Report of the Director

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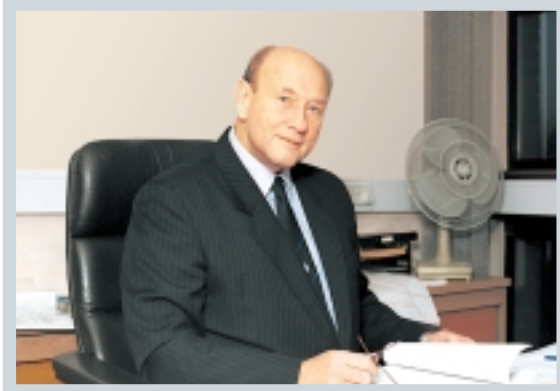
Global perspectives of factors influencing agricultural, biological and environmental sciences, and their associated industries : 1999-2000*

Preamble

Food production and the use of products from living organisms for non-food purposes – timber, paper, rubber, starches, oils and fats, cotton, wool, medicines, cosmetics *etc*. – are subject to complex market, social, legal and political forces. In recent years, catastrophic food shortages caused by biotic and abiotic factors have not figured large in reports by the broadcast and publishing-based media, irrespective of severe problems for large numbers of subsistence farmers in less-developed countries (LDCs). For example, in India, following crop failures, around 1000 farmers committed suicide in Andhra, Karnataka, and Maharashtra in the last 3 years, according to P Chengal Reddy. At the same time, the scale of public-sector investments world-wide into research on improved cultivars and animal breeds, pests and diseases of crops and livestock, whole-organism physiology and biochemistry, and the associated agronomic and development work, declined further. By way of example, financial support for the institutes comprising the Consultative Group on International Agricultural Research (CGIAR) system has been sharply constrained. Parenthetically, the European Union's administrative funding failure in 1999 reduced the financial support of the CGIAR's International Potato Center (Centro Internacional de la Papa) by $1.9m, leading to a major deficit. Agriculture, horticulture, and forestry – the primary production industries – are especially vulnerable to adverse weather and the rapid surmounting of control measures by a vast array of pests, weeds and diseases. Yet primary production is no longer regarded internationally as a high-priority area of research spend. In other words, comforted by current levels of global production, there is a largely urban-based assumption that the existing scientific, engineering and technological effort is adequate to safeguard the growing global population. Over-production in certain areas, aided by the continuing decline in commodity prices, has placed further pres-



* This review updates and enlarges on themes developed in my previous accounts in the *SCRI Annual Report* series.

sure on investments in the primary industries and their associated research activities.

In the more-developed countries (MDCs), pressure groups and special-interest groups gained greater influence over democratically elected governments, and many non-governmental organisations (NGOs) engaged directly with international governmental-based bodies. Certain pressure groups were actively opposed to the application of modern scientific advancements which they regarded in a political context as manifestations of globalisation, multi-national corporations, undesirable social change and environmental harm, all reinforced by a legally complex patent protection system. Cynicism, suspicions, misconceptions and prejudices about 'profits' and the rôle of the profit motive and private-sector companies in modern socio-economic systems were frequently expressed. Some of the more physically active pressure groups continued to enjoy the taxation benefits of charitable status and uncritical support by large sections of the press and television.

One particular target in the UK for many anti-technology protestors, some of whom were willing to attack legally permissible field trials, was the agricultural biotechnology sector. Playing on the naïvety of a substantial proportion of the population and political representatives to understand basic principles of conventional plant breeding, ecology, genetics, scientific research, risk-benefit analyses, the difference between regulatory and so-called scientific failures, certain groups effectively destabilised agriculturally related European plant biotechnology. Agriculture in the UK was also influenced by the aftermath of the bovine spongiform encephalopathy (BSE) fiasco, animal-rights protestors, livestock and crop diseases, proponents of 'organic' manure-based systems, increased regulation and associated imposed costs, falling commodity prices, falling profits, raised standards and customer expectations, the growing discontinuity between scientists and the public, and entrenched attitudes to subsidies of various kinds. Mistrust of the food supply and the high levels of subsidy inputs meant that the industry increasingly assumed the mantle of a quasi-nationalised public service, more akin to urban transport, attending to the needs of a population that is becoming both divorced from, and unappreciative of, the challenges facing producers and processors, organic and conventional alike.

Almost all areas of human endeavour influence the agricultural, biological and environmental sciences, and their associated industries. Research and Development (R&D) programmes are directly and indirectly shaped by a multiplicity of factors, including economic performance, political decisions, trading blocs, employment and intellectual property (IP) laws, population pressures, defence-spending, wars, refugee pressures, poverty, taxation and consumer issues, media pressures, scandals, balance of payments, profitability and entrepreneuralism, international comparators, the quality of the labour force, perception of science and technology and, not least, by the stream of scientific discoveries and inventions.

Early in 2000, the 'first draft' of the human genome was completed, well in advance of the projected completion date. The genetic revolution has raised major bioethical issues in the use of human embryonic stem and germ cells, on ownership and exploitation of genetic information –particularly by medical insurance companies, cloning, transgenic organisms, and transgenic foodstuffs. Infectious diseases world-wide accounted for 13.3m of the 53.9m deaths world-wide in 1998, according to the World Health Organization (WHO); the main diseases were acute respiratory infections (including influenza and pneumonia, 3.5m), AIDS (2.3m), diarrhoeal diseases (2.2m), tuberculosis (1.5m), malaria (1.1m), and measles (0.9m). Infectious diseases accounted for 50% of deaths in LDCs, and took place against a background of growing drug resistance of microbes and poor nutrition. In 1999, a large number of outbreaks of infections in the UK were attributable to human consumption of contaminated food and water, caused principally by *Campylobacter; Salmonella; Rotavirus (Reovirus); Giardia lamblia; Cryptosporidium; Shigella; Clostridium difficile; Escherischia coli*, especially *O157; Entamoeba histolytica; Astrovirus; Aeromonas; Yersinia; Listeria; Calicivirus; Brucellosis; Staphylococcus aureus; Pleisomonas shigelloides;* and various *Bacillus* species. Provisional data for England and Wales revealed a total of 103 000 reported cases of food poisoning for 1999, with estimates of reported cases being only a small proportion of total cases, raising again the potential problems of manure-based agricultural and horticultural systems, problems compounded by the longevity of many bacteria and gut parasites, and poor food hygiene.

Fruit and vegetables (*e.g.* apples; tomatoes; citrus fruits; soft fruits such as raspberries and blueberries; cruciferous vegetables, such as broccoli, cabbage, turnip and swede *etc.*), and products derived from them, were associated with disease prevention,

notably of various kinds of cancer and ischaemic stroke. Uncontaminated foods derived from plants contain a wide range of compounds that may not have direct nutritional benefit, but which may affect the consumer. Those compounds may be exogenous (*e.g.* agrochemicals) or endogenous (*e.g.* potential toxins if consumed to certain levels, including alkaloids, cucurbitacins, cyanogenic glycosides, furocoumarins, glyco- and glucosinolates, hydrazine derivatives such as agaritine and gyromitrin, lathrogens, lectins, nitrates, phytoestrogens, protease inhibitors, psoralens, safrole, saponins, and vasoactive amines). Food preparation and processing can often add adventitious compounds, and offer opportunities for microbial contamination. A major target of plant breeding has been the reduction or elimination of undesirable, naturally occurring, endogenous compounds; new targets include the enhancement of factors regarded as beneficial to health.

In areas of science akin to the life sciences, there were exciting new discoveries and reports. Thus, B Conrad and R Taylor (Harvard), C Breuil (Université de Paris-Sud), and F Diamond (Rutgers) were able to prove the full Taniyama-Shimura Conjecture, that every elliptic curve is a projection of a modular curve. In nuclear chemistry, there was strong evidence for the existence of comparatively stable superheavy elements. This arose from joint research at the Joint Institute for Nuclear Research in Russia and the Lawrence Livermore National Laboratory in California, who announced the synthesis of element 114. Also, research at the Lawrence Berkeley National Laboratory, also in California, provided evidence for elements 116 and 188. These three super-heavy elements have a nuclear structure giving them half-lives much longer than their lighter short-lived neighbours on the periodic table of elements, and constitute members of the so-called 'island of stability', and are possibly stable enough to have commercial or industrial application. L Becker (University of Hawaii) provided evidence from extracts of the 4.6 bn-year-old Allende meteorite that the all-carbon, hollow, cage-like fullerines exist in nature, and were they to be present in asteroids and meteorites, could have provided some of the carbon essential to life on Earth. R H Baughman of AlliedSignal, New Jersey, reported the development of carbon nanotubes that flexed in response to changes in applied voltages, enhancing therefore their utility in microscopic and nanoscopic engineering applications. Developments by F Keilman and B Knoll (Max Planck, Martinsried), in atomic-force microscopy involving a tunable infrared (IR) beam focused on the tip, and an associated IR detector to detect scatter from the sample, have enabled high-resolution analyses of the chemical composition of thin films.

The most detailed composite images ever of electronic bonds were obtained by J C H Spence and J M Zuo (Arizona State University) using x-ray diffraction pattern analysis from a copper oxide compound. This research has particular relevance to the development of high-temperature superconductors. In applied chemistry, a team at the University of California, Los Angeles, and Hewlett-Packard Laboratories, Palo Alto, led by J R Heath, reported the use of the synthetic complexes, rotoxanes, as the first operational molecule-based logic gate, giving rise to the possibility of molecular-based 'chemical' computers within the next decade.

In atomic and optical physics, there was major progress in the USA, Japan and Germany in the development of atom lasers, whereby the output is a beam of atoms that exist in coherence *i.e.* have the same de Broglie wavelength. Atoms (sodium or rubidium) are trapped to form a new kind of matter – the Bose-Einstein Condensate (BEC) in which the atoms exist in the same quantum state. Thereafter, a portion of the trapped BEC is permitted to emerge as a beam, albeit short-lived. Nevertheless, the potential range of applications, including microscopy, lithography, and even atom holography to build tiny structures atom-by-atom, will create huge interest in life-science companies and academia.

One of the most apparent manifestations of globalisation is that of international jurisdiction, especially where it interferes with or overrides state sovereignty and local human rights laws, if any. This phenomenon was extended by the efforts made during the year to establish an International Criminal Court to try war-related crimes, crimes against humanity, and genocide; the initiative was brought into being by the Rome Statute which was signed by 89 states in 1998. Developments arising from the International Criminal Tribunal for the former Yugoslavia served to highlight current deficiencies in the jurisdiction of international tribunals, highlighting the potential for double standards, vexatious litigation, and the erratic incorporation of conventions such as the 1984 International Convention Against Torture, or the European Convention on Human Rights, into national legal systems.

Biological weapons, along with nuclear and chemical weapons, telecommunications and Internet-based attacks were regarded as potential threats from modern terrorism. The International Institute of Strategic Studies pointed out that modern terrorism involved individuals or small cells of activists driven, uncompromisingly, by fanatical beliefs or single issues. World-wide, according to a US State Department report, there were 273 terrorist attacks in 1998 and, although it was the lowest annual total since 1971, 741 people were killed and 5952 injured.

Plant-derived narcotics such as cocaine, heroin, and cannabis, exercised governments and international agencies such as the UN International Narcotics Control Board. Increasing well-publicised tolerance of recreational drugs and fumatories by politicians and the public, clandestine manufacture and distribution of synthetic drugs, along with poor importation and policing controls, would appear to reinforce the view that the so-called 'war on drugs' has not been as effective as originally hoped. Controls on the major growing areas in Latin America, Afghanistan and Pakistan could potentially involve biological control agents such as species-specific plant diseases, but their use would of necessity involve exceptionally carefully planned and monitored research and development work prior to reaching international agreement on the principles of such operations.

In the world of the media, the Internet exerted a major effect on television, radio, newspapers, magazines, journals and books, all of which are routes to transmit scientific, engineering and technological information. Deregulatory climates in many countries led to consolidation and conglomeration of media companies at the global level. Great emphasis was placed on entertainment and advertising and often involved telecommunication systems as a means to garner additional income. Cable and satellite television, as well as new radio stations, diminished the impact of the main traditional broadcaster, and the quality and spread of scientific- and fact-based broadcasting suffered. A similar pattern occurred in the competitive world of newspaper publishing; free newspapers, business news, lifestyle publishing, and sensationalism related to entertainers and the aristocracy, were primary areas of focus. Few newspapers were able to report scientific developments authoritatively, demonstrating to a large extent the inability of scientists properly to present their work to the public. Electronic publishing would appear to offer major opportunities for scientists, with the potential to replace conventional journals and books. On-line editing was becoming commonplace, as was the development of large-scale on-line relational databases required for bioinformatics. Questions of copyright and related intellectual property, and profitability, have yet to be properly addressed.

Prominent developments in higher education included the rapid development of information technology and social science, with traditional science courses in mathematics, physics and chemistry proving difficult recruiting grounds for outstanding students. Consortia of universities were initiated, such as Universitas 21 (a group of 21 universities in Australia, Canada, China, New Zealand, Singapore, UK and USA) aimed at attracting multinational business clients, and a European Consortium of Innovative Universities, comprising universities from Denmark, Finland, Germany, The Netherlands, Portugal, Spain, Sweden, and the UK, formed to benefit co-operatively from private-sector financial support. Universities in most countries actively sought non-state finance, and resisted attempts by governments to impose bureaucratic controls.

In the UK, the Millennium Dome was built to celebrate the year 2000. Standing on the prime meridian on a reclaimed site in Greenwich, near to the Thames Barrage, the Dome was noted for its roof of tensioned fibreglass membrane covering 8 hectares and suspended from 12 masts. Such is the standing of science that early hopes that the building would house British scientific, engineering and technological achievements, and exciting new R&D projects, did not materialise, despite an expenditure of over £600m derived for the most part from National Lottery funds.

Economics and Politics

Financial stability started to return to stock markets in developed countries by the second quarter of 1999, following the depressed period that followed in the wake of the Asian financial crisis starting in July 1997, and the default of debt in Russia in August 1998. The International Monetary Fund (IMF) revised up its projections for growth in 1999 from 2.3% to 3%, in tune with improving global economic conditions. According to the Organisation for Economic Co-operation and Development (OECD) *Economic Outlook*, December 1999, the percentage annual change in real gross domestic products (GDPs) of all developed countries was estimated to average 2.8%, compared with 2.4% in 1998, and 3.5% in 1997. The

highest levels were achieved by the USA (3.8%), and Canada (3.7%), demonstrating the dynamo effect of North America in the world economy. At 1.7%, the UK figure was less than the average of the European Union (EU) (2.1%). With an average of 3.5%, economic growth of the LDCs exceeded that of the MDCs, continuing a trend established over the past three decades.

As a result of massive price and cost rises during the 1970s, the almost universal application of fiscal disciplines by governments to fight inflation have now given rise to a situation whereby global inflation is at its lowest level for 40 years, with remarkably little variation in national inflation rates. In some countries, there were oft-expressed fears of deflation. Increased global competition impacted positively on supply-side price suppression. More detailed analysis of globalisation reveals the extent of economic integration and the expansion in foreign direct investment (FDI), particularly through mergers and acquisitions. About 70% of FDI flows was between multinational companies based in North America and Europe, but about 25% involved Asian LDCs. In 1999, there were about 60 000 transnational companies with about 500 000 affiliates. In 1998, sales by the affiliates were about $11 trillion, compared with world exports of slightly less than $7 trillion, and FDI rose by more than 40% to exceed $640bn with a total stock valuation of over $4 trillion. According to the UN Conference on Trade and Development (UNCTAD), FDI could have exceeded $700bn in 1999.

At the beginning of 1999, 11 of the 15 member states of the EU introduced a new single currency, the euro. This event coincided with a continuing deceleration in growth in the so-called 'euro zone'. The reasons for this included the effects of tight fiscal policies by those nation-states seeking to qualify for economic and monetary union in the preparatory phase for launching the euro, as well as a decline in demand for goods and services by LDCs. A combination of lack of international confidence by the money markets in the euro, and interest-rate amendments by the European Central Bank (ECB), led to substantial depreciation by at least 11% of the euro against all the major currencies. In the UK, this affected many R&D organisations that received substantial EU research grants. Euro depreciation both increased the competitive position of euro-zone exporters and stoked inflationary risks as demand in the domestic markets rose. The euro zone is protected from international free trade, and imports by the 11 members account for only 10% or less of GDP and inflation was therefore suppressed. By remaining outwith the euro zone, the more extrovert UK economy was able to retard inflationary tendencies to well below the government's 2.5% target, but special difficulties were posed for UK manufacturers and exporters irrespective of buoyant domestic demand. Nonetheless, there was ample evidence of rapid adaptation to the new export market scenario. A strong separation was evident between those leaders of industry and commerce in favour of entry to the euro zone, and those opposed to the imposition of economic and social 'harmonisation'.

In exceeding IMF growth projections, the UK economy showed unexpected resilience to the effects of a relatively strong appreciation of the pound-sterling against all the major currencies. With consumer demand growing by an annual rate of 5.2%, a low inflation rate regardless of oil-price rises and a housing boom in the south-east of England, a fall in unemployment, suppressed public expenditure, interest-rate cuts, and muted pay pressures despite the introduction of a minimum wage, the UK economy was relatively robust compared with the euro-zone. Price Waterhouse Cooper reported that using the Office for National Statistics definitions, the UK tax burden has risen from 35.5% of GDP in 1996-1997 to a projected 38.5% in 2001-2002. During this period, the percentage difference between the tax burden in the UK and the EU excluding the UK will have declined from six to less than two percentage points. S Nickell, N Batini and B Jackson noted that the labour share (proportion of wages, salaries and self-employment income in the gross domestic product) has risen to its highest level since the mid-1970s, indicating that wages have risen faster than productivity. A productivity gap between the UK economy and that of its international competitors could in the opinion of many commentators reflect a combination of a history of uncompetitive interest rates, a steadily depreciating currency and labour-management problems, not least the neglect of investment in innovative science, engineering and technology, and a lack of focus on design with quality. According to C Daykin, the Government Actuary, the number of people claiming incapacity benefits over the next two decades is projected to rise from 1.5m to 2.5m – more than 10% of the population. The current cost of sickness and incapacity benefits are already £7bn a year.

Further scrutiny of the euro-zone reveals that in addition to their languages, the economic structures, pension systems, development paths, political systems and

attitudes to wealth creation of the 11 founding countries were also diverse. Large budget deficits remained in France, Germany and Italy, limited as they were to a maximum of 3% under the terms of the Stability and Growth Pact. At 9.4%, the level of unemployment in the zone was high. GDP growth varied from 8.6% in Finland, 7.5% in Eire, 3.5% in Luxembourg, 3.4% in Spain, 3% in Portugal, 2.5% in The Netherlands, 2.5% in France, 2% in Austria, 1.4% in Belgium and Germany, and 1.2% in Italy (the UK figure was 1.7%).

The euro remained susceptible to comments by officials of the European Central Bank (ECB) and senior politicians in EU member states, and there was growing dependence on intervention aided by the Group of Seven industrialised nations G7 in the foreign exchange markets. One major factor influencing market sentiment was the persistent outflows of long-term capital, particularly to North America, where the market-place was deemed to be more liberal and less hidebound by regulation and labour-related social impositions. By the third quarter of 2000, inflation in all the euro-zone economies exceeded the ECB target of 2%. Another factor was the impact of rising oil prices. As an aside, there is the potential for non-oil-producing LDCs to be seriously affected by oil-price rises and oil shortages. For all MDCs, any disruption to supplies, possibly coinciding with seasonally related high demand, would amplify the effects of weakened equity markets. All oil-importing countries would inevitably suffer deteriorating terms of trade, not aided by the fact that many countries use oil-related taxation as a major component of their taxation base. The International Road Transport Union claimed that UK fuel taxes were the highest in the developed world, and according to the Finnish Technical Research Centre, the vehicle excise duty on a 40 tonne articulated vehicle in the UK was the highest in Europe. Modern agriculture, horticulture, forestry and retailing are heavily fuel-dependent.

In addition to the problems of the euro, were the constitutional crisis that followed a devastating report on the European Commission, delays to competition reform as well as to the Common Agricultural Policy, gross under-achievement of EU members in peacemaking operations in the Balkans, delays to enlargement of the Union, and disagreements between member states over BSE. A report in March 1999 by teams of former judges and auditors confirmed most of the allegations of a junior internal auditor, who had been arrogantly denounced previously by a complacent Commission. On the night that the report detailing mismanagement and nepotism, even in the area of research support, was published, J Santer and his 19 fellow commissioners resigned en bloc. A new Commission was appointed, led by R Prodi. In June, there was overall a poor turnout for elections to the European Parliament, with participation as low as 25% in some countries.

Globalisation is expressed through the operation of a large number of international organisations, many functioning at government level (Table 1), and many involve agriculture, horticulture and forestry at the level of primary production through to international trading and protection of rights. Complexity reigns within trading blocs; for example, the EU operates through a number of bodies that cut across the activities of the 15 nation states (*e.g.* The Council of the EU, the European Commission, the European Parliament, the Court of Justice of the European Communities, the Committee of the Regions, the Economic and Social Committee, the European Central Bank, the European Court of Auditors, the European Investment Bank, and the European Police Office). Such issues as enlargement and external relations, the legislative processes, the Community budget, the single market relating to non-tariff barriers and the European Economic Area, the European Monetary System and the associated single currency, common foreign and security policies, and, not least, the reform of the Common Agricultural Policy (CAP), are shaped by the major treaties (Treaty of Rome, 1957; the Maastricht Treaty, 1991; the Amsterdam Treaty, 1997, and the forthcoming Treaty of Nice).

Many believed that world trading conditions would deteriorate in 1999, but the projected rise in volume of world trade was 3.7%. Growth in global exports was restrained to 2.4%, the value of global exports were estimated to be $6.844 trillion. Recovery of East Asian economies coupled with the strength of the US economy contributed in large measure to drive international trade. MDCs increased their imports by 5.9% above the 1998 level, but imports by countries in economic transition were depressed.

According to the 2001 index of economic freedom, produced by the Heritage Foundation and the Wall Street Journal, Hong Kong has the freest economy followed by Singapore and then the Republic of Ireland; the USA is fifth and the UK seventh. In neat juxtaposition, Transparency International, the global anticorruption organization, stated in its *Bribe Payers*

Body	Founded	Member States
Andean Community http://www.comunidadandina.org	1997	Bolivia, Colombia, Ecuador, Peru, Venezuela
Arab Maghreb Union (AMW) http://www.maghrebarabe.org	1989	Algeria, Libya, Mauritania, Morocco, Tunisia
Asia-Pacific Economic Co-operation (APEC) http://www.apecsec.org.sg	1989	Australia, Brunei, Canada, Chile, China (Hong Kong), Indonesia, Japan, Republic of Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, Peru, the Philippines, Russia, Singapore, Taiwan, Thailand, USA, Vietnam
Association of South East Asian Nations (ASEAN) http://www.asean.or.id	1967	Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Vietnam
Caribbean Community and Common Market (CARICOM) http://www.caricom.org	1973	Antigua and Barbuda, the Bahamas (but not the Common Market), Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, Montserrat, St. Christopher and Nevis, St Lucia, St Vincent and the Grenadines, Suriname, Trinidad and Tobago. Haiti due to be admitted, and other countries are associate members or observers.
The Commonwealth http://thecommonwealth.org	1926 (Imperial Conference) 1947, 1949 and 1991 (Harare Commonwealth Declaration)	54 member states together with their associated states and dependencies. With exception of Mozambique, all were formerly parts of the British Empire or Legion of Nations.
Commonwealth of Independent States (CIS) http://www.cis.minsk.by	1991	Armenia, Azerbiajan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan
Council of the Baltic Sea States (CBSS) http://www.baltinfo.org	1992	Denmark, Estonia, Finland, Germany, Iceland, Latvia, Lithuania, Norway, Poland, Russia, Sweden, EU
The Council of Europe http://www.coe.fr	1949	41 member states, with special guest status to Armenia, Azerbaijan, and Bosnia-Herzegovina
The Economic Community of West African States (ECOWAS) http://www.cedeao.org	1975	16 member states
The European Bank for Reconstruction and Development (EBRD) http://www.ebrd.com	1991	58 countries, the EU, and the European Investment Bank
European Free Trade Association (EFTA) http://www.efta.int	1960	Iceland, Lichtenstein, Norway, Switzerland, (Austria, Denmark, Finland, Portugal, Sweden and UK left to join the EU)
Food and Agriculture Organisation of the United Nations (FAO) http://www.fao.org	1945	180 states and the EU
International Fund for Agricultural Development (IFAD) http://www.ifad.org	1977	161 members
International Monetary Fund (IMF) http://www.imf.org	1944	182 members
League of Arab States	1945	Algeria, Bahrain, the Comoros, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Palestine, Qatar, Suadi Arabia, Somalia, Sudan, Syria, Tunisia, UAE, Yemen
Mercosur http://www.mercosur.org	1988	Argentina, Bolivia, Brazil, Chile (Associate), Paraguay, Uruguay

Table 1 Examples of international, government-level organisations connected to economic, cultural and scientific development, health and defence.

Table 1 (cont.)

The Nordic Council http://www.norden.org	1952	Åland Islands, Denmark, Greenland, Iceland, Faroes, Finland, Norway, Sweden
North American Free Trade Agreement (NAFTA) http://www.nafta.net	1992	Canada, Mexico, USA
North Atlantic Treaty Organisation (NATO) http://www.nato.int	1949	Belgium, Canada, Czech Republic, Denmark, France, Germany, Greece, Hungary, Iceland, Italy, Luxembourg, The Netherlands, Norway, Poland, Portugal, Spain, Turkey, UK, USA
Organisation for Economic Co-operation and Development (OECD). http://www.oecd.org The OECD is associated with the Nuclear Energy Agency, International Energy Agency, Development Centre, Centre for Educational Research and Innovation, and European Conference of Ministers of Transport	1961	Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary,Iceland, Irish Republic, Italy, Japan,Republic of Korea, Luxembourg, Mexico, The Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, UK, USA
Organisation for Security and Co-operation in Europe (OSCE) http://www.osce.org	1975	55 participating states
Organisation of African Unity (OAU) http://www.oau-oua.org	1963	53 members
Organization of American States (OAS) http://www.oas.org	1890/1948	35 member states
Organisation of Arab Petroleum Exporting Countries (OAPEC) http://www.oapeccorg.org	1968	Algeria, Bahrain, Egypt, Iraq, Kuwait, Libya, Qatar, Saudi Arabia, Syria, Tunisia (membership dormant), UAE
Organisation of the Black Sea Economic Co-operation (BSEC) http://www.bsec.gov.tr	1992	Albania, Armenia, Azerbaijan, Bulgaria, Georgia, Greece, Moldova, Romania, Russia, Turkey, Ukraine
Organisation of the Islamic Conference (OIC)	1971	55 members
Organisation of the Petroleum Exporting Countries (OPEC) http://www.opec.org	1960	Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, UAE, Venezuela. Ecuador and Gabon have withdrawn membership
The Pacific Community http://www.spc.org.nc	1947	26 member states and territories
South Asian Association for Regional Co-operation (SAARC) http://www.south-asia.com	1985	Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan, Sri Lanka
Southern African Development Community (SADC) http://www.saep.org/sadc/sacd.html	1992	Angola, Botswana, Democratic Republic of the Congo, Lesotho, Malawi, Mauritius, Mozambique, Namibia, South Africa, Seychelles, Switzerland, Zambia, Zimbabwe
The United Nations (UN) http://www.un.org	1942/1945	188 member states

Comprises six principal organisations:

1 The General Assembly, responsible for other specialised bodies:
a. The Conference on Disarmament (CD)
b. The United Nations Children's Fund (UNICEF)
c. The United Nations Development Programme (UNDP)
d. The United Nations High Commissioner for Refugees (UNHCR)
e. The UN Relief and Works Agency for Palestine Refugees in the Near East (UNRWA)
f. The United Nations High Commissioner for Human Rights
g. The UN Centre for Human Settlements (Habitat)
h. The UN Conference on Trade and Development (UNCTAD)
i. The Department of Humanitarian Affairs (DHA)
j. The International Seabed Authority
k. The UN Environment Programme (UNEP)
l. The UN Population Fund (UNFPA)
m. The UN Institute for the Advancement of Women (INSTRAW)
n. The UN University (UNU)

Table 1 (cont.)

o. The World Food Council (WFC)
p. The World Food Programme (WFP)

2 The Security Council

3 The Economic and Social Council

4 The Trusteeship Council

5 The Secretariat

6 The International Court of Justice

There are also independent Specialised Agencies linked to the UN:

• Food and Agriculture Organisation of the UN (FAO) qv.
• International Civil Aviation Organisation
• International Fund for Agricultural Development (IFAD) qv.
• International Labour Organisation
• International Maritime Organisation
• The International Monetary Fund (IMF) qv.
• International Telecommunications Union
• UN Educational, Scientific and Cultural Organisation (UNESCO) qv.
• UN Industrial Development Organisation (UNIDO) qv.
• Universal Postal Union
• World Bank (International Bank for Reconstruction and Development, International Development Agency, International Finance Corporation) qv.
• World Health Organisation (WHO) qv.
• World Meteorological Organisation (WMO) qv.

There are also independent Non-Specialised Agencies linked to the UN:

• International Atomic Energy Agency
• World Trade Organisation (WTO) qv.

United Nations Educational, Scientific and Cultural Organisation (UNESCO) http://www.unesco.org	1946	188 member states
United Nations Industrial Development Organisation (UNIDO) http://www.unido.org	1966	168 member states
Unrepresented Nations and Peoples Organisation (UNPO) http://www.unpo.org	1991	52 full members and 5 supporting members
Western European Union (WEU) http://www.weu.int	1948/1954	28 members, associated members and observers

The World Bank (International Bank for Reconstruction and Development, IBRD) http://www.worldbank.org — 1945 — 181 members

Two affiliates: International Finance Corporation (IFC), and International Development Association (IDA)

The Consultative Group on International Agricultural Research (CGIAR) was established in 1971 and is an informal association of 58 public- and private-sector members that supports a network of 16 international agricultural research centers. The CGIAR's budget for 1999 was US$330m and is co-sponsored by the World Bank, the Food and Agriculture Organisation of the United Nations, the United Nations Development Programme, and the United Nations Environment Programme, together with individual donations and contracts. The CGIAR's mission is to contribute to food security and poverty eradication in LDCs through research, partnership, capacity building, and policy support. It promotes sustainable agricultural development based on environmentally sound management of natural resources, focusing on five major thrusts:

(i) Increasing productivity in developing-country agriculture through genetic improvements in plants, livestock, fish, and trees, and through better management practices; (ii) protecting the environment through conservation of natural resources (especially soil and water) and reductions of the impact of agriculture; (iii) saving biodiversity, through one of the world's largest *ex situ* collections of plant genetic resources (over 500,000 accessions of more than 3,000 crop, forage, and agroforestry species), held in trust for the world community; (iv) improving policies that influence the spread of new technologies and the management and use of natural resources; and (v) strengthening national research in developing countries through partnerships with national programs and training in research techniques, administration, and management.

The 16 CGIAR Research Centers are:

• CIAT – Centro Internacional de Agricultura Tropical (International Centre for Tropical Agriculture – founded 1967) http://www.ciat.cgiar.org/
• CIFOR – Centre for International Forestry Research – founded 1993 http://cifor.cgiar.org/
• CIMMYT – Centro Internacional de Mejoramiento de Maiz y Trigo (International Center for the Improvement of Maize and Wheat – founded 1966) http://www.cimmyt.org/
• CIP – Centro Internacional de la Papa (International Potato Centre – founded 1971) http://cipotato.org/

Table 1 (cont.)

• ICARDA – International Center for Agricultural Research in the Dry Areas – founded 1977 http://icarda.cgiar.org/ • ICLARM – International Center for Living Aquatic Resources Management – founded 1977 http://www.cgiar.org/iclarm • ICRAF – International Centre for Research in Agroforestry – founded 1977 http://www.icraf.cgiar.org/ • ICRISAT – International Crops Research Institute for the Semi-Arid Tropics founded 1972 http://www.icrisat.org/ • IFPRI – International Food Policy Research Institute – founded 1975 http://ifpri.cgiar.org/index.htm • IITA – International Institute of Tropical Agriculture – founded 1967 http://www.cgiar.org/iita • ILRI – International Livestock Research Institute – founded 1995 http://www.cgiar.org/ilri/ • IPGRI – International Plant Genetic Resources Institute – founded 1974 http://www.ipgri.cgiar.org/ • IRRI – International Rice Research Institute – founded 1960 http://cgiar.org/irri/ • ISNAR – International Service for National Agricultural Research – founded 1979 http://www.cgiar.org/isnar/index.htm • IWMI – International Water Management Institute – founded 1983 http://www.cgiar.org/iwmi/ • WARDA – West Africa Rice Development Association – founded 1971 http://www.cgiar.org/warda/		
World Health Organisation (WHO) http://www.who.ch	1946	191 members
World Intellectual Property Organisation (WIPO) http://www.wipo.int The International Union for the Protection of New Varieties of Plants (UPOV) founded in 1961, is linked to WIPO, and has 40 members. The European Patent Office operates under the European Patent Convention, covering 20 signatory states and is not an instrument of the EU.	1967	173 members
World Meteorological Organisation (WMO) http://www.wmo./ch	1950	179 member states and 6 member territories
World Trade Organisation (WTO) http://www.wto.org	1995	134 members, with 31 further applicant states

Index, that China, South Korea, Taiwan, and Italy were among the 19 leading exporting countries most involved in paying bribes to public officials, contrasting sharply with such countries as Australia, Austria, Canada, and Sweden. In its Corruption Perception Index, Azerbaijan, Cameroon, Indonesia, and Nigeria, were listed as the world's most corrupt countries.

Although the WTO meeting in Seattle in late 1999 took place at a time of global economic slowdown, and was widely regarded as a failure (see Agriculture and Food Section), the seventh annual meeting of the 21 members of the Asian-Pacific Economic Co-operation (APEC), held beforehand in Auckland, New Zealand in September 1999, was considerably more positive. There was agreement by the member countries who account for two-thirds of world trade to resist protectionist measures and liberalise trade operating with free and fair competition. Nevertheless, progress by the member states to achieving the deadline of removing trade barriers, by 2010 for MDCs and 2020 for LDCs, has been limited. What is more, anti-capitalist demonstrations in Seattle led to the arrest of 500 people and damage of more than $2.5m. Similar demonstrations took place at the subsequent WTO meetings in Washington, the World Economic Forum in Melbourne, and the International Monetary Fund (IMF) and World Bank Group meeting in Prague. The protestors were diverse but in essence sought protectionist measures to counter lack of safeguards against the exploitation of labour and the environment. Through the Global Compact, the UN sought in July 2000 a partnership between business and the UN, involving 50 companies and 12 labour organisations and environmental groups in an attempt to promote free trade unions, core labour standards and protection of the environment. Rather than confront companies by issuing a legally binding code of conduct, the UN generated a declaration of nine principles drawn from the Declaration of Human Rights, the Earth Summit of Rio de Janeiro in 1992, and the Social Summit held in Geneva in 1995.

By the end of 1999, there were over 100 regional trade agreements in force, whereby trading barriers were removed between members of the groupings. Of all the trading blocs, however, that of the EU appeared to be the most self-centred such that intra-regional trade accounted for 62.5% of total trade compared with, for example, the Association of South-east Asian Nations (ASEAN) where intra-regional trade was around 20%. Bilateral free-trade agreements were beginning to be regarded as the best way to stimulate global liberalisation compared with

broader slow-moving multilateral schemes, with Singapore a prominent participant.

The overall current accounts of MDCs started to move into deficit after six consecutive years of surplus, much of the movement being accounted for by the growth in deficits of Australia, Germany, Spain, UK, and USA. Most euro-zone countries, however, had large surpluses reflecting the competitive boost given to their exports by depreciation of the euro.

In the LDCs, which most often are highly agriculture-dependent, the current account deficit fell from $77bn in 1998 to $56bn in 1999, as higher oil prices improved the lot of oil-exporting countries. Even so, the position for Africa remained challenging at $19bn, and the external debt of the LDCs rose to $2.3 trillion. In April 2000, 30 of the world's poorest nations formed the World Association of Debt Management Offices (WADMO), a self-help group designed to improve their debt management capacity and to inspire confidence in the donor countries. According to the IMF (*World Economic Outlook*, October 1999), output in 1999 was expected to increase by 3.5% in the LDCs, compared with 3.2% in 1998. Latin America, however, mainly suffered from a drop in output. Thus, trade in the Southern Core Common Market (Mercosur), comprising Brazil, Paraguay and Uruguay, fell dramatically during 1999, reflecting primarily the effects of recession and the devaluation of the Brazilian real. Contrasting with a failure to liberalise intraregional trade, the member countries considered the proposal from Argentina on the adoption of a single currency, perhaps based on a basket of currencies such as the dollar, yen and euro. In September, Brazil and Argentina opened talks on the problems threatening the unity of Mercosur, not least the effect of the real devaluation. Only the Asian LDCs were expected to show a marked increase in output with a 5.3% annual change in real GDP, up from 3.7% in 1998. Africa was projected to show a 3.1% increase, the Middle East and Europe 1.8%, the Western Hemisphere 0.1%, and those countries classified as 'in transition', 0.8%.

One undesirable symptom of the globalisation of trade was the 'banana' war launched by the USA with some Caribbean countries against the EU in respect of the EU banana import regime. This high-profile disagreement started in 1995, leading to a WTO panel finding in 1997 that, by giving preferential entry to a fixed tonnage of bananas from associated African, Caribbean and Pacific countries, the EU violated the rules of the WTO. The ruling was confirmed by an Appeals Body in late 1997. A revised EU banana regime was eventually adjudicated by a new WTO Panel to be inadequate, and arguments persisted over whether the USA could pursue a policy of imposing penalty rates of duty on a diverse range of European goods. Unresolved issues about the appropriate mechanisms to support agrarian-based LDCs, cultural links, and the range of options open to nations under the dispute settlement procedures of the WTO, were aired by groups and individuals dissatisfied with globalisation.

According to the *Financial Times*, nearly all stock markets continued their upward trends in 1999 and the first part of 2000. By the year-end close of 1999, only the Brussels BEL20 (-5%), the Irish ISEQ overall (0%), and Manila Composite (9%) posted less than 12% increases during the year. Various commentators pointed towards the inter-related trends of attractiveness of technology stocks, the impact of new technologies on increased international competition and greater price transparency, and a more permanent shift to higher growth with low, stable inflation. A similar era was noted by DeAnne Julius, the economist, in the period 50 years up to World War I, a time when new technologies drove global growth and eventual price stability. Round-the-clock electronic trading using electronic communication networks – computerised systems for matching the orders of buyers and sellers of securities without the intervention of specialists or market-makers – as well as increased access to the Internet, started to alter profoundly the investment scene as on-line brokerages began to threaten the hitherto closed operations of the world's traditional stock exchanges which had consistently impeded off-exchange trading. The open competition, however, created regulatory concerns, especially with regard to internal controls and risk-management systems designed to protect investors.

Consolidation of financial services in Europe and the USA, particularly leading to the integration of banking and insurance, was a pronounced feature of 1999-2000. Policy differences were expressed on the allocation of supervisory responsibilities for financial conglomerates incorporating banks, insurance companies and securities firms, but there was no international governmental consensus on how to oversee transnational organisations. Related supervisory issues concerned classification of assets, loan-loss provisions, the rôles of external and internal auditors and associated financial-reporting practices, risk-based capital

adequacy standards, the effective use of market discipline, and money laundering. An increasing level of importance was attached to the Basel Committee on Banking Supervision.

In *Productivity Developments Abroad*, C Gust and J Marquez, two Federal Reserve economists, reinforced the view that the high level of US productivity over the past quinquenium was a reality rather than a statistical mirage. Only two other countries in the OECD, Australia and Switzerland, recorded similar improvements in productivity growth. In Japan and most of the large EU countries, productivity growth declined over the period, even though there were substantial investments in information technology. The US improvement could be satisfactorily explained in terms of the business cycle. Likewise, there was no correlation between the use of hedonic price indexing which takes into account improvements in quality as well as changes in prices and measured productivity growth. There was no evidence to indicate improvements in the quality of the US workforce. Rather, they point to a combination of the growth of spending on information technology – which has raised its share of total US capital stock to 7.4% compared with 2% to 3% in the larger EU economies, and network efficiencies and other beneficial effects of utilising IT equipment effectively (*e.g.* number of Internet sites and secure Internet servers).

Leaked reports from the World Bank claimed that 223 of its funded projects in October 1999 would result in the involuntary (forced) resettlement of 681 000 households and more than 2.6m people, mainly in the East Asian and Pacific region. As a counter to such criticism, the Bank implemented a new operational directive and established a compliance operation. Large dam projects, in particular, frequently fail to deliver promised benefits and underestimate the social disruption and environmental damage they cause, according to the World Commission on Dams, a group set up in 1998 by the World Bank. China and India, however, pressed ahead with major schemes for generating hydroelectric power, controlling floods, and supplying irrigation schemes. The international committee of government ministers overseeing policy noted that the Bank should focus its efforts and work out an appropriate division of labour between itself and international agencies such as the UN Development Programme. International standards of fiscal and monetary policy are favoured by the (G7) industrialised nations, and it is envisaged that the IMF should have a central rôle in the surveillance of codes and standards, and promoting their implementation. The Financial Stability Forum – the international network of central bankers and financial market regulators - favours incentives for countries to adopt such standards. Transparency is seen as the key to avoid future financial crises, yet the Group of 24 (G24) countries, which includes influential emerging market countries, contested the trend towards compulsion, claiming that the application of codes and standards was highly asymmetric, and that industrialised countries should first demand transparency from their hedge funds.

In *The Least Developed Countries 2000 Report*, UNCTAD pressed for reconsideration of aid, debt and trade between MDCs and LDCs. Economic stagnation or decline has occurred over the past decade in 22 of the 48 countries classified by the UN as LDCs. UNCTAD seeks a substantial rise in aid, improved debt relief, greater access to foreign markets for LDC experts, and modification of domestic policies to enhance productive capacity and global competitiveness.

Of all UN agencies, the UN Development Programme (UNDP) has the broadest remit and the widest geographical spread of 136 countries. In relying on voluntary contributions, it has been squeezed during the aid squeeze of the 1990s to operate on a core 'no-strings' budget of $700m, down from $1.2bn in 1992, but non-core, project-related funding has reached $1.6bn. Unlike the World Bank, the UNDP is regarded as being much closer to recipient rather than donor countries. Much of its work is in governance and policy advice, laying the foundations of, but not monitoring, elections. It also facilitates self-help projects, internet projects, helping administer and co-ordinate governance in politically and economically fragile countries. It even helps improve co-ordination between UN agencies. There is an expectation by LDCs that the UNDP will take a high profile in debt relief, preferential trading arrangements and official development assistance, relieving LDCs of internationally imposed constraints.

A plethora of world-wide web-based e-commerce (.com) sites were launched during the year; few were profitable, but until technology stocks became unattractive in mid-2000, investors behaved as if e-commerce would provide substantial capital and income returns in the short term. Several more traditional service-based companies adjusted their marketing strategies to improve their allure to investors and to improve their efficiency of operation. Business-to-

business (B2B) trade began to have strong deflationary Internet effects. Stock-market activity throughout the world increased markedly.

Internationally, there were concerns about Internet transactions leading to the potential loss of sales-related taxes, abrogation of intellectual property rights, on-line and credit-card fraud, failure to provide pre-paid goods, data-privacy, computer virus infections, unsolicited e-mail messages, socially disruptive communications, and forms of intercommunications that diminished the representational rôle of conventional politicians. Science thrived in the Internet environment, however.

Exploitation of the capacity of the Internet was aided by sharp declines in the costs of computer hardware and software, as well as by high-speed Internet access *via* digital subscriber lines, cable modems, and satellite downloading. Antitrust suits were filed in the USA against Microsoft and the Intel Corporation. Mobile telephone access to the Internet stimulated rapid expansion of large sectors of the microelectronics market and telecommunications industry.

Research in 2000 by Goldman Sachs (*The IT Revolution – New Data on the Global Impact*) pointed out that the use of information and communications technology (ICT) in the UK merited an upward revision from 2.9% to 3.43% in business-sector growth over the 1996-1999 period, matching the US experience. Although there is debate about whether there is an ICT-derived 'new economy', ICT investment has been associated with growth in the USA and UK, if not in Japan. Further scrutiny of data for labour productivity growth in the UK, however, reveals a decline from an average of 3.35% *per annum* during 1990-1995 to 1.77% for the 1996-1999 period.

Conflicts and Populations

Defence expenditure during peacetime poses special difficulties for democratic governments, and the competition with civil expenditure can be fraught, not least in the area of research outlays. Historical precedence shows that the sheer magnitude of challenges that have to be addressed during and following periods of conflict, and the effects of conflicts on civilian populations and the economy, serve to demonstrate the wisdom of sustaining a healthy but balanced defence infrastructure that can offer assistance to afflicted countries. During 1999, conflicts occurred in Angola, the Democratic Republic of the Congo (Congo-Kinshasa), and Sierra Leone. Russia embarked on an offensive against Chechnya; the civil wars in Afghanistan and Sri Lanka continued to test the resolve of the people directly involved; border disputes occurred between India and Pakistan as well as between Ethiopia and Eritrea. The civil war in Colombia and offensive manoeuvres between North and South Korea were long-standing conflicts. A UN-organised peacekeeping force was commissioned to curb the ethnic violence, forced migration, and anarchy in East Timor. In Europe, a 78-day bombing campaign was launched by the North Atlantic Treaty Organization (NATO), under the leadership of the USA, against Serbia in an attempt to prevent maltreatment of ethnic Albanians in Kosovo.

Negotiations on nuclear-arms treaties did not progress satisfactorily during the year. The Comprehensive Test Ban Treaty was rejected by the US Senate in October, no further amendments were made to the 1972 Anti-Ballistic Missile Treaty, and the Russian legislature refused to ratify the 1993 Strategic Arms Reduction Talks II Treaty. In respect of non-nuclear arms, the 1997 Ottawa Landmines Convention came into force in March 1999, although landmines were used by ethnic Serbs and Albanians in Kosovo, and by Russia in Dagestan. A new Conventional Forces in Europe treaty was signed at the November meeting of the Organization for Security and Co-operation in Europe.

In April 1999, a summit was held in Washington, USA, to record officially the 50th anniversary of the formation of NATO, welcoming the formal membership of the Czech Republic, Hungary and Poland, and agreeing the new Strategic Concept. Concerns were expressed about the expansion of NATO into Eastern Europe engendering an anti-NATO position by non-participants. A Membership Action Plan for nine aspiring European democracies was also agreed at the meeting. The NATO bombing campaign against Serbia, however, created tension with Russia and China, as it was a conflict based on humanitarian or moral reasons rather than on security reasons, and disregarded the primacy of national sovereignty. By avoiding the use of ground forces and relying on US military capability, the cohesion of NATO was sustained. There was a view that NATO should have received specific UN authorisation, but that would have been unrealistic given the history of UN interventions. In April 1999, only six (Armenia, Belarus, Kazakstan, Kyrgyzstan, Russia and Tajikistan) of the nine signatories to the 1992 Commonwealth of Independent States (CIS) sought to sign the prolongation protocol, whereas Azerbaijan, Georgia, and Uzbekistan refused. Georgia, Ukraine, Uzbekistan, Azerbaijan, and Moldova formed

the loose GUUAM grouping as a counterbalance to the Russian-dominated CIS.

At the beginning of 1999, the number of refugees and people of concern to the Office of the United Nations High Commissioner for Refugees (UNHCR) was around 22m, over 11m of which were refugees as defined by the 1951 UN Refugee Convention and are legally entitled to international protection, and more than 5m were internally displaced persons, and the remainder returnees, asylum seekers, and stateless people. It is estimated that there are around 20-25m internally displaced persons for whom UNHCR does not have a mandate. Most were in Africa, Asia and Europe, half were women and 14% were children under 5 years of age. More than 80% of the 5 200 UNHCR staff were in the field, working in 120 countries. The main donors to the UNHCR were the USA, Japan and the EU.

Approximately 450 000 Sierra Leonians fled the country and sought refuge mainly in Guinea and Liberia. More than 330 000 other refugees returned to Mali and Niger. In the Horn of Africa, there were further displacements and mass expulsions arising from the conflict between Eritrea and Ethiopia. By the beginning of 1999, Sudan hosted 392 000 refugees from Chad, Eritrea, Ethiopia, Uganda, Democratic Republic of the Congo (Congo [Kinshasa] formerly Zaire) and Somalia. Complicated patterns of conflict in the Great Lakes region of Africa accounted for mass displacement of peoples in Congo [Kinshasa] and the Republic of the Congo (Congo [Brazzaville] formerly the French colony of Middle Congo), involving the movement of refugees into Tanzania and northern Zambia. There was also transhumance of refugees from Burundi to Tanzania, and from Angola to Congo [Kinshasa] and Zambia.

In Asia, about 100 000 Karen and Karenni refugees from Myanmar (Burma) remained in camps along the border with Thailand. It was estimated that as a result of the conflict between government forces and the Liberation Tigers of Tamil Eelam, there were 650 000 internally displaced persons in Sri Lanka. In South America, around 1.6m appear to have been displaced within Colombia, and many had fled to neighbouring countries.

Elsewhere, more than 250 000 people were displaced by the Russian forces from Chechnya, many fleeing into Ingushetia. Over 33 000 people were displaced in Dagestan. Well over 1m refugees and displaced people were to be found in the Transcaucasus, principally in Armenia, Azerbaijan, and Georgia. In Spring 1999, 1m people left their homes in Kosovo only to return within 11 weeks. Unsettled conditions in Afghanistan meant that by the end of 1999 there were more than 150 000 internally displaced persons, with thousands of refugees in neighbouring countries.

The USA accepted about 50% (78 000) of refugees resettled by UNHCR; by the end of 1998, Canada hosted 159 000 persons of concern to UNHCR, over 13 000 of whom were accepted as refugees.

With remarkable candour, Kofi Annan, the Secretary-General of the UN, acknowledged in September 1999 deficiencies in both the operations of the organisation and the actions of some of its member states. Much of the inability of the UN to act to prevent large-scale state- or rebel-induced violations of human rights reflected its problems of funding and inefficiencies in some of its associated organisations. It was only by the payment of $824m that the USA was able to save its vote in the General Assembly after it had been warned about its persistent failure to meet its UN Charter obligations. The estimated cumulative debt of the USA to the UN was between $1.2bn and $1.6bn. Japan was in arrears ($506m) as was Germany ($98m).

During the year, the UN abandoned its peacemaking rôle in Afghanistan and virtually terminated its Observor Mission rôle in Angola after the abandonment of the Lusaka Protocol. The UN unsuccessfully interacted with Iraq whilst France, UK and the USA enforced 'no-fly' zones. Likewise, it had difficulty in gaining unanimity for the support of NATO air strikes against Yugoslavia, but the UN High Commissioner for Refugees (UNHCR) tried to repatriate about 900 000 refugees and 600 000 displaced persons although by the end of the year it was not possible to restore the multi-ethnic composition of Kosovo. After the Libyan government surrendered for trial in The Netherlands two of its citizens suspected of involvement in the 1988 destruction over Scotland of Pan Am flight 103, the UN lifted sanctions on Libya. The Security Council created the UN Transitional Administration in October 1999 to run East Timor after the collapse of order in the Indonesian province. Two important failures of the UN were noted by the Secretary-General: (i) allowing in 1995 Serbs to overrun the Bosnian so-called 'safe area' of Srebenica; and (ii) neither preventing the 1994 genocide in Rwanda nor punishing the guilty parties.

Hitherto, in its peacekeeping rôle the UN would wait for the parties to fight to a standstill and then respond to their call to monitor the resulting truce, remaining resolutely neutral throughout. The August 2000 Brahimi Commission Report noted that the standing and credibility of the UN peacekeeping effort in the 1990s was damaged by its failure to distinguish victim from aggressor. In recommending faster deployment of peacekeepers into the field, and switching regular peacekeeping administrative costs to the main UN budget, it was realised that the UN Department of Peacekeeping Operations was trying to function on a budget in 2000-2001 of just $2.6bn, attempting to run 15 different peacekeeping operations, 27 000 soldiers and 9 000 police, with tiny administrative staffing and administration costs of less than 2% of total budget. Kofi Annan in his speech to the General Assembly championed intervention on humanitarian grounds regardless of whether it infringed sovereignty. Questions arose as to who will meet the costs or the responsibility of carrying out the new policy; non-democratic developing countries in turn feared they may come subject to UN intervention.

In view of the fact that many countries have not recently, or have never, taken a population census, global and national population figures are estimates. Accurate current data even for the populations of capital cities are scarce, and the definition of cities and their areas are variable. The UN report *The Sex and Age Distribution of the World Populations*, revised in 1994, provided the following medium variant data for the total population of the world: 1930, 2.07bn; 1960, 3.019bn; 1995, 5.176bn; 2000, 6.158bn; 2010, 7.032bn; 2020, 7.888bn; 2030, 8.671bn; 2040, 9.318bn; 2050, 9.833bn. The increase to date has been made possible by the increased availability of high-quality food, and improved healthcare. Further analysis of the data shows great divergence in the continental areas that are expected to bear the brunt of the population increases between 2000 and 2050. Africa will expand from 832m to 2.14bn; Asia 3.754bn to 5.741bn; Latin America, including Mexico and the remainder of the American south of the USA, 524m to 839m; North America 306m to 389m, and Oceania 31m to 46m. In contrast, the population of Europe is projected to decline from 730m to 678m.

Agriculture and Food

During 1999-2000, world agricultural markets were subject to pressures ranging from greater competition as a result of increases in food production, persistent but declining effects of the economic problems affecting many parts of Asia and Russia, decreasing food aid, the declining political and economic influence of agriculture in both MDCs and LDCs, the growing rôle of the World Trade Organization (WTO) in loosening regulation of agricultural trade, changes to the agricultural policy of the EU, continuing substantial support payment to US farmers, and highly publicised consumer-related trading issues such as BSE, GM crops, the USA-EU 'banana war', and American beef treated with hormones.

Analyses by the UN Food and Agriculture Organisation (FAO; http://apps.fao.org; FAO *Production Yearbook*; and the online FAOSTAT database http://apps.fao.org/default.htm) revealed increases in the crucial indices of total agricultural and food production (Table 2), although the increase in food output was less than the rise in global population so that *per capita* food production declined slightly.

Regarded by many as a debacle and failure, the Seattle meeting of ministers from the 135 member countries of the WTO, during 30 November to 3 December 1999, was disrupted by protestors unwilling to accept a new round of negotiations to liberalise international trade. Presaged by the Uruguay Round, agriculture was a focus for exporting nations seeking access to importation markets mainly by the elimination of subsidies that distort trading and ratcheting down the controls exerted by state trading agencies. There were opposing views as to whether agricultural products

	Total agricultural production					Total food production					*Per capita* food production				
	1995	1996	1997	1998	1999	1995	1996	1997	1998	1999	1995	1996	1997	1998	1999
World	109.0	113.2	116.0	117.4	118.7	109.8	114.2	116.9	118.8	120.0	102.0	104.6	105.7	106.0	105.7
MDCs	94.5	97.3	98.8	97.5	98.1	94.9	98.0	99.4	98.5	98.8	92.6	95.2	96.3	95.1	
LDCs	120.9	126.4	130.3	133.9	135.8	122.5	128.0	131.8	136.1	138.1	112.2	115.3	116.8	118.7	118.6

Table 2 Indices of World Agricultural and Food Production in More-Developed Countries (MDCs) and Less-Developed Countries (LDCs). (1989-1991=100).

should be treated the same as other traded products, and subject to the same rules. Both the EU and Japan overtly subsidise and protect their agricultural sectors, the USA less so, but members of the Cairns Group offer minimal-to-zero market support. The USA and EU represent the two largest agricultural trading blocs. At least, the WTO ministers agreed that existing tax moratoria on sales over the Internet should be extended for a further 2 years. The WTO talks resumed in Geneva in April 2000, where members again failed to agree on who should chair the agricultural liberalisation talks over the coming year.

As a result of the collapse of the Seattle WTO meeting, and deferral by the US Congress of the bilateral China-USA negotiations, the accession of China to the WTO was under threat, especially because of the tight regulatory control China imposed on agricultural products.

Estimates of production, utilisation and ending stocks of the major agricultural commodities usually require amendment as trading data are released. The following accounts must be considered in concert with my previous Annual Reports.

In 1999-2000, the US Department of Agriculture (USDA) revised previously released data and forecast that the production of wheat, coarse grains (barley, maize, millet, oats, rye, and sorghum) and milled rice was 1 856m metric tonnes (mmt), down from production levels of 1 871 mmt in 1998-1999. Utilisation of cereals for livestock feed use, for human food, and for non-food industrial feedstocks, rose from 1 854 mmt in 1998-1999 to an estimated 1 859 mmt in 1999-2000, with most of the increased utilisation attributable to the consumption of milled rice. Minimal declines in grain ending stocks were expected, from 347 mmt in 1998-1999 to 345 mmt in 1999-2000. Stocks remained at 19% of utilisation.

Wheat production declined from 589 mmt in 1998-1999 to 584 mmt in 1999-2000, irrespective of near-record harvests in Argentina, Australia and Canada. Production levels declined in the other major producing nations, and wheat ending stocks fell to 131 mmt. Global rice production increased from 392 mmt in 1998-1999 to 396 mmt in 1999-2000, but trading levels and prices in the commodity were expected to decline as various Asian countries reduced their imports, so that ending stocks rose from 57 mmt in 1998-1999 to 59 mmt in 1999-2000. World production of coarse grains was expected to fall from 890 mmt in 1998-1999 to 876 mmt in 1999-2000, matching utilisation levels, and with world trade expected to shrink, prices were expected to be lower than originally projected.

The global production of the seven major oilseeds (soybean, cottonseed, groundnut or peanut, sunflower seed, rapeseed, copra, and palm kernel) was forecast by the USDA to rise from 293.6 mmt in 1998-1999 to 296.9 mmt in 1999-2000. Declines in soybean and groundnut production were offset by an increase from 36.7 mmt in 1998-1999 to 42.7 mmt in 1999-2000 in rapeseed production, chiefly in Canada, China, India, and the EU. There were increases in the production of vegetable oils and high-protein meals, and record utilisation of oilseeds and their products meant that there was increased world trade and consequently lower ending stocks (27.6 mmt). Nonetheless, prices remained weak and subject to competitive pressures from cereal products.

Data from the World Health Organization (WHO) on the number of tobacco smokers provide the scale of the challenge to implement the organization's anti-smoking treaty. World-wide, there were 1.142bn smokers, the bulk of whom reside in the East Asia and Pacific zone (401m), Eastern Europe and Central Asia (148m), Latin America and Caribbean (95m), Middle East and North Africa (40m), South Asia (86m cigarettes and 96m biris). A proposed framework convention on tobacco control, due for adoption in 2003, will state objectives for reducing tobacco use, and will have legally binding protocols on specific measures such as advertising, sponsorship, health warnings, taxation, and reduced production subsidies – a special point in respect of CAP policies.

The Environment

Expectations that the Kyoto Protocol would become fully operational by early 2001, with functional compliance-monitoring regimes and commencement of technology-transfer mechanisms for the benefit of LDCs, were downgraded following the talks held in Bonn in June 1999, where it was agreed to submit a series of draft texts to the next Conference of Parties to the UN Convention on Climate Change in November 2000 covering the clean development mechanism, emission trading, joint implementation and apportionment of blame. At, and following the UN Conference on Environment and Development (the Rio Conference) in 1992, the UK alongside 180 other countries signed and ratified the Framework Convention on Climate Change, and intended to

reduce the risks of global warming by limiting the emissions of 'greenhouse' gases. The 1997 Kyoto Protocol to the Convention was signed by 84 parties, but only ratified by 22 to date. Under the Protocol, MDCs agreed to cut emissions of greenhouse gases (the six main gases are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride) by 5.2% below 1990 levels by 2008-2010. EU members agreed to an 8% reduction, but the target set for the UK is 12.5%. Phenomenal complications in weather patterns caused by variable solar activity, volcanic eruptions, local warming arising from growth of towns and cities, large-scale vegetational (habitat) modifications, El Niño and La Niña events *etc*., when viewed against known records of 'extreme' weather events, make it difficult properly to assess anthropogenic effects on modifying weather by altering the gaseous composition of the atmosphere. Predicting the impacts of climate change and attempts to curtail greenhouse-gas emissions are fraught with difficulty, especially in judging over time the buffering and reservoir capacity of the seas, oceans, and terrestrial vegetation, and the ability of ecological habitats to adjust to environmental perturbation. In the previous Annual Report, I referred to the breathtaking naïvety of attempts by the international community to stabilise climate change and consequential ecological change by adjusting a few variables, *i.e.* certain atmospheric emissions. Such an observation does not detract from the need for vigorous pursuit of energy efficiency, renewable energy sources and elimination of pollution, however, and it may well be possible to address the problem of 'holes' in the ozone layer.

Under the auspices of the UN Environment Programme, the Intergovernmental Negotiating Committee for an Internationally Legally Binding Instrument for Implementing International Action on Certain Persistent Organic Pollutants (POPs) agreed that production of eight of the 12 POPs should cease when the Treaty comes into force in 2002 or 2003. Thus, aldrin, chlordane, dieldrin, endrin, heptachlor, mirex, toxaphene and hexachlorobenzene would be banned. Against the wishes of the World Wide Fund for Nature, DDT would be permitted as an antimalarial insecticide. Polychlorinated biphenyls would continue to be allowed only in electrical equipment, but the position of dioxins and furans was unclear.

In September 1999, a multipollutant protocol to the UN Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution was agreed, setting limits for emissions of ammonia, nitrogen oxides, sulfur, and volatile organic compounds, all of special relevance to agriculture. Initial indications were that 32 European countries would agree to the unmodified protocol, and Canada and the USA would agree to a modified version. Both the European Commission and several northern European states sought unsuccessfully for tougher action at a diplomatic meeting of the EU Council of Ministers later in that month.

A specific target of Greenpeace and environmental activists, the Brent Spar episode finally came to an end with its conversion to a quay rather than being dumped at sea. Contrary to impressions given by environmentalists to the public and politicians, the $68 million conversion involved a net energy cost slightly more than double that of the ocean-disposal option. Moreover, only 150 tonnes of oil were in its tanks, considerably less than the 5000 tonnes claimed by Greenpeace.

Pressure continued to be exerted on the nuclear industry, regardless of the claims that viable alternative sources of energy would lead to greater enhanced emissions of greenhouse gases.

Sea-surface temperatures that were colder than usual were detected in 1999 across the eastern and central Equatorial Pacific Ocean, triggering abnormally active weather patterns and various extreme events. This *La Niña* (the Little Girl) was associated with a pronounced hurricane period during June to November in the Caribbean and Atlantic basins. Evidence is accumulating to support the view that the frequency of *El Niño* events that are associated with *La Niña* events are increasing in frequency as a result of global climate change (see www.elnino.noqq.gov). Coral core records indicate that during the 19th Century, *El Niño* occurred every 10 to 15 years, but since the late 1970s, it has shifted to a four-year cycle. The year 2000 was predicted to be one of the hottest years on record. During the *El Niño* climate cycle, there is a weakened atmospheric circulation in the Pacific Ocean, triggered by higher-than-usual sea-surface temperatures, so that lighter, warmer waters flow eastward to the American coastline, replacing cooler, upwelling nutrient-rich waters that give rise to abundant fisheries such as those off the coast of Peru. Surface atmospheric pressure tends to be high over Australia and low over the southeastern Pacific, leading to weak trade wind circulation. The effects of *El Niño* are felt world-wide, wreaking havoc with weather patterns in the Americas, Africa, and Asia.

In September 1999, the UN General Assembly held a meeting called by the 42-member Alliance of Small Island States to discuss the danger posed by rising sea levels and increasingly violent and erratic weather associated with global-warming trends.

By acceding in 1999 to the Antarctic Treaty, Venezuela brought to 44 the number of nations that have agreed to use the region south of 60°S latitude for peaceful purposes only. The Treaty entered into force in 1961, and is essentially a managerial mechanism that encourages scientific research and cooperation, enforces and monitors environmental protection, and defers the contentious issue of sovereignty. Non-consultative, non-signatory nations are urged to adhere to the Treaty's new (1998) Protocol on Environmental Protection. Unregulated fishing was addressed in 1998 by member nations of the Antarctic Marine Living Resources Convention. Nearly 16 000 tourists were expected during the 1999-2000 season, many of whom were attributed to welcoming in the new millennium. There was intense scientific interest in Lake Vostok, an ancient and pristine body of water akin to Lake Ontario in area and depth, deep beneath the ice of East Antarctica. By stark contrast with the Antarctic, no treaty regime applies to the Arctic, nor agreed definition of a zone that may be described in terms of physical location (north of the Arctic Circle, latitude 66°30' north), botanic (above the northern limit of the tree line), climatic (above the 10°C July isotherm), or cultural (region encompassing the circumpolar cultures). Portions of seven nations (Canada, Finland, Greenland (part of Denmark), Norway, Russia, Sweden, and USA) are regarded as the Arctic zone, together with the Arctic Ocean. The land area consists of permanent ice cap, tundra, or tiaga, and the total population was estimated in 1999 to be 375 000.

In *Trade, Global Policy, and the Environment*, (World Bank Discussion Paper No 402, 1999, see also http://www.worldbank.org/) P.G. Fredriksson and associates attempted to analyse in detail the empirical links between trade and the environment, the 'pollution haven' hypothesis, and economic instruments for resolving global environmental problems. There appears to be a consensus that more open trade improves growth and economic welfare, and that increased trade and growth without appropriate environmental policies in place may have unwanted effects on the environment. Three 'effects' were considered. The 'scale' effect refers to the fact that more open trade creates greater economic activity, demanding greater inputs (*e.g.* raw materials, transportation, energy) and if existing technologies are deployed to increase outputs, then there is an increase in emissions along with depletion of resources. The 'composition' effect relates to changes in the relative size of the various economic sectors and sub-sectors following a reduction in trade barriers. Freer trade leads to countries specialising in sectors where they have a competitive advantage where they may have relatively abundant factors (minerals, labour *etc.*). Lax environmental regulations lead to polluting or resource-depleting industries. The 'technique' effect refers to changes in production methods that follow trade liberalisation. From a global perspective, free trade results in a more efficient use of resources. These three effects have both local and global implications.

In studies on trade, growth, and environmental and health effects, computerised general-equilibrium models were used to predict the environmental impacts of trade liberalisation. In the case of Indonesia, the damage caused by trade liberalisation was estimated to be only a fraction of the damage that normal projected economic growth and structural change would cause by the year 2020 if trade and environmental policies remained unchanged. In other studies, not surprisingly, there are widely differing trade and growth effects, and these environmental and health effects, of differing liberalisation programmes, *e.g.* linking with different trade blocs, or undergoing unilateral or complete liberalisation, select specific sectors for action, or restrict the extent of reforms. Such factors determine the scale, composition and technique effects.

In the debate as to whether economic growth leads to improved welfare, there are four key questions. Does pollution follow a 'Kuznets' curve, an inverted-U relationship, first rising and then falling as income increases? At what income level does the turn-around occur? Do all pollutants follow the same trajectory? Is pollution reduction in LDCs due primarily to structural change, or to regulation? H Hettige, M Mani and D Wheeler, in a fascinating article in the Discussion Paper, tested for a Kuznets effect by measuring the effect of income growth on three proximate determinates of pollution: the share of manufacturing in total output; the sectoral composition of manufacturing, and the intensity (per unit of output) of industrial pollution at the 'end-of-pipe'. Manufacturing share followed a Kuznets-type trajectory; the other two determinants did not. Sectoral composition became 'cleaner' through middle-income status and then stabilised. At the 'end-of-pipe', pollution intensity

declined strongly with income. On the basis of recent trends in water pollution in the OECD, the Newly Industrialised Countries, Asian LDCs and the ex-COMECON economies, the authors concluded that industrial water emissions level off in richer economies because pollution intensity has an elastic response to income growth. Unitary elasticity, however, implies that total emissions remain constant unless other factors intervene. Industry tends to deconcentrate or relocate over time as infrastructure and prosperity spreads, but the combined existence of seriously polluted waterways in prosperous MDCs would show that the Kuznets-type hypothesis does not always hold true.

Trade liberalisation strongly impacts on agriculture, horticulture and forestry, and in a case study in Kenya, preferential horticultural trade between Kenya and the EU had little effect on land use or Kenya's rural environment, but safeguarded marginal, survival-level producers. In the Sahel, distortions in paraffin (kerosene) and petroleum (gasoline) prices had almost no impact on the rate of woodland degradation.

Weak environmental regulations could be expected to lead to pollution-intensive industries ('pollution havens'), particularly in LDCs. Studies would indicate that factory locations and trade patterns do not appear to be strongly affected by environmental regulations, as LDC production is mainly focused on domestic markets. Sometimes, policy-makers compensate firms subjected to regulations (*e.g.* the 'Polluter Pays Principle' rarely hold true in agriculture), and stock markets, even in LDCs, are significantly affected by reports of environmental performance. The question of trade sanctions against 'free-riders' in international environmental agreements (*e.g.* the Montreal Protocol) is germane whilst there is no supranational enforcer. Political drag and regulatory chill in environmental policy-making invariably reflect on trade assessments by individual countries, but the existence of healthy democracies enforces the shouldering of global responsibilities. Environmental policies that involve taxation could well amplify existing tax distortions, just as subsidies to pollutors (such as intensive livestock agriculture and energy producers) distort the speed of addressing environmental pollution. There were also detrimental effects of weak environmental regulations on public finances, market prices, and competition. Fortunately, capital markets enforce environmental performance, where there are concerns over legal liability and damage to reputations. Not all polluters are stock-market listed, however: sobering as it is, publicly owned organisations and governments, especially in the centrally controlled economies, have been some of the worst-ever global polluters.

Nominally, the UN Environment Programme (UNEP) is the world's focal point for environmental concerns, the first UN body to be based in the developing world, in Nairobi. It was designed to act as a repository and disseminator of information, and co-ordinator of international responses. After a period of decline in the 1990s, the *Global Environment Outlook 2000* UNEP document offers a return to a central rôle, but this is now in jeopardy with proposals for the creation of a World Environment Organisation, and also with confusion over UNEP's interface with the Commission for Sustainable Development, based in New York. At the Montreal Biodiversity Conference in January 2000, the draft Cartegena Protocol on Biosafety was passed, and finalised at a meeting in Nairobi in May 2000. The protocol will take effect within 90 days after having been signed by 50 nations. In that it has the purpose to ensure public safety, maintain biodiversity, and protect and utilise organisms by providing guidelines for international trade and their use in foods, feed and processed goods, it will have a dramatic effect on biotechnology R&D, and the biotechnology industry. It is the first international treaty to incorporate the 'precautionary principle', rather than manage hazards by requiring hard scientific proof and qualification of risks; the precautionary principle insists that potential environmental risks should be dealt with even in the absence of any scientific certainty. Some regard the protocol as unworkable because it is too vague, legally and scientifically, leading to arbitrariness and vulnerability to industrial or environmental lobbyists. It is also regarded as an impedance to progress (see Plant Biotechnology section).

UK Perspectives

Reform of the House of Lords continued with the loss of right of the 750 hereditary peers to sit in the upper house. Interim arrangements were put into place whereby 92 hereditary peers were elected by their fellow hereditary peers to sit alongside the 580 life peers, bishops, and law lords. The future and constitutional rôle of the House of Lords remained unclear.

Under a system of proportional representation, elections were held in May 1999 for a new Parliament for Scotland, and a National Assembly for Wales. In Scotland, a Labour-Liberal Democrat coalition administration was formed; in Wales, a Labour minority administration was established. Elections in June to the European Parliament also involved the proportional representation voting system, which favours minority and marginal parties. A turnout of only 23% was taken by many to be a symptom of large-scale euroscepticism.

In December 1999, the Northern Ireland Assembly assumed wide powers of self-government, some nine months later than presented in the 1998 Good Friday Agreement. The failure of paramilitary groups to decommission arms essentially destabilised the executive, a position exacerbated by various actions which were regarded as offensive to the unionist and nationalist traditions.

Within the UK, environmental protection is sustained by over 50 international conventions and over 300 European Directives, plus the implementation of UK legislation through the Environment Agency, the Scottish Environment Protection Agency, and the Environment and Heritage Service for Northern Ireland. The EU-based effort is based on the Fifth Environmental Action Programme, *Towards Sustainability*, which was adopted in 1992 and is due for replacement by the Sixth Environmental Action Programme in 2001 if agreement can be reached. Sustainable development is an elastic term, but is widely defined to incorporate social and economic development as well as environmental development, *i.e.* development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. The first UK national sustainable development was published by Government in 1994, and the first set of indicators in 1996. The latest strategy, *A Better Quality of Life*, was published in May 1999, and contained 15 headline indicators backed by a further 150 indicators, against which progress will be measured in both the public and private sectors. Under Local Agenda 21, which was derived from the Rio Conference in 1992, Local Authorities will be expected to adopt sustainable development strategies by the end of 2000. A draft UK climate-change programme was published in March 2000, proposing a 20% cut in carbon dioxide emissions by 2010; a climate change levy to be introduced in April 2001; carbon trading, energy efficiency and management measures; reducing pollution and vehicular congestion, better countryside management and reduction in the use of fertilisers. A separate climate-change programme is envisaged for Scotland. Conservation of the natural environment through legislative enforcement was considered through both UK and EU routes. The UK was deemed to have been deficient in designating sites of international interest for birds – Special Protection Areas, and for other species – Special Areas for Conservation. Atlantic oakwoods, bogs and salmon rivers were omitted from the UK listing which is intended to form part of a Europe-wide network of conservation sites, termed Natura 2000. Moreover, Greenpeace won a legal ruling to have marine Special Areas for Conservation included within the UK's exclusive 200-mile economic zone and not only within the 12-mile territorial waters. Extra protection of Sites of Special Scientific Interest (SSSI) was one of the main features of the Countryside and Rights of Way Bill wending its way through Parliament, but the proposals to give public rights of access to moorland, downland, and registered common land caused disquiet in rural communities and wildlife bodies. Government-backed development of the tidal mudflats in Cardiff Bay to produce a marina was completed in November 1999. In so doing, the SSSI-designated mudflats were destroyed, removing a major over-wintering site for migratory birds, and incurring criticism from the EU. A nearby nature reserve on the Gwent Levels was thought to be inadequate as a replacement.

Although research and development (R&D) are regarded as subsets of science, engineering and technology (SET), R&D in the UK accounts for the overwhelming proportion of public expenditure on SET. Much of the remaining SET expenditure is directed towards scientific and technical postgraduate education and training, and technology transfer. Civil R&D spend is apportioned either in the funding directly from Government departments – as in the

case of SERAD's support for the Scottish Agricultural and Biological Research Institutes including SCRI – or through the Higher Education Funding Councils (HEFCs) and the Research Councils (RCs) such as the Biotechnology and Biological Sciences Research Council (BBSRC). The HEFCs support education, training and research at universities, whereas the RCs sponsor R&D both at academic institutions and other research bodies, although institutions are not eligible to apply for virtually all of the HEFC and RC spends. HEFCs funding is a component in the Vote of the Department for Education and Employment in England and Wales, and its equivalent north of the border, whereas the RCs are financed by the Office of Science and Technology through the Science Budget or Science Vote. These two funding streams constitute the Dual Support System.

Using the base year 1997-1998, government-funded R&D declined in real terms from £6.32bn in 1995-1996 to £6.12bn in 1998-1999, but is set to increase to £6.79bn in 2001-2002. Further analysis of the figures shows that the R&D spend in the civil departments, as opposed to the universities and RCs in support of the 'science base', is set to decline from £1.28bn in 1997-1998 to £1.17bn in 2001-2002, continuing a trend that has been evident since the late 1980s.

In the *Forward Look* (Cm4363, July 1999) issued by the UK Government, the three main thrusts of public expenditure were to (i) ensure that British science is and continues to be world class; (ii) support the exploitation and development of existing and new technologies, particularly through encouraging partnerships and the flow of people between universities and business; and (iii) support Government departments in meeting their policy commitments – hence the phrase "evidence-based policy". In their *Fifth Report*, the House of Commons Select Committee on Science and Technology recommended that in future editions of *Forward Look*, there should be another objective – to generate useful knowledge and inventions, both as a contribution to enhancing the competitiveness of the UK economy, and as a stimulus through innovation to wealth creation and improved quality of life. The *Fifth Report* was hard-hitting, noting deficiencies in the latest Foresight programme, expressing anxiety over the decline in civil department's R&D investment, recommending the creation by the Government of a sustainable environment to encourage investment by industry in R&D, and concluding that departmental arrangements be amended to improve the status and impact of SET.

The Government's science White Paper produced by the Department of Trade and Industry (DTI; http://www.gov.uk/ost/aboutost/dtiwhite/.html) recognised that innovation is the motor of the modern economy, requiring a combination of scientific excellence, the right climate, competitive markets, public confidence and incentives to flourish.

Bibliometric analysis during the period 1981-1998 demonstrated that the UK's record for scientific analysis for scientific research and excellence is second only to the USA, and the UK leads the world in the life sciences. According to the Office of Science and Technology (a sub-set of the DTI), with only 1% of the world's population, the UK is responsible for 4.5% of the world's spend on science, yet produced 8.2% of the world's scientific papers, received 9.2% of world citations, and claimed around 10% of internationally recognised prizes steadily throughout the last century. In 1998, exports *per capita* of high-technology goods and services were the highest of the G7 countries. The key proposals of the White Paper were (i) a £1bn programme in partnership with the Wellcome Trust to renew the infrastructure for science; (ii) a £250m spend in key new areas - genomics, e-science, and basic technology such as bioengineering, nanotechnology, and quantum computing; (iii) improved remuneration for research students; (iv) launch in partnership with the Wolfson Foundation and the Royal Society an initial fund of £4m to assist in the recruitment of up to 50 top researchers; (v) raising the profile of science to young people; (vi) facilitating the creation of networks linking public and private-sector bodies, and researchers and industries; (vii) provide the best framework for scientists and businesses to make international links; (viii) establish a Higher Education Innovation Fund of £140m over 3 years; (ix) launch a new Foresight fund initially up to £15m; (x) run a further round of the University Challenge Competition; (xi) create new Regional Innovation Funds of £50m a year, support 50 Business Fellows and, inspired by the US Small Business Innovation Research Fund, introduce a Small Business Research Initiative; (xii) change the rules for Government-funded research so that all research bodies own the Intellectual Property Rights, encourage incentives and risk-taking by staff, and provide £10m to commercialise public-sector research; (xiii) Government to act to the highest standards as a regulator, implementing stronger guidelines on how scientific advice should be used in drawing up Government policies and committing scientific advisers to Government to

adopting high levels of openness and transparency in their work.

With regard to the future of its excellence in science, the UK is witnessing the fall in numbers of graduates in physics, chemistry, chemical engineering, and technology.

To ensure that applied work and interdisciplinary collaboration are not constrained by the Research Assessment Exercise (RAE) carried out by the Funding Councils, there will be a combination of monitoring the outcome of the next RAE in 2001 and the launch of the Higher Education Innovation Fund mentioned above. Science and technology are central to gaining competitive advantage, but many UK industries invest less in R&D than those in competing countries. The pharmaceutical sector is the most important innovative, high-technology industry in the UK, accounting for nearly 25% of high-technology R&D investment compared with an OECD average of 8%. This performance, however, could be imperilled by animal rights activists and legislative and regulatory changes that impede the progress of research.

In a much-welcomed and constructive response to the Baker Report on Public Sector Research Establishments (PSREs; see *Creating Knowledge-Creating Wealth: Realising the Economic Potential of Public Sector Research Establishments* Published 1999 – available at www.hm-treasury.gov.uk/docs/1999; and *The Government's Response to the Baker Report* – available at www.hm-treasury.gov.uk/pubs/html/docs/main.html), the Government accepted the thrust of the recommendations, and specifically implemented changes, including (i) prompt changes to the civil service conduct rules to allow government scientists new incentives and rewards, subject to safeguards, for participating fully in exploitation and entrepreneurialism *e.g.* through equity in spin-out companies; (ii) tackling the well-known risk-avoidance culture in PSREs, encouraging well-managed risk-taking; (iii) addressing the need for advice to help commercialise their discoveries and inventions; (iv) all relevant departments and RCs, in partnership with PSREs, to produce timetabled action plans for ensuring that PSREs can effectively pursue knowledge-transfer activities; (v) ensure that PSREs are able to participate fully in governmental schemes which incentivise the transfer of knowledge to industry; (vi) ensure that the next Prior Options Reviews of PSREs fully address the recommendation that departmental PSREs are put at greater arm's length from government.

Despite frequent reports in the media and accounts of anti-science and anti-technology activists, the White Paper noted that over two-thirds of people in Britain agreed that science and technology are making our lives healthier, easier and more comfortable, over three-quarters agreed that scientists and engineers make a valuable contribution to society, and 84% agreed that they were amazed by the achievements of science. That around 14 to 27% disagreed or neither agreed nor disagreed with any of the three propositions might be deemed to be an expression of ignorance or an inability to accept the pace of change.

Legislation and regulation rapidly introduced by forceful demands in the media (*e.g.* the statistically unjustifiable ban on beef-on-the-bone, the unenforceable requirement to label genetically modified food in restaurants, excessive spending and accountability controls in the public sector *etc.)* essentially pander to a risk-averse society, ironically as symptoms of greater open government, and lack of trust in regulators and scientists. Simply to remove the bulk of legislation, however, let alone retard wholesale the introduction of new legislation, would expose ministers, civil and public servants, to the vagaries of bad publicity as well as adversely affect vulnerable consumers and weaker members of society. One challenge for government regulation comes in its interface with a single dominant company or organisation in a prominent area of activity, to ensure 'public interest', however that is defined. Government wishes neither to be the manager nor adversary of the business, if the confidence or private-sector investors is to be maintained. There is a large body of informed opinion that the establishment of a robust competition framework provides a suitable mechanism for dealing with dominant or monopolistic organisations, and where absolutely necessary, assets can be retained in the public sector but their operations can be transferred to competing private companies. This argument can be turned and extended to research provision where the public sector has until recently become a virtual monopoly addressing public-sector interests and industry-sector, but nowadays most advances in computing, telecommunications and biotechnology are being made in the private sector, and new forms of interlinking are required.

One of the most important and succinctly written documents on UK agriculture is the annual account *Agriculture in the United Kingdom* produced by the Ministry of Agriculture, Fisheries and Food, the Scottish Executive Rural Affairs Department, the Depart-

ment of Agriculture and Rural Development (Northern Ireland), and the National Assembly for Wales Agriculture Department. (See also www.maff.gsi.gov.uk/esg and *Basic Horticultural Statistics for the UK*.) Provisional Data in the calendar year 1999 edition indicated that the contribution of agriculture to the total economy gross value added (GVA), at current prices £6.991bn), declined from 1.0% in 1998 to 0.9% in 1999, following a long-term trend of decline; in the period 1988-1990, the average contribution was 1.5%. About 2.1% (593 000) of the UK workforce was employed in agriculture, a figure that omits many groups whose employment is dependent on primary production, such as many employees in the public sector, food-processing, and industrial-feedstock industries. Importation of food, feed, and drink amounted to £17.269bn, compared with £17.198bn in 1998, and amounted to 8.8% of total UK imports. Imports of alcoholic drinks amounted to £1.787bn for the EU and £0.757bn for the rest of the world. Statistical factors have been introduced to devalue processed imports to the value of their unprocessed food content. This has reduced the estimated value of food imports, which in turn reduced the estimated value of food consumption, and thus UK food production as a percentage of UK food consumption has increased. Exports of food, feed, and drink declined from £9.246bn in 1998 to £8.715bn in 1999, of which alcoholic drink contributed £1.081bn to the EU and £1.658bn to the rest of the world. These agriculturally related exports amounted to 5.3% of total UK exports, down from 5.6% in 1998, and an average of 6.1% in the period 1988-1990. The UK was 68.4% self-sufficient in all food types in 1999, compared with 67.3% the year before, and an average of 73% in the period 1988-1990. For indigenous-type food, however, the UK was 81.6% self-sufficient; the level for 1998 was downgraded from 82.3% to 81.4%. Household final consumption expenditure on household food and alcoholic drink at current prices was up from a revised £84.196bn in 1998 to £85.3bn in 1999; yet again, there was an astoundingly high proportion of that spend – over 36% - devoted to alcoholic drinks (£31.2bn)! Household food and alcoholic drinks accounted for only 15.2% of total household final consumption expenditure. Domestic food expenditure alone was only 9.7% of total household expenditure compared with 5.6% for alcoholic drinks.

In June 1999, the total area of agricultural land, including common rough grazing, was 18 579 000 hectares, of which 4 709 000 hectares were devoted to crops, and 33 000 hectares were left fallow. In the period 1988-1999, an average of 18 932 000 hectares, were committed to agriculture, 5 135 000 hectares of which were harvested for crops. More detailed analysis of the cropping data reveals that the area devoted to cereals declined from a revised figure of 3 420 000 hectares in 1998 to 3 141 000 hectares in 1999, mainly attributable to increased compulsory set-aside (raised from 5% to 10%) leading to declines in the wheat area from 2 045 000 hectares to 1 847 000 hectares, and in the barley area from 1 255 000 hectares to 1 179 000 hectares. The potato area increased to the area grown in 1996 of 178 000 hectares. Other arable crops, excluding potatoes, were grown on an increased area of land, up from 1 192 000 hectares in 1998 to 1 211 000 hectares in 1998. This increase was accounted for by the dramatic increase in the area devoted to linseed, up from 99 000 hectares in 1998 to 209 000 hectares in 1999. In contrast, there were declines forecast for oilseed rape, down from 506 000 hectares to 417 000 hectares; sugar beet not for stock feeding, down from 189 000 hectares to 183 000 hectares; and peas for harvesting dry and field beans, down from 213 000 hectares to 202 000 hectares. The area of land for horticulture was 179 000 hectares, closely similar to the 1998 value of 178 000 hectares. Of this area, the bulk was attributable to vegetables grown in the open (126 000 hectares, up from 123 000 hectares in 1998); with 28 000 hectares committed to commercial and non-commercial orchards; 13 000 hectares for ornamentals; 9 000 hectares for soft fruit including wine grapes; and 2 000 hectares for glasshouse crops.

Without taking account of direct subsidy payments, the average price of agricultural products fell by 4% between 1998 and 1999, and inputs fell by 1.8%. The average price of agricultural products has fallen by 25% over the last 4 years from a peak in 1995. Illustrating the pressure on producers, the average price of agricultural products is 11% lower than 10 years ago, whereas the average price of inputs has increased by 13%.

In terms of production, despite the 8% decline in cereal growing area, overall production of cereals fell by 1.3% to 22.5mmt. The value of production fell by 6.1% to £2 349m. Provisional cereal yields in 1990 were 8.12 tonnes per hectare for wheat, 5.74 for barley, and 6.17 for oats. Wheat production declined from 15.47 mmt in 1998 to 15.11 mmt in 1999, valued at £1,545m. Barley, one of SCRI's mandate

crops, recorded a small increase in production from 6.63 mmt in 1998 to 6.67 mmt, but the value of production declined over the same period from £397m to £330m. Oat production declined to 0.575 mmt with a value of £57m.

Potato production in 1999 sharply increased from the 1998 trough of 6.417 mmt to 7.1 mmt, valued at £755m. In 1995, the crop which is a key mandate crop for SCRI, was valued at £1 088m. Potato seed production, including farm-saved seed, increased from 404 800 tonnes to 427 600 tonnes. Oilseed rape production was forecast to have increased from 1.57 mmt to 1.667 mmt with a production value of just £356m, compared with £407m the previous year's crop. Sugar beet production in 1999 was adjudged to have been 10.328 mmt, adjusted at standard 16% sugar content, and was valued at £291m. Linseed was clearly seen as a financially safer planting option than crops such as oilseed rape, and production rose dramatically in line with the doubling in planting area from 143 000 tonnes to a provisional 295 000 tonnes with a value of £129m of which 79% was accounted for by subsidy payments.

In horticulture, vegetables grown in the open in 1999 on an estimated total area of 148 500 hectares were valued at £646m, and £317m for protected crops grown on an area of 1 200 hectares. The highest valued horticultural commodities were mushrooms (£173m), lettuces (£102m), carrots (£94m), tomatoes (£67m) and cabbages (£65m), followed by peas (£50m) and cauliflowers (£38m). Orchard (top) fruit production on an area of 25 300 hectares was valued at £108m, and soft fruit at £132m on an area of 8 900 hectares, mainly attributable to two crops of importance to SCRI, strawberries (£84m) and raspberries (£36m). Raspberry production in Scotland continued with its long-term decline to around 2 400 tonnes. In the UK, the planted hectares of raspberries has declined to 2 355 with a yield of 5.6 tonnes *per* hectare; in Scotland, the yield is even lower at 3.9 tonnes *per* hectare. Ornamental production on 18 700 hectares was valued at £682m, compared with figures of production on 19 200 hectares valued at £659m in 1998. The value of production in 1999 was attributed to £371m for hardy ornamental nursery stock, £273m for protected crops, and £37m for flowers and bulbs in the open.

MAFF estimated that the measure 'Total Income From Farming' (TIFF), which is acutely sensitive to relatively small percentage changes in the values of outputs and inputs, was broadly unchanged from the 1998 value, at £2 339m, though considerably less than the 1997 figure of £3 193m or of £5 279m in 1995. Paid labour costs in 1999 were estimated to be £1 963m, slightly less than in 1998. Net Value Added at Factor Cost is one of the best measures of value added by the industry because it includes all subsidies on production (some are not included in output *e.g.* set-aside and agri-environment payments), but makes no allowance for interest, rent or labour costs. In 1999, it was estimated to be £5 110m, a fall of 1.9% from the previous year. TIFF is derived by deducting interest, rent and paid labour costs from Net Value Added at Factor Cost. It was because interest payments were 13% lower than the previous year, and both rent and labour costs were slightly lower, that TIFF was largely unaffected. According to the accountants Deloitte and Touche, farmers have experienced an effective 90% drop in income over the past 5 years and can expect to see heavy losses in 2001. Thus, the average farmer would register a profit of £8 000 in 2000, but a loss of £4 000 in 2001, equivalent to a loss of £22 *per* hectare. The main factors were adjudged to be rising fuel costs, the strength of sterling relative to the euro, and the failure of retailers to pass on profits to the producers. Across the EU, there was a 4% drop in income in 1998-1999 from agriculture, but the most pronounced falls occurred in Ireland (-13%), Denmark (-11%), Spain (-8%), Belgium (-7%), The Netherlands (-6%), and Germany (-5%), whereas increases were posted in Luxembourg (+5%), Sweden (+6%) and Portugal (+14%). Within the UK, the TIFF figure of £2 339m comprised £1 989m for England, £239m for Scotland, £71m for Northern Ireland, and £40m for Wales. Agriculture's share of total regional gross value added at basic prices was 0.9% for the UK, 0.9% for England, 1.3% for Scotland, 2.4% for Northern Ireland, and 1.1% for Wales. In terms of the share of total regional employment, agriculture accounted for 2.1% in the UK, 1.8% in England, 3.1% in Scotland, 8.5% in Northern Ireland, and 5.2% in Wales.

The total UK public expenditure on agriculture in 1999-2000 was forecast to decrease by about £310m to £3.1722bn. Of this, spending under the CAP heading was forecast to decrease from £3.193bn in 1998-1999 to £2.924bn in 1999-2000, of which 42% was apportioned to the arable area payments scheme, 16% to beef and veal (non-BSE measures), 13% to sheep meat, 11% to beef and veal (BSE measures), 5%

to milk, 5% to sugar, and 2% to cereals.

Among the numerous agricultural policy developments in 1999 were attempts to reform the CAP throughout the Agenda 2000 negotiations. The limited changes should deliver annual net savings to the UK economy of approximately £200m in 2001 rising to £500m in 2008. Under the EU Rural Development Regulation (RDR), the 'second pillar' of the CAP, plans were submitted to the European Commission for England, Scotland and Wales. The RDR integrated framework supports agri-environment schemes, less-favoured areas, woodland planting and management, and structural adjustments in the farming industry. Complex economic, environmental and social factors surround the implementation of schemes relating to modulation; cross-compliance; set-aside; area aid compensation; intervention prices; commodity payments for cereals, oilseeds, fibre, flax, hemp and sugar; payment windows; structural funds; the wine regime; the agrimonetary system; marketing schemes; environmentally sensitive area schemes; countryside and rural stewardship schemes; organic farming scheme; habitat scheme; farm woodland premium scheme; countryside premium scheme; Tir Gofal (Land in Care); nitrate sensitive areas scheme; nitrate vulnerable zones; farm waste grants; producer organisation funds; short-rotation coppice establishment grants *etc*. This is further complicated by a tranche of livestock-related schemes.

During 1999-2000, the first statutory review of the British Potato Council (BPC) took place, involving a consultation exercise, an economic evaluation, and a poll of levy payers. Established to commission or undertake R&D, collect and disseminate statistical information, promote potatoes on the home market, and develop export opportunities, the BPC occupies a pivotal position connecting industry and academia. Confirmation of its continuation was widely welcomed by the R&D community. Likewise, following statutory review, the continuation of the Horticultural Development Council (HDC) was announced for another term of 5 years. The HDC commissions near-market R&D on behalf of the horticulture industry, but excluding the producers of apples, hops and pears. For both levy boards, meeting the needs and perceptions of the growers is a tough challenge during a period of low profitability.

In November 1999, the Bill to establish the Food Standards Agency (FSA) received Royal Assent as the Food Standards Act 1999. The FSA is a non-Ministerial government department accountable to Parliament through Health Ministers and to their devolved equivalents. It provides the primary source in Government of advice on food safety and standards, taking a strategic view of policy across the whole food chain and operating at arm's length from Ministers and the devolved administrations. Regional executives were appointed in Scotland and Wales. Formed largely as a response to the BSE and *E.coli* O157 debacles, the FSA is designed to operate with a presumption of openness, addressing issues of food safety, public confidence and risk. Its four main functions will be to (i) develop policy and provide advice and information to Ministers, devolved administrations and other public bodies; (ii) provide advice and information to the public and other interested parties; (iii) commission research and surveillance and keep itself informed of relevant developments; (iv) set standards for and monitoring of food law enforcement. Sir John Krebs, the eminent scientist, was appointed Chairman. At some time in the future, the relationships between the various food-related agencies in the EU, and their rôles in international trade will come under close scrutiny, especially in the development of policies that are proportionate to the real risks involved.

Plant Biotechnology

Biologists are now entering an exciting phase of research, the post-genomic era of investigating the functional analysis of genes and their direct and indirect products. Functional genomics employs a battery of approaches including (i) the creation of stable and transient-expression transgenic organisms; (ii) phage display systems, for example, searching domain repertoires; (iii) procedures for studying protein-protein interactions, particularly *via* transcriptional activation of one or several reporter genes; (iv) high-throughput gene expression profiling at the transcript level (DNA microarrays); (v) differential display; (vi) serial analysis of gene expression; (vii) protein composition, configuration and levels proteomics; (viii) gene trap methodology; and (ix) bioinformatics and computational genomics. DNA microarray analysis enables the survey of thousands of genes in parallel, and is deployed in expression monitoring, polymorphism analysis, and, to a limited extent, sequencing. Proteomics is a term that encompasses all the methods that analyse patterns of gene expression at the protein level, *i.e.* the proteome – the complete set of proteins encoded by

the genome, including the set of proteins expressed both in time (*e.g.* development and disease status) and space (location). Two approaches tend to be adopted: the expression model and the cell-map model.

Regardless of the rapid advances in structural and functional genomics, proteomics and 'metabolic profiling' (the latter is a term A M M Berrie, B A Knights and I employed in 1972 at Glasgow University as we embarked on extensive analyses of plant extracts using combined gas chromatography – mass spectrometry; the modern jargon is 'metabolomics'), genetically modified (GM) crops and GM foods agitated politicians, pressure groups and the media, "organic" growers, and beekeepers. By the end of 1999, most supermarket chains withdrew foods containing GM ingredients. In October, the Government announced that no new GM foods would be allowed on sale in the UK before 2002. Even though biotechnology clearly encompasses R&D and products that transcend transgenic organisms and their products, the issue of GM crops and GM foods dominated biotechnology-related industrial, commercial and public-sector research agendas in Europe generally, and the UK in particular.

"In this book, I have tried to show that the scientific attitude has a well-defined rôle in the dialogue between the possible and the actual. The seventeenth century had the wisdom to introduce reason as a useful and even necessary tool for handling human affairs. The Enlightenment and the nineteenth century had the folly to consider it to be not merely necessary but even sufficient for the solution of all problems. Today, it would be still more foolish to decide, as some would like, that because reason is not sufficient, it is not necessary either. Yet, while science attempts to describe nature and to distinguish between dream and reality, it should not be forgotten that human beings probably call as much for dream as for reality. It is hope that gives life a meaning. And hope is based on the prospect of being able one day to turn the actual world into a possible one that looks better." François Jacob, The Possible and the Actual. 1982

In the authoritative *Brief Global Status of Commercialized Transgenic Crops: 1999*, by C. James, from the International Service for the Acquisition of Agri-Biotech Applications (see www.isaaa.org and also www.agbiotechnet.com), the following points were made that illustrate the expanding influence of transgenic technologies in agriculture: (i) Despite mainly European-based resistance to GM crops, the global area of transgenic crops increased in 1999 to 39.9m hectares, a 44% increase over the 1998 level. (ii) Seven transgenic crops (soybean 59% of area; maize 23%; cotton 10%; oilseed rape/canola 8%; potato; squash and papaya) were grown in 12 countries (USA, 28% of total; Argentina 6.7%; Canada 4.0%; China 0.3%; and smaller areas in Australia, South Africa, Mexico, Spain, France, Portugal, Romania and Ukraine). By 1999, 30% of the global area devoted to soybean was down to transgenic soybean, 14% of the oilseed rape/canola area was transgenic, 10% of the cotton area, and 8% of the maize area. (iii) The dominant transgenically introduced traits were herbicide tolerance, insect resistance, and stacked genes of insect resistance and herbicide tolerance. (iv) The transgenic seed market was estimated to reach a value of $2.7-3.0bn in 1999. (v) Expansion of transgenic crops is anticipated, particularly in LDCs, but public acceptance in MDCs (especially the EU) will be influential in shaping market demand, introducing regulatory processes such as food labelling and farming procedures, and thereby affecting commodity prices. (vi) Phenomenal advances in genomics-based R&D, plus a wide range of new transgenic products in the R&D pipeline, emphasise the huge potential of transgenic crops (especially wheat, rice and maize), to address the major challenges facing mankind in such countries as China and India, as well as generate new wealth-creating markets and address quality of life issues. (vii) Governments have a crucial rôle both to implement regulatory programmes that inspire public confidence and to exert leadership in communicating information on transgenic biology.

Throughout the debate on GM crops, the production of improved or superior cultivars/varieties that have desirable input and output traits continue to present the greatest challenge to global agriculture, and figure as the prime target in international foresight programmes on agriculture and horticulture. In countries such as China, where a fifth of the world's population is dependent on just 7% of the world's cultivated land area, as well as in other LDCs, there is no current viable alternative to investigate the potential of transgenic crops and trust that conventional agriculture continues to perform as well as it does. Nonetheless, the theoretical risks of transgenic technology have been aired to such an extent that the EU invoked the 'precautionary principle'. On the basis that there is insufficient scientific evidence to conclude that there is no risk to consumers from trans-

genic crops or products derived from them, imports of certain GM crops have been prohibited, and commercial transgenic crops plantings largely brought to a halt. The fact that transgenic crops and their products pose no greater a risk to health and the environment than conventional or 'organic' agriculture has not persuaded the EU and most of the member states to adopt a more sophisticated approach to the GM public-perception issue, and put in place regulatory and monitoring systems that are trusted by the public. At the end of February 2000 in Edinburgh, Sir John Krebs closed the OECD GM-food Conference in Edinburgh, noting that current GM releases had so far shown no ill-effects on human health. Nonetheless, as new and more sophisticated GM foods come on stream, the mechanisms needed to approve these foods must be enhanced, modified and improved. The concept of 'substantial equivalence', coined by the OECD in 1993, would have to be reviewed. The conference was attended by about 400 scientists, regulators, NGOs and representatives of consumer organisations, the food industry, and pressure groups.

In Hunger Site 2000 (http://www.thehungersite.com) it is reckoned that in LDCs, 24 000 people die each day from chronic malnutrition. Livestock and crop performance at a global level are grossly inadequate. With regard to food crops, the scientific targets are numerous: increased yield; better water use efficiency; better nutrient-use efficiency; improved resistance to biotic stresses (viruses, bacteria, fungi, nematodes, insects, weeds *etc.*); improved tolerance of or resistance to abiotic stresses (temperature, salinity, aluminium toxicity, drought *etc.*); delayed senescence/ripening; enhanced quality (proteins, lipids, carbohydrates, minerals, vitamins *etc.*); improved harvestability; diminished allergens or toxins; better taste, texture and appearance; greater uniformity; and improved storage and processing qualities. Similar targets apply to non-food and dual-purpose crops, such as cotton (see Table 3). Many such non-food crops tend to be low-yielding and place heavy demands on inputs that have deleterious environmental effects. Access to freshwater, just 0.007% of all the water on earth, is the major limiting factor to crop production. In fact, agriculture accounts for 93% of global consumption of water through rainfall or irrigation. According to the World Meteorological Organization (*Comprehensive Assessment of the Freshwater Resources of the World*, 1977), two-thirds of the world's population could be facing water shortages by 2025.

Mention should be made of such advances as the work of I Potrykus and P Beyer who demonstrated in rice the incorporation of several genes simultaneously that code for β-carotene, the precursor of vitamin A, and the joint work between the University of Florida and Monsanto Inc. in incorporating the gene for glutamate dehydrogenase derived from *Chlorella sorokiniana* into wheat, leading to greatly increased soil nitrogen use efficiency. In fact, the recent achievements of the maize, rice and wheat breeding programmes have been prodigious. This gives optimism for overcoming the current annual genetic gain in cereal productivity of less than 1% *per annum*, subject to overcoming impediments such as market-distorting subsidies and regulations, underfunded agricultural R&D projects, malfunctioning public-private partnerships *etc*.

A convoluted set of inter-company relationships and overlapping technologies in the agricultural genomics industry coupled with mergers, acquisitions, alliances, spin-out companies as well as intense legal activity over intellectual property ownership and rights, have collectively presented an awkward face to investors, to NGOs, and to those opposed to biotechnology. Consequently, the year was one of crop biotechnology facing shrinking investments, an irony when the scientific potential has never been so great, and future food-security needs so pressing.

For the poor, and those that represent them and act on their behalf, the benefits of agricultural biotechnology require a measure of 'freedom to operate'. Given population pressures, the steady loss of cultivated land, diminishing access to freshwater, falling commodity prices, and reduced support for the publicly funded network of research bodies in MDCs and LDCs, the poor farmers in LDCs can only but contrast their lot in life with the technologically dependent rich in their own countries and elsewhere. Such is the impact of modern communications technology in raising expectations. M S Swaminathan has made the point that India has over 16% of the world's population, and 15% of its farm animals, but occupies only 2% of the land area and receives only 1% of its rainfall. Despite being largely illiterate, India's farmers have harnessed new technologies, saving India from mass starvation, but the scale of the demand for food is increasing remorselessly, and India needs to double food production in the next 10 years to ensure food security.

Of the various concerns – biological, social, economic, ethical, political – about agricultural biotechnology, the issue of risk and benefit comes to the fore. Do the

benefits apply only to the few? What are the risks of not applying the technology? What are the known and theoretical risks of applying the technology to health and to the environment? What acceptable alternatives are there? What are the risks and benefits when the issue is driven by the publishing and broadcast media? Is it possible to insure against risks to people, property and the environment ('common goods')? What are the risks and benefits of a patenting system or UPOV system and can they be combined? What are the risks of having monopolistic suppliers of seed – public or private?

These questions must be placed alongside the analyses of the International Food Policy Research Institute (IFPRI) in *The World Food Situation : Recent Developments, Emerging Issues, and Long Term Prospects*, 1997. Increases so far in world food production have actually kept in advance of the increases in global population. Even so, the growth rate of world agriculture has declined from 3% in the 1960s to just 2% in the last decade; aggregated projections with reasonable initial and modestly optimistic assumptions, indicate that the world food supply will continue to outpace world population growth at least to 2020. The *per capita* availability of food is projected to increase by about 7% between 1993 and 2020. As G J Persley in *Agricultural Biotechnology and the Poor* (CGIAR and the US National Academy of Sciences, 2000) points out, therein lies a paradox. Firstly, despite the increasing availability of food, currently around 0.8 billion of the global population are food-insecure, with children and women the most vulnerable to dietary deficiencies. Secondly, food insecurity is remarkably prevalent at a time when, for various reasons, global food prices are in decline. A F McCalla pointed out in 1998 that, in the period 1960-1990, world cereal production doubled, *per capita* food production increased by 37%, calories supplied increased by a similar amount, yet real food prices fell by almost 50%. Persley noted that the basic cause of the paradox is the linkage between poverty and food security, *i.e.* access to food depends on income, at a time when according to the 1997 report of the World Bank, *World Development Indicators*, more than 1.3bn people in LDCs are classified as absolutely poor, with incomes per person of $1 a day or less, with another 2bn people only marginally better off. In the LDCs, most of the population depend on agriculture and devote their energies and income on food.

K M Leisinger, in the 1999 IFPRI report *Biotechnology for Developing Country Agriculture*, and in *Agricultural Biotechnology and the Poor* mentioned above, considered ethical changes of agricultural biotechnology for LDCs, and attempted to distinguish between technology-inherent and technology-transcending risks. The former are essentially biosafety risks where they relate to health and the environment; the latter emanate from the political and social context in which the technology is used *i.e.* not risks specific to the technology but where its deployment may carry certain risks (*e.g.* reducing biodiversity, increasing poverty gaps between and within societies, adversely affecting trade).

Possible areas of concern over GM crop technology in respect of human health cover potential toxicity, carcinogenicity, food intolerances, use of antibiotic-resistance gene markers, potential allergies, and unintentional modification of nutritional value. There are no clear cases of harmful effects of authorised and released GM crops and food products derived from them, on human or livestock health. Nonetheless, as with any technology, including long-established plant breeding, any potential risk is addressed by considering any potential release on a case-by-case basis.

Food allergens have exercised many in the GM debate, oftentimes quoting the well-publicised study of J A Nordlee, S L Taylor, J A Townsend, L A Thomas and R K Bush in 1996 (*New England Journal of Medicine* 334, 688-692) in which a gene encoding a Brazil nut methionine-rich seed-storage protein was introduced into soybean. It was because the protein was derived from a well-known allergenic source, and that serum and skin tests confirmed the presence of the allergen, that the development of the modified soybean was discontinued and not allowed into the marketplace. Food allergies, *i.e.* adverse immunologically mediated reactions to antigen molecules in foodstuffs, affect about 2% of adults and 4% to 6% of children, and are mainly attributed to exposure to four animal foods (eggs, fish, shellfish, milk) and four plant foods (peanuts/groundnuts, soybeans, wheat, tree nuts), but other major foodstuffs such as chicken, oriental and yellow mustard, tree and grass pollens, latex, apples *etc*. contain known allergens. The allergens are proteins or glycoproteins with an acidic isoelectric point and molecular masses in the range 10,000 to 80,000 daltons, and tend to be resistant to food processing and digestive enzymes. The concern that GM crops might specifically cause allergies is not supported by evidence. In fact, GM technology (antisense RNA) has been used by T Matsuda, A M

Alvarez, Y Tadce, T Adachi and R Nakamura in 1993 to reduce the expression of a major allergen found in rice. Also, very detailed studies by S B Lehrer and C Reese in 1997 (*International Archives of Allergy and Immunology* 113, 122-124) demonstrated in modified soybeans that, qualitatively and quantitatively, the transgenic high-oleate strain appeared to be allergenically the same as the parental wild-type despite the fact that the levels of several proteins were elevated. To date, there is no cause for concern about the allergenic potential for proteins introduced into foods from sources with no history of allergenicity. There is no room for complacency, however, and from the work of H A Simpson, S L Taylor, and R L Fuchs in 1996 (*Critical Reviews in Food Science and Nutrition, IFBC/ILSI* 36(s), 165-186), there is now a safety-assessment multipartite decision-tree for assessing the allergenic potential of foods derived from GM crops, beginning with the characterisation of the source of the introduced gene, and assuming that genes transferred from sources known to be allergenic, encode for one or more allergens unless proven otherwise. This framework for risk assessment involves assessment of introduced proteins in the context of their known history of allergenicity, similarity of their amino acid sequences to known allergens, the ability of the proteins to be digested, and their level of expression. In assessing and attempting to minimise risks, at this juncture there are no specific peculiarities of transgenic technology that do not also apply to conventional breeding. Moreover, allergy is a disease more frequent among the middle- and upper- income classes in MDCs than in the LDCs, where it is not a major factor in health and nutrition of the population.

Another contentious issue is the extent to which GM crops introduce ecological and environmental risks. R J Cook of Washington State University, in *Agricultural Biotechnology and the Poor*, mentioned above, observed that there is no evidence of any crop species having become invasive weeds because of plant breeding. He reinforced the fact that there are no new unique issues in the testing of GM crops, emphasising that the same protocols used to assess the environmental effects of GM plants equally apply to plants derived from conventional plant breeding – both in the past and currently. It is the product rather than the process that should be evaluated. Among the new risks envisaged and imagined outwith the normal range of sexual compatibility include the potential for spread of traits through outcrossing (gene transfer – the resultant hybrids may alter the population dynamics of species in natural habitats giving rise to 'genetic pollution'); induction of difficult-to-control weediness; the inadvertent selection of pesticide resistance in insects and nematodes populations (super-pests); a reduction in biodiversity caused by weed-free monocultural systems; the creation of new pathogens through recombination of viruses or virus components (in plant viruses, genomic variation caused by remarkable levels of mutation is amplified by recombination events of great complexity, pseudo-recombination [genome segment reassortment in multipartite genomes], and acquisition of extra nucleic acid components); pleiotropic effects including formation of allergens and toxins, the inadvertent expression of genetic material from pathogens will cause uncontrolled hypersensitive responses in susceptible species, tantamount to a 'genetic disease'; and human pathogenic microorganisms incorporating antibiotic resistance from antibiotic-resistance marker genes in the first generation of GM crop releases.

Not only are there strange concepts over 'ownership' or 'belonging' of genes to certain species, or even over what is considered to be 'conventional' breeding, there would also appear to be the erroneous view that species and ecosystems are genetically static. Gene flow occurs at various rates in all ecosystems. Virtually all agriculture and horticulture – including domestic gardening – involve the use of alien species, sometimes leading to the introduction of new pests and diseases, but most often the introduced species reaps the benefits of growing in environments lacking the depredation of the pests and diseases from their centres of origin. During the past century, thousands of new cultivars have been introduced into global agriculture and horticulture. Conventional plant breeding has reduced rather than increased (i) the tendency for crops to become weeds, (ii) the level of anti-nutritional and toxic compounds, (iii) erratic dormancy, (iv) traits harmful to non-target organisms, frequently to the point of decreasing the competitive ability and increasing the vulnerability of crops to pests and diseases, (v) variability or pleiotropy, through rigorous screening and statutory testing. In those cases where theoretical or actual gene flow occurs, the fundamental questions distil down to 'so what?' and 'how can it be controlled?' Conventional agronomic practices provide environmental risks in respect of the effects of replacing native flora and fauna with monocultures, modifying the water and nutrient states of the soil, tillage disturbance, modification of the soil microflora

and microfauna by crop rotations, use of pesticides that disrupt flora and fauna, and large-scale disturbance to natural gene flow patterns, including migratory pathways. Erosion and loss of *circa* 0.3% of global cultivated land (approximately 1.5bn hectares), per annum caused by a combination of urban encroachment and poor agronomic practices, mean that the efficiency of production on the restricted land area must be raised without further imperilling natural and semi-natural habitats, ecological refugia and dispersal corridors for flora and fauna. The very essence of good agronomic practice, with both conventional and GM crops, is to reduce risks, *e.g.* prevention of gene flow from outcrossing with wild or crop relatives by the use of herbicides, crop rotations, establishing minimum distances between crops, harvesting before flowering, or not growing the crop. Crop pests and diseases are controlled by the cultivation of resistant varieties and/or pesticides. Such measures ensure sustainability of the cropping system, and may require monitoring by independent authorities, not least in the European context where there is a sensitised public and body politic, concerns over agricultural sustainability, and realisation that a higher proportion of land is farmed in Europe than in the USA, meaning that what is deemed to be 'biodiversity' must be allowed to thrive in the farmland area, alongside and within crops. In many instances, advances in modern agricultural engineering advances mean that weed-infested crops can be cleaned and separated post-harvest, opening up the possibility of using diverse crop mixtures rather than monocultures. Biotechnological approaches also allow biodiversity to be monitored and quantified.

As far as technology-inherent risks are concerned, there are no demonstrable adverse effects from the cultivation and consumption of current GM crops, but precautionary biosafety guidelines and protocols for assessing risks on a case-by-case (crop-by-crop, gene-by-gene) basis are available from the OECD, UN Environment Programme, UN Industrial Development Organisation, the World Bank, and the EU, offering science-based hazard identification and risk assessments. Straightforward, non-pejorative regulatory frameworks will need to be devised with each new generation of transgenic material, with sunset clauses operating in these cases where crops and products have been demonstrated to be of very low risk.

Scientists have difficulty in addressing technology-transcending risks and ethical issues in the deployment of transgenic crops, regardless of using such terms as 'genetically improved' crops. There is no doubt that potential food-safety and environment risks have been grossly and sometimes obscenely over-publicised as a vehicle to draw attention to technology-transcending and/or 'ethical' and 'moral' issues of concern, and it is interesting to compare the public treatment of mobile telephones with that given to GM crops, in respect of perceived risks, acceptability, and benefits. As in information technology and computing, the major advances in biotechnology have been driven by the private sector which requires various degrees of exclusivity, sometimes confidentiality, in order to function competitively in the marketplace. This alone raises particular challenges for public-sector bodies in MDCs and LDCs to establish constructive relationships with the private sector.

Oppressive intellectual property rights; restricted access to foodstuffs; the neglect of medicines, dietary nutrients and crops crucial for LDCs (the so-called low-profitability 'orphan' products and crops); focus on just one essential technology to the exclusion of other, more conventionally but less financially attractive technologies; pressure to downgrade regulatory processes; market policies which are overtly not pro-poor even to the extent of not boosting the economies of LDCs; and the perceived lack of consumer benefits have all been raised as reasons to retard the advance of biotechnology. The CGIAR system (see Table 1) agreed in 1998 to a statement of ethical principles underlying the use of biotechnology by its various Centers. Emphasis was placed on its objectives, transparency of operation, commitment to fairness, honesty, integrity, intellectual rigour, accountability, and precautionary approaches to genetic resources. Interestingly, the statement made reference to the fact that the CGIAR is guided by its particular humanitarian and equity-based concerns, and not to the pursuit of knowledge for its own sake. Fundamental concerns about the sacred and inviolate nature of life forms and their ownership ('core values') are more problematical for scientists knowledgeable about genes, functioning in a pluralistic society, and cognisant of perpetual human intervention in food production, environmental modification, and the domestication of pets, livestock and crops. Blatant disregard for such perceptions and sensitivities would be wholly unjustified, however, given the exquisite sophistication and unquantifiable value of all life forms, and the fascination they hold for all biologists. For some members of society, biotechnology represents an example of the unacceptable rapid rate of progress and societal pres-

sure, with alien vocabulary and techniques. Hitherto, society has evolved almost imperceptibly in tune with its foodstuffs and cultivars – but this is no longer the case, nor can it be. Whereas it is justifiable to argue that the unfettered pursuit of knowledge and understanding is intrinsically good for humanity and the progress of scholarship, it is my firm view that scientists must be interested in and concerned about moral, ethical and social issues that result from their studies, and be willing to comment publicly on them. As science, engineering and technology are increasingly shaping the development of civilisation, human interrelationships and the environment, there is now unprecedented analysis of science, the attitudes of scientists, and their responsibilities for the applications of their work, often without the participation of scientists themselves. Elements of originality, professionalism, integrity, pragmatism, rationality, responsibility, erudition, openness, independence, strength of character, and determination to function for the betterment of humanity, are all required by scientists, overarching any short-term functions or bending to political or popularity pressures, regardless of discomfiture caused.

Related to ethical aspects of ownership is market-place ownership and the concept of intellectual property (IP) as categorised by plant variety rights, patents, trademarks, copyright, designs, licences, and trade/commercial secrets. All categories of IP offer market advantages and certain disadvantages, some more than others. Patents, above all, exercise consumer groups, anti-capitalists, and those representing the poor. On the one hand, patents provide the owner of that patent with monopoly commercial rights to the invention for a limited period, usually not exceeding 20 years, and only in the country that grants that patent. This offers the owner an opportunity to recoup R&D costs, legal, manufacturing and marketing costs, plus the opportunity to make a profit. Without the prospects of monopoly rights and the incentive to make profits, expensive-to-develop technologies would never enter the marketplace. It is the special feature of industrialised economies that they have rigorous IP regulations, which in turn provide a main driver to the operation of capital markets, safeguarding the rights of patent owners and incentivising technological developments. The monopoly position achieved by the patent holder is at the price of public disclosure of the invention to enable other scientists, engineers and technologists to use the invention in their research, and for the public and society to benefit from the acquired knowledge. Membership of the WTO enables a minimum-level measure of harmonisation of legal frameworks across national borders under the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs), which should start to apply to relevant LDCs by 2005 and, in this regard, the World Intellectual Property Organisation will provide technical assistance and training. In the area of genomics-based biotechnology, there are certain developments that will be the subject of a large period of legal debate, exacerbated by a complex of overlapping patents. Much hinges on Article 27 of TRIPs which provides for the availability of patents for any inventions (products, processes, systems *etc.*) in all fields of technology provided that they are new and not obvious, involve a demonstrable inventive step, and not least, are capable of industrial application. The legal costs of sustaining a dormant IP portfolio cannot be justified in public-sector bodies, other than to ensure the exploitable availability of the technology and to prevent a monopoly position from being taken in vulnerable LDCs. Certain provisional patents in biotechnology would appear to be discoveries rather than inventions, and some are obvious and may be formulated to inhibit the patent positions of others: such may be the basis of future patent challenges.

Human ingenuity and considerable expenditure can be involved in isolating and patenting naturally occurring genes, but if specific uses/functions cannot be ascribed for those genes, especially in broad-sweeping claims that overlap with other patents (a feature of the US Patent Office), then there must be doubt as to the validity or longevity of such patents in the international arena. There have been claims that the agricultural biotechnology industry is transforming into a small number of multinational companies that could monopolise world food supplies. At present, though, around 70% of the world seed trade is controlled through the public sector. Nonetheless, for three of the major staple crops (maize, wheat, potato), more than 3000 out of a total of 3500 patent applications for gene sequences have been filed by nine companies (Affymetrix, AstraZeneca, Aventis, Danisco, Dow, Du Pont, Monsanto, Novartis and National Starch). There is obviously a fundamental difference between a patent application and a patent awarded, and even after being awarded, expensive defence of the patent may be needed. To this uncertainty must be added the effects of delaying market releases, reducing the opportunity even to recoup costs.

One of the potential downsides of IPR enforcement

for transgenic organisms and biological materials containing genetic information is their ability to self-reproduce, but molecular fingerprinting techniques for monitoring and policing purposes provides a valuable tool for detecting both transgenic and conventionally-bred organisms and their transgenic-gene-linked products. For LDCs, concerns have been expressed about the patent system at levels *viz*: (i) increased costs to cover royalties, alone considered to be a factor in prompting the tendency to avoid IPR strictures; (ii) jeopardised existing indigenous industries, products and services; (iii) hidden constraints on local R&D efforts regardless of the fact that the patent system should not infringe the freedom to use patent information and products for research purposes, indeed IPR enforcement will give confidence to donors that IP will be safeguarded; (iv) misgivings and misconceptions over the loss or theft of indigenous natural resources including know-how by MDCs (see *The Commercial Use of Biodiversity. Access to Genetic Resources and Benefit-Sharing* by K ten Kate and S A Laird, a report for the EC published by Earthscan 1999) contravening the provisions of the Convention on Biological Diversity; (v) lack of information about patents being issued, and the costs and complexities of challenging patents internationally – concerns shared by MDCs; (vi) specific technologies such as genetic use restriction technologies or even biotechnology itself could be regarded as unethical or immoral absolutely, or just unethical and immoral when used in a capitalist context. Fortunately or unfortunately, depending on the philosophical standpoint taken, the market-place will decide. Knowledge comes at a price.

As discussed in previous SCRI reviews, the UPOV convention has been widely regarded as a reasonably efficient mechanism for dealing with the entry and use of conventionally bred cultivars in the marketplace. The rights of breeders, researchers and farmers are protected. Transgenic modification of existing cultivars to address certain market niches needs a fresh appraisal, and review of the interrelationship with patent law and rewards to the IP owner. Of greater potential concern, but necessary for orderly development of most capital markets, is the existence of commercial secrecy arrangements which could lead to cartels and suppression of essential knowledge. Balancing the rights and needs of individuals, companies, the state, and trading blocs, is awkward, but the increasing tendency for scientists of all affiliations to be more conscious of the wealth-creating possibilities of their work, places special responsibilities on them to ensure that high professional standards are applied.

A particularly useful report by H Ross and D Tennant *A Definitive Guide to GMOs, Genetically Modified and Novel Foods in the EU. The Law and Technology of GMOs in Europe*, Monitor Press, 2000, highlights ill-conceived, piecemeal EU legislation regulating GMO release, GM food and GM additions; it also considers claims for functional foods and the relationship of UK producers with EU legislation. The current legal situation is complex, trying to cope with 'concerns', 'fears', risks and hazards, often taken to extreme. The furore over the accidental sowing in the UK during the Spring of 2000 of Canadian-sourced GM oilseed rape seeds served to emphasise the gulf that separates North American and European perceptions of GM technology. In May 2000, the Tokyo Grain Exchange became the first exchange in the world to launch a futures index specifically for non-GM soy bean futures as a reaction to Japanese processors refusing to use GM products.

In the UK, the *Food Safety Act 1990* implements the EU-wide obligation to maintain acceptable food safety. As given in previous Annual Reports, the deliberate release of live GM organisms into the environment *e.g.* by cultivating a GM crop, either for experimentation or for releasing GM products into the marketplace, is governed by *Council Directive 90/220/EEC*, implemented in the UK through the *Environmental Protection Act 1990* and the *Genetically Modified Organisms (Deliberate Release) Regulations 1992*. As is well-known at SCRI, a protracted process is involved in notifying the Competent Authority (in the UK, the Department of the Environment, Transport and the Regions, other departments and agencies, and the Advisory Committee for Releases into the Environment) of the intention to release a GMO into the environment, by submitting a detailed technical dossier specifying the GMO, its physiological, pathological and ecological characteristics and the potential for gene flow, descriptions of the receiving environment, monitoring and emergency controls, and the personnel involved. Accompanying the technical dossier is a statement regarding background information and potential impacts and risks of the release on human health and the environment. Summaries of GM-release notification are forwarded to other EC Member States. Often, further information is sought and enquiries may be held, leading to difficulties in scheduling seasonally dependent activities. A notice of the intention to release a live GMO into the environment must be published in the relevant local news-

papers, and notified to owners of the site, Scottish Natural Heritage (or the Nature Conservancy Council in England, or the Countryside Council in Wales) and other agencies if the proposed release might affect controlled waters. The conditions of release, when permitted, are inviolate. Criminal proceedings can be initiated by the Competent Authority if the terms of consent are breached. There is a continuing duty of notification if any new relevant information comes to hand. Usually, there are conditions placed on land use and monitoring post-harvest. It is hoped that simplified procedures will be introduced for those GMOs which are of known low risk and/or hazard, and/or are repeat releases.

Consent at EU level is required to market any product containing GMOs. For products that will not be eaten, an extensive dossier is needed, including constraints on the conditions of use, handling, labelling and packaging. *Directive 97/35/EEC* introduced compulsory labelling for all new agricultural products containing GMOs notified under *Directive 90/220/EEC*, but the amount of information needed for mixtures of GMOs and non-GMOs is limited and there is no enforcement of segregating GM crops at source. Unlike the environmental-release phase, other Member States can impede the market-release phase until qualified majority agreement can be reached, and EC Commissioners or national Ministers can in any case delay placing their signatures on documents. The concept of a continuing duty to notify Competent Authorities of new information on health and environmental matters still applies. Blocking action by Austria, Italy, Luxembourg, and others, on the marketing of GM products should be placed before the European Court of Justice, otherwise the WTO may be needed to resolve a potential trade war with those countries exporting GM goods. In principle, current processes fulfil the cautious species-by-species, gene-by-gene approach advocated by SCRI, but the mechanisms are a bureaucratic contortion.

Should GM crops or products be sold as foodstuffs or be used as an ingredient in other foodstuffs, then a further application must be made in the UK under the *Novel Food and Novel Food Ingredients Regulations 1997* to address any potential food safety issues. This UK statutory instrument relates to the hastily introduced *EU Novel Foods Regulations : Regulations (EC) No 258/97* which also applies to products (foods and food ingredients) other than GMOs. It encompasses products that have not been used to any significant (but not quantified) degree for human consumption in the EU; foods containing GMOs as defined in *Directive 90/220/EEC*; food and ingredients produced from but not containing evidence of GMOs; food and ingredients with new primary or molecular structures; food and ingredients consisting of or isolated from microorganisms including fungi and microalgae; food and ingredients from plants and animals other than those with a history of safe use and produced by traditional or conventional methods; food and ingredients involving novel processes and where significant changes to that food may occur. There are various exclusions, *e.g.* flavourings, processing aids such as enzymes and various additives, and extraction solvents. *Recommendation 97/618/EC* details the scientific requirements needed to support an application which will be dealt with by the Competent Authority, other Member States and the European Commission, and the Standing Committee on Foodstuffs. Lack of confidentiality, anti-competitive trade practices, overburdening bureaucracy, and wanton lack of velocity have been levelled at the EU processes. In the UK, applications are considered by the Advisory Committee on Novel Foods and Processes (ACNFP) which may consult other bodies. New legislation has been drafted (the *Novel Foods and Novel Food Ingredients (Amendment) (England) Regulation 1999)*, with parallel proposals for Scotland and Wales, opening up further the deliberation of ACNFP to public scrutiny and comment.

The existence of GM products already in the marketplace (*e.g.* Monsanto's Round-up Ready soybean, *Commission Decision 96/281/EEC*; and Novartis' Bt Maize, *Commission Decision 97/98/EEC*) before the introduction of *Regulation (EC) No 258/97* led to the introduction of *Regulation No 1813/97* and *Regulation 1139/98*, specifying certain contradictory and anomalous labelling requirements. Negative lists; threshold levels; the type of wording; exclusions; options available to Member States; the incompatibilities that exist between legislation, enforcement and demands by pressure groups and retailers; and the difficulties facing the food producing and processing industries in interpreting rapidly evolving law collectively need to be resolved.

GM additives have attracted special attention. *Regulation (EC) No 50/2000* came into force in April 2000, specifying labelling requirements for foods containing additives and flavourings that have been genetically modified or produced from GMOs. The concept of 'substantial equivalence' is crucial, for labelling is not

required if the additives or flavourings are equivalent to their traditional counterparts in such aspects as composition, nutritional values, metabolic and physiological effects, and intended uses of the product. Clearly, the presence of transgenic DNA or protein would rule out equivalence, and due allowance must be made for natural variation. New and powerful analytical technologies arising from developments in sequence analysis, proteomics and metabolomics will assist in assessing compositional variation.

'Nutraceuticals', 'functional foods', health foods and drinks, food supplements, and medicines interdigitate to some extent scientifically, socially and legally, a situation which is likely to become commercially and legally active with the widespread introduction of GM technology. Central to European deliberations in this sector is *Directive 65/65/EEC* which defines a medicinal product as any substance or combination of substances presented for treating or preventing disease in human beings or animals. A medicinal product is also defined by the Directive as any substance or combination of substances which may be administered to human beings or animals with a view to making a medical diagnosis or to restoring, correcting or modifying physiological functions in human beings or in animals. Such broad-ranging definitions sit uneasily with the UK's *Medicines Act 1968*, a position that is being adjusted by judgements from the European Court of Justice. Claims in the EU about the health benefits of functional foods and the like have to face the challenge of *Directive 79/112/EEC* which prohibits claims for any food preventing, treating or curing human disease, as well as *Directive 65/65/EEC*, in addition of course, to national law. Further convolution arises from 'organic' foodstuffs and the operation of *Regulation 2092/91*, implemented in the UK by the *Organic Products Regulations 1992*, which designates the UK Register of Organic Food Standards as the national Competent Authority. It issued 'standards' requiring organic food and farming to remain free of all aspects of genetic engineering and its products, this presents special challenges for practitioners, regulators and consumers to agree thresholds, definitions and monitoring processes. Such 'standards' are promulgated regardless of the fact that on current evidence, GM foods are amongst the safest food products on the market, subject as they are to unusually high levels of testing.

Driven by the 'precautionary principle', the development, release and marketing of GM crops, GM products, and probably all biotechnology, could be brought to a halt where there are possible risks to health or the environment, even where the scientific evidence is insufficient, inconclusive, or even uncertain. As S Holm and J Harris of the University of Manchester pointed out in *Chemistry & Industry* p 913, December 1999, normally it is rational to weigh each piece of evidence according to its epistemic warrant *i.e.* the reasons for believing it. Good epistemic warrant supported by a robust theory and many experiments should hold sway over evidence with a lesser epistemic warrant. The precautionary principle, for which there is no agreed definition, distorts judgement, favouring precautionary measures to prevent the possibility of harm, even if the causal link between the activity and the possible harm has not been proven, or the causal link is weak and the harm is unlikely to occur. It would not be possible even to generate empirical data to assess if the theoretical risks were real. Such irrationality would stifle all scientific and technological progress at a stroke, and is also a weapon for restraining free trade.

Substantial equivalence, equivalence and wholesomeness (see *Commission Recommendation 97/618/EC*, in tandem with *Council Directives 90/219/EC, 90/220/EC, 94/15/EC*, and *Regulation 258/97/EC* on labelling) are the subject of powerful, even daunting, regulatory controls. Possible 'feed-through' effects in respect of feeding GM products to livestock were considered by L Donaldson and R May in their 1999 report *Health Implications of Genetically Modified Foods*, which made five recommendations strengthening monitoring and regulatory controls, and research, and encouraging the phasing out of antibiotic-resistant marker genes.

Government has expressed a desire to support the success of the UK biotechnology industry and ensure that the lead is sustained in Europe. The sheer range of products and processes arising from biotechnology, its phenomenal potential, and its integral rôle in the knowledge economy, mean that all nations and trading blocs need to embrace and foster biotechnology. In promoting a suitable environment for biotechnology, the concept of industry clusters as an important component of success has gained acceptance after analysis of the position in the USA. Clusters can be defined as geographic concentrations of interconnected companies, specialist suppliers, service providers, firms in related industries, and associated institutions. In *Biotechnology Clusters*, the August 1999 report from the Department of Trade and Industry, ten factors are seen to be critical for success:

(i) A strong science base with a critical mass of leading-edge science and academic entrepreneurs, operating with clear intellectual property policies. (ii) An entrepreneurial culture. (iii) A growing company base with support for the early development of research-driven companies. (iv) The ability to attract and retain the best management and scientific staff from overseas and larger companies: quality of life, employment opportunities for partners, career development and share options were regarded as important incentives. (v) Availability of finance during a period of a growing shortfall in the amount of equity finance available for biotechnology companies. Changes in capital gains taxation could help. (vi) Specialist premises with flexible leasing arrangements and planning-system modifications are required. (vii) Proximity to business support services including patent agents, appropriate lawyers, and recruitment and property advisers are helpful, as is proximity to large-scale companies in industries related to biotechnology such as pharmaceutical, agri-food and chemical companies. (viii) To date, biotechnol-ogy companies have

Carbohydrates
- Fabric stiffeners
- Detergents
- Fermentation substrates
- Cosmetics and toiletries
- Paint additives
- Pharmaceuticals and nutraceuticals
- Water-purification treatments

Oils, fats and waxes
- Biodegradable polymers, plastics and plastic foams
- Biosolvents
- Fuels (e.g. biodiesel)
- Linoleum
- Lubricants and anti-binding treatments
- Paints and surface coatings (e.g. varnishes, alkyl resins)
- Printing inks
- Surfactants, soaps and detergents
- Emulsifiers
- Oilcloth
- Rubber additives
- Plasticisers
- Hydraulic fluids
- Non-drying, semi-drying and drying oils
- Polishes
- Cosmetics

Proteins
- Adhesives and glues
- Controlled release of pharmaceuticals and other chemicals
- Cosmetics
- Packaging
- Pharmaceuticals and nutraceuticals
- Plant-protection and pest-control agents

Fibres
- Composites, including laminates, particle and ply boarding
- Geotextiles
- Growth media
- Insulation, fillings and stuffings
- Ion-exchange
- Matting and non-woven products for filtration
- Woven textiles, cordage and twine
- Pulp and paper
- Extenders for plastics
- Absorbents

Whole plants
- Timber, leaves and shoots for construction, furniture, fencing, packaging and protection, shelter, vessels, pilings, cooperage
- Energy by combustion of whole plants and their derivatives (e.g. fuel wood and charcoal)
- Cork for seals, gaskets, flooring, insulation and floats
- Fumatories
- Pollution control of land, air and water, including control of particulate matter, noxious and toxic chemicals, noise, sewage
- Hydrological management
- Ground stabilisation and reclamation, shelterbelts
- Soil treatment, including composts, green manures and mulches
- Carbon dioxide management (Kyoto Protocol)
- Visual amenity – the living landscape
- Habitat structure, including recreational habitats (domestic, urban, parks)
- Decoration

Speciality extracts and preparations
- Colourants and dyes
- Disinfectants
- Antibiotics
- Dentifices
- Preservatives
- Essential oils
- Insect attractants and repellants
- Masticatories
- Odours and perfumes
- Personal care and beauty products
- Plant-protection compounds and mixtures
- Polishes
- Resins and varnishes
- Rubber and balata products
- Astringents
- Sweeteners
- Medicinals (depressants including sedatives, narcotics and tranquilisers, psychodelics and hallucinogens, stimulants, analgesics, emetics, laxatives, cathartics, birth-control agents, purgatives, ointments, liniments, anthelmintics, etc.)
- Sizings
- Rayon
- Leather manufacture
- Insulators
- Acid-resistant receptacles
- Plant growth regulators
- Popular health-care products

Many species can have dual-purpose food and beverage, and non-food uses. Primary production sources from agriculture, horticulture, forestry, and from natural and semi-natural habitats. See IENICA http://www.csl.gov.uk/IENICA/index.htm

Table 3 Uses of Non-Food Annual and Perennial Angiosperms and Gymnosperms

been able to recruit scientists and technicians to meet their needs, and in many areas there are innovative training programmes. Even so, entrepreneurial abilities are still lacking, to build the skills needed for commercialising R&D. (ix) Effective networks are developing rapidly through regional development bodies; the BioIndustry Association provides the national focus. (x) Finally, a supportive policy environment, recognising that clusters must be business-driven, sets the macro-economic conditions which support innovation and ensure that regulations are both necessary and proportionate. Regional economic development agencies can play a leading catalytic rôle.

In fact, proteomics replaced genomics as the buzzword in the investment portfolios in biotechnology. The enormous range of protein compositions and configurations require massive computing power, analytical capabilities and laboratory skills to discover their modes of action and potential wealth-creating utility.

My previous reviews have concentrated on food-related matters, but non-food primary products are of critical importance to humanity, and will increasingly be the focus of biotechnology. The actual and potential benefits of plant-derived non-food products are based not only on their intrinsic utility but also on their renewability or sustainability, especially compared with oil-based products. With few exceptions, they can be biodegradable and are not considered toxic. These desirable characteristics were emphasised by the House of Lords Select Committee on Science and Technology in their report of December 1999 into non-food crops, and by M Askew in the IENICA project. Botanists are well aware of the extraordinary number of uses of plant-derived products (Table 3), as well as the actual and potential higher-plant species available for exploitation. Application of modern sciences can and will dramatically shift the balance of industry towards utilising the full panoply of benefits of renewable resources, and agricultural and forestry biotechnology will inevitably start to play a major rôle in optimising the sourcing of customised plant products.

Concluding comment

Once again, I am pleased to state unequivocally that the Institute, MRS Ltd and BioSS still thrive, producing high-impact globally relevant scientific research and development with unrivalled value-for-money and productivity, and meeting end-user needs. We play a full rôle in UK and international science, launching major scientific initiatives, and we participate extensively in higher educational science, launching major scientific initiatives, and we participate extensively in higher educational activities. I thank SERAD and all our sponsors, and congratulate and offer my gratitude to my colleagues for their loyalty, forbearance and outstanding efforts. I thank especially Mr J E Godfrey and the Governing Body for their commitment and contribution to our development.