production. Others have reservations over the lack of uniform and comprehensive international standards for GM regulation, approval and labelling.

2. The widespread use of genetic modification might lead to the erosion of biodiversity, with increased dependence on a narrowing range of agricultural and horticultural crops. Biotechnology, however, provides the tools to measure and extend biodiversity, and improved crop performance reduces pressure on fragile habitats.

3. Not enough is known about how ecosystems work, and the release of GM crops could have disastrous consequences. GM crop release could disrupt the environment through the undesired spread of a modified crop, by transfer of chemical or pathogen resistance to weedy relatives, or the unexpected production of harmful toxins. World-wide, GM crop releases to date prove otherwise, but monitoring is essential.

4. Herbicide-tolerant crops may tie farmers in to seed-agrochemical packages, possibly leading to increased herbicide use and the risk of herbicide-tolerant crops and their genes spreading into the wild environment. Of course, herbicide tolerance exists in conventionally bred cultivars, and experience of herbicide-tolerant GM crops, albeit only over a short time scale, shows major environmental benefits in reduced herbicide usage. US farmers report a 5% yield rise and 33% less herbicide use in Herb® GM soyabean crops.

5. Using biotechnology to develop pest- and disease-resistant crop varieties could possibly lead to the creation of new pests or diseases, or the transfer of resistance to wild relatives. This has not been shown to be valid to date, but monitoring is required.

6. Herbicide- and antibiotic-resistance genes used as markers in the GM process might be transferred into the environment or human food chain. Many of the marker genes were only required in the early steps of breeding selection and have been superseded; to date, there are no unacceptable risks.

7. Biotechnology could inadvertently result in higher levels of human toxins, a reduction in beneficial nutrients, unexpected allergic reactions, or even the inducement of long-term metabolic consequences. This is an area for the regulatory authorities.

8. For some religious and other groups and individuals, biotechnology is 'unnatural', 'ungodly', and unacceptable ethically and morally. Strongly held views are difficult to change and democratic rights must be expressed to ensure safeguards. A UN code of bioethics is expected in 1997. It is really the threat of misuse of genetic engineering that raises questions of ethics.

9. Some patent protection relates to discovery rather than invention, and some patents are unacceptably broad-spectrum, oppressing releases of competing products or organisms. In their decision in the Biogen v Medeva biotechnology case, the House of Lords in 1996 considered priority dates, the need for the specification to contain an 'enabling disclosure' to allow the invention to be performed over the full width of the claims, the date at which the specification would be sufficient, and obviousness. Broad claims in future will be difficult to sustain legally without adequate enabling disclosure.

In February 1997, the team led by Ian Wilmut at the Roslin Institute in Edinburgh and PPL Therapeutics gained world-wide publicity surrounding the birth of a live lamb, 'Dolly', developed from a single cell originating from a mammary-gland cell line taken from an adult sheep. Dolly, whose picture graced front pages and covers of newspapers and journals, was the first mammal to be asexually cloned by transferring the nucleus from a donor sheep cell, cultured *in vitro,* to an unfertilised sheep oocyte from which the nucleus had been removed. As a consequence, Dolly was (with due allowance for cytoplasmic effects) genetically identical to the sheep from which the donor nucleus had been taken. This excellent research was disgracefully and inaccurately projected by certain sections of the media and various zealots. Hastily drafted legislation to ban human cloning, rather than introduce a brief moratorium, was effected in many countries, obstructing highly desirable aspects of human cloning, such as skin grafts, drug production and 'spare-part' organs. As an editorial in *Nature* points out, the history of science suggests that efforts to block its development are misguided and futile. The quest for knowledge is inevitable; the responsible deployment of knowledge, however, presents the greatest challenge to modern society, and to those who cannot comprehend, adapt to, or benefit from change.

It should be pointed out that for thousands of years, plants have been asexually cloned from cuttings, offshoots, corms, bulbs, rhizomes, tubers, stolons and buds. Modern biotechnology, in tandem with tissue, organ and single-cell culture systems, make plant cloning more efficient, more predictable, and invaluable for phytosanitary, mass propagation and phytochemical purposes. Selective nuclear and organelle additions and subtractions are revealing the rÛles of the various cellular components. By introducing a dedifferentiation phase, it is possible to create valuable and fascinating somaclonal variation.

New forms of legislation, regulation, product labelling, industry-wide codes of practice *(e.g.* that operated by the British Society of Plant Breeders, the National Farmers Union and United Kingdom Agricultural Supply Trade Association), monitoring systems and the like have been or are being implemented within the EU. Some are fully justified, but others meet poorly informed, often paternalistic political and pressure-group concerns. Resources that could be spent on R&D are being diverted to overbearing regulation and resource-sapping bureaucracy in a zealous application of the precautionary risk principle. Professor John Marsh of Reading University stated that *"there is a serious problem in striking a socially responsible balance between the influence of the articulate and the evidence of the informed".*

Within the EU, labelling will only be voluntary for transgenic maize, soybean and 11 other products awaiting approval. Thereafter, all transgenic seed and products deemed to be 'live' must be labelled to allow users further down the food chain to identify them. Labelling will not be necessary for derived ingredients and products from transgenic crops which are chemically identical to conventional foodstuffs. Scientists are fully in favour of all information being provided to consumers, *via* labelling if necessary. The labelling must be complete, equitable, non-pejorative and cover conventional and transgenic organisms.

In North America and Europe there are no food shortages and there is growing awareness of food safety and environmental issues. Biotechnologically derived medicines or non-food items (*e.g.* chemical feedstocks, fibres, environmental clean-up) and processes do not provoke such adverse reactions as GM foods. Nonetheless, in 1996, large quantities of genetically engineered maize, soybeans, cotton and potatoes were planted in the USA and much larger areas were scheduled for 1997. Thus, in 1996, there were 200,000 hectares of Bt maize, representing 0.6% of the total maize crop, with the projection of a ten-fold increase in 1997. For Herb® soyabeans, the 400,000 hectare planting in 1996 was expected to increase to 3-4 million hectares in 1997, with an additional 100,000 hectares in Argentina. By 2000, the USDA expects 40-50% of US crops to be GMOs. Transgenic crops were also grown extensively in China, Australia and elsewhere. Enzymes and other metabolites that influence the texture, appearance, preservation, flavour and nutritional quality of food are under biotechnological development.

In September 1996, the Senior Advisory Group Biotechnology and the European Secretariat of National BioIndustry Associations, which includes the UK BioIndustry Association, united to form EuropaBio, the new European Association for Bioindustries. EuropaBio will represent the interests of more than 500 companies and 8 national associations in Europe involved in the R&D, testing, manufacture, sales and distribution of biotechnology products. The industry has already created more than 180,000 jobs in Europe.

According to Keith Binding of Arthur Andersen, in 1996 in the UK there were 219 'biotech' companies (31 'agbio', 76 'biopharm', 50 diagnostic and 62 suppliers), employing more than 10,500 staff, with a revenue of £702m and an R&D spend of £190m. By the end of 1998, it is estimated that there would be 265 companies (45 'agbio', 125 'biopharm', 45 diagnostics and 50 suppliers) employing over 13,750 staff, with forecast revenue of the current companies alone in excess of £1.5bn and R&D spend of £319m. Very little venture capital is invested in non-health biotechnology at present, but never before have the R&D advances, discoveries and inventions been so exciting.

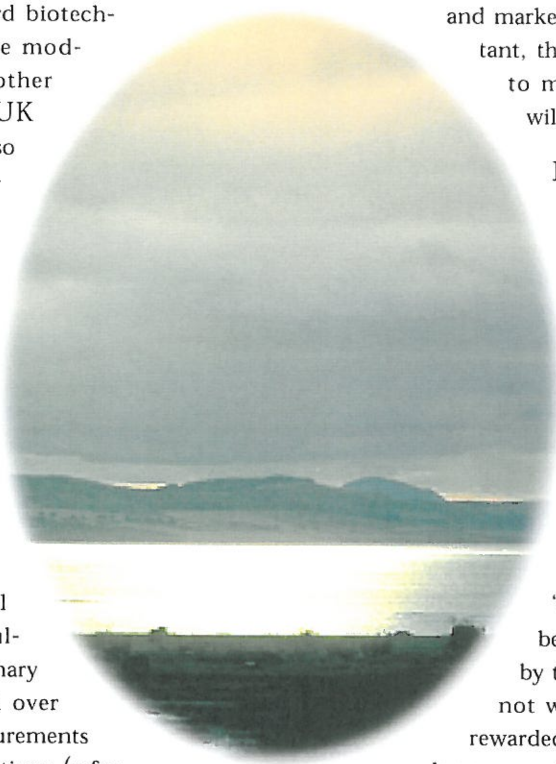
Most investments in molecular genetics relate to human genomics. The pace of the Human Genome Project (HGP) quickened in 1996. Scientists from the USA, Canada, Europe and Japan published the most complete map to date, detailing the sequence and location of more than 16,000 of the estimated 50,000-100,000 human genes. The new map, available on the Internet through the US National Library of Medicine (http://www.ncbi.nlm.nih.gov/science96/), is a valuable source of information. The range of agricultural, horticultural and forestry crops, their economic and environmental value, genetic complexity and genome size, will eventually mean that a future redistribution of effort and resource from the HGP to crop genomics will have to take place. The high-profile genomics research projects at SCRI are especially productive and influential; their potential impacts on agriculture, horticulture, forestry and the natural environment are beginning to be appreciated outwith the scientific community.

Research Assessment in the UK

Public-sector research in the financial year 1996-1997 contracted in financial terms and in the numbers of scientists and support workers employed. The contraction is set to continue. The trends and the various reviews, initiatives and constraints are described in previous Annual Reports. One conspicuous feature of British science has been the virtual demise of pure and applied botany in academia, to leave but relatively few specialist university departments and individuals to link with the few Public Sector Research Institutes concerned with the plant sciences. There is a real shortage of UK-based, qualified botanists to review scientific manuscripts and grant applications, and many of the existing staff will retire within the next 10 - 15 years. In contrast to the squeeze on UK science funding, however, the rate of global scientific progress has accelerated and links with industry have become increasingly productive. Attempts have been made to measure the quality, productivity and impact of the research funded by the public sector. Considerable emphasis seems to be placed on bibliometric data, particularly on citation analysis, which is claimed to measure the international impact of the research (*i.e.* amount of attention given to a piece of work) with a large measure of impartiality said to contrast with peer review.

Citation indices do have drawbacks *e.g.* (i) there is a varying time lag between publication and citation, depending on the journal and the field of study. The citation window of three years used by the major providers of data has only empirical support and will vary from subject to subject, particularly where long-term multidisciplinary research is involved. (ii) Publications covered by the main US provider of data do not include books, a large number of specialist journals, and conference reports. (iii) A strong bias exists towards US journals, disfavouring non-US journals, and thereby prompting scientists to publish in expensive journals and 'bandwagon' journals. On-line journals such as *Molecular Plant Pathology On-Line*, pioneered by Adrian Newton at SCRI, are not presently incorporated in citation analyses. (iv) Citation can be positive or negative, and although there are attempts to eliminate self-citation, there is a modern trend to brevity by citing reviews, effectively eliminating citation of originators, discoverers and pioneers. (v) Citation cartels can build up, as groups collaborate and for funding reasons wish to reduce recognition of competitors. (vi) There is a strong techniques bias and bandwagonning into high-impact topics to the detriment of specialist, but nonetheless crucial areas of science. Those in unique and highly specialist, sub-discipline-related areas are particularly disadvantaged. Applied and strategic areas of work and the relevant journals are diminished in stature, even though applied and strategic areas of science can initiate areas of basic science. Citation analysis works best for basic or fundamental research driven by curiosity at an individual level, but is not always a measure of innovation. (vii) Although widely carried out, cross-field comparisons are invalid; research communities differ greatly in their size, nature and duration of their work, and their methods of communication. (viii) Citation analyses reflect history - so-called fast-track fossil records - potentially supporting the declining rather than recognising the rising individual group or institution. (ix) Problems exist over the classification of articles, their titles, key words, names and initials of authors, their addresses, other index terms *etc.*

Alternatives to citation analyses are not hard to find with the necessary attributes of impartiality and international impact. At SCRI, our mission and remit are related to, and coordinated with those of the other Scottish Agricultural and Biological Research Institutes and our sister institutes of the Biotechnology and Biological Sciences Research Council, and Horticulture Research International; namely, we are driven by a quest to solve difficult, long-term research problems that will lead to wealth creation and improved competitiveness for our related industries, and we aim to contribute to the understanding and quality of life. The research is essentially but not exclusively strategic in nature; sustaining, characterising and exploiting international-grade genebanks and germplasm collections; advancing plant breeding, genetics, pathology and physiology; taking forward biotechnology; pioneering predictive modelling; and fostering many other areas highlighted in the UK Foresight Programme. We also sustain underpinning innovative research.



The research programme in each of these various institutions, although not based simply on the curiosity of an individual, is dependent on talented and special individuals. Our programmes are multidisciplinary, high-quality, and demonstrably high-impact simply by virtue of their enormous beneficial effects on agriculture, horticulture, biotechnology and veterinary studies throughout the world over many years. Thus, such measurements as numbers of relevant publications (refereed and non-refereed), peer-reviewed books and chapters, full economic costs *per* publication, and *per* scientist, invited addresses to conferences, refereed conference proceedings, patents, cultivar releases, and their market share, competitive grants and contracts awarded, peer reviews, industry links *etc.* collectively have long been deployed by senior staff in the UK institutes to measure quality, productivity and impact. As industrial funding, exclusivity and market impact become more important, the relevance of citation indices to mission-driven organisations will diminish.

In an age of ferociously tight budgeting, forensic monitoring and perpetual review, cross-comparisons between individuals, groups, institutions and nations are in danger of attaining new heights of intellectual sterility. Scientific output needs sophisticated measures and patience, without which publicly funded science will become very short-term and 'clubby'. Science is also fast becoming a career to be avoided by talented young people, who do not want an unstable and poorly rewarded vocation that depends on a long apprenticeship learning and exploiting the vocabulary, concepts and technologies of science. SCRI, pleasingly, provides a productive and quality environment for research, in a beautiful setting by the River Tay. We plan for the future.