Report of the Director

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Global perspectives of factors influencing agricultural, biological, and environmental sciences, and their associated industries : 2000-2001*

Preamble

For many, the third millennium did not begin until 1 January 2001, given that the widely adopted Gregorian calendar ordained by Pope Gregory XIII in 1582 did not include the year 0 in the transition from Before Christ (BC or *Ante Christum*) to *Anno Domini* (AD - in the Year of Our Lord). A miscalculation – a shortcoming - by Dionysius Exiguus (Dennis the Short), a 6th-century monk, was apparently integrated into the Christian calendar, according to M. Bolt, an historian of matters astronomical, masking the widely held view by scholars that Christ was born around 4 or 6 B.C. If true, it would seem that the third millennium is not as new as it is widely assumed to be, festivals and celebrations notwithstanding. Fortunately, no apocalyptic or cataclysmic predictions came true in 2000 or in the transition from 2000 to 2001. There were no major wars, and the 'Y2K' computer problem was barely detectable. A new President of the USA, G.W. Bush, was elected by a small margin. Globalisation in its various guises; the onward march of science, engineering, and technology; and social protection and public health programmes were occasional headline issues alongside the plethora of entertainment and sporting frivolities. Politics at all levels became more complex and demanding, and on a global level, taxation levels increased. Protesters of diverse types from liberal democracies coalesced to direct their ire at multinational institutions and companies. There was disturbing evidence of destabilisation of Central Asian states fomented in Afghanistan, disruption founded as with many conflicts elsewhere and in times past, on dogmatic and intolerant religious interpretations of lifestyle. Centrifugal nationalist and regional forces counteracted globalisation and integration trends. Agriculture was not regarded in the more-developed countries (MDCs) as a growth industry and investments declined, as did the numbers of scientists engaged in agricultural research and development (R&D). In contrast, the array of modern bioindustries linked by common-denominator molecular-genetics technologies, advanced natural product chemistry, and computational developments thrived intellectually, particularly in the private sector, although the downturn in stock markets during the year curtailed the number of products entering the market place. There were further signs of economic weakness towards the end of the year as expenditure in advertising and several areas of R&D declined, the usual early indicators of impending economic stress, and company contractions, mergers, and acquisitions became more frequent.

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

Greatest amongst the sustained achievements of the human race is modern agriculture. Food is no longer the preoccupation of most human beings, a feature distinguishing them from other life forms, and one permitting them to engage in all the facets of civilisation, including the quest for knowledge and understanding.

The most prominent scientific achievement in 2000 was the announcement in June of the completion of a rough draft of the sequence of the human nuclear genome (see www.sanger.ac.uk/HGP/policy-forum.shtml#ref1). Founded on the legacy of Gregor Mendel's laws developed in the mid-1800s, the analysis of nuclei by F. Miescher, the discovery by O.T. Avery that DNA carried genetic material, W. Flemming and E. Strasburger's work on chromatin and mitosis, the proposed double-helix structure of deoxyribonucleic acid (DNA) by Watson and Crick in 1953, and various technological and conceptual advances in the separation, identification and mode of action of nucleic acids, the public-sector-funded Human Genome Project and a private-sector company, Celera Genomics, finally came together to speed up completion of the rough draft sequence. With such profound positive implications for medical and veterinary science in new forms of diagnostics and treatments, it is important to stress that other benefits have come from related technological, engineering, and software developments, and have strongly influenced, and been influenced by parallel studies in other animals, microbes, and plants. Most striking was the commonality of genes between different groups of organisms. Gene functionality, mode of action, location, and control need to be unravelled, and represent the real target of human endeavour – understanding the processes underpinning the creation, functioning and interactions of phenotypes. The genomes of humans are more than 99% identical but unique to an individual (see www.ncbi.nlm.nih.gov/genome/guide). It is still too early to determine what can be considered as being in the 'normal' range of sequences.

Professor John Hillman, and Mrs Irene Geoghegan (left), present prizes to the recipients of the special needs section of the painting competition sponsored by SCRI and Ladybird Books.

Annotating the entire genome of all organisms, *i.e.* characterisation of all the genes and working out their functions, will firstly require identification of all the protein-coding regions which will indicate the total number of functional genes. Thereafter, gene structures, identification of regulatory elements and then assignation of functions will ensue. Complicating matters are questions about the accuracy of the many public databases that receive deposited sequences and annotations. Intellectual property (IP) considerations will lead to a reappraisal of the so-called Bermuda Rules. These were derived from an agreement reached at the International Strategy Meeting on Human Genome Sequencing held in Bermuda in February 1996, which stated that "All human genomic sequence information, generated by centres funded for large-scale human sequencing, should be freely available and in the public domain in order to encourage research and development and to maximise its benefit to society". Equivalent rules do not apply to plants and microorganisms, but there are strong international collaborations.

Although the future of medicine was advanced by the draft sequencing of the entire human genome, the year was marked by outbreaks of infectious diseases, principally cholera, new variant Creutzfeld-Jakob disease, dengue fever, Ebola haemorrhagic fever, hantavirus, Legionnaire disease, leptospirosis, malaria, measles, polio, tuberculosis, *West Nile virus*, and yellow fever. About 130 million new cases of malaria occurred in 2000, over 90% of which were in Africa, fully justifying calls for increasing the relatively modest investments by the World Bank and MDCs in the Roll Back Malaria programme. Recombinant vaccines, DNA vaccines and prime-boost approaches, transgenic vaccines, and genomic and proteomic approaches represented promising routes to control the protozoan parasites that cause malaria. Many believe that DDT (dichlorodiphenyltrichloroethane) remains the most cost-effective tool to control the vectoring mosquitoes.

During the year, the World Health Organisation (WHO) documented the extent to which certain infectious diseases, particularly AIDS, diarrheal diseases, malaria, pneumonia, and tuberculosis, were developing antimicrobial drug resistance, a phenomenon which is also shared by many food-poisoning organisms. The misuse of antibiotics and other antimicrobial agents was regarded as the primary cause of the spread of resistance.

Agrarian economies are affected by the health of the population. The UN calculated that by the end of 2000, 21.8 million people had died of AIDS, and that an additional 36.1 million were infected with the HIV virus, 24.5 million of whom lived in southern Africa; most were desperately poor. Around 70% of the AIDS cases were in sub-Saharan Africa, with projections that life expectancy in that region would drop to around 30 years by 2010 in the absence of effective control measures. As a prelude to the 13th International AIDS Conference in Durban, South Africa, 5 228 physicians and scientists from 80 countries felt obliged to sign the Durban Declaration which stated that the evidence that AIDS is caused by the human immunodeficiency virus, HIV-1 or HIV-2, is clear-cut, exhaustive and unambiguous. AIDS was recorded as spreading rapidly in the Caribbean, China, Eastern Europe, India and the Far East. Vaccines are now regarded as the single intervention most likely to control the AIDS pandemic; during the year more than 70 different vaccines were being trialled.

New medical treatments introduced included constraint-induced-movement therapy and robot-aided exercising for stroke-disabled victims, islet-cell transplant techniques to eliminate need for insulin injections with poorly controlled type 1 (insulin-dependent) diabetes, and minimum surgery treatments to treat gastroesophogeal reflux disease. Two promising treatments that are likely to be introduced as a result of trials were the use of interferon-la (Avonex) to delay the development of established, clinically definite multiple sclerosis, and novel vaccine-like approaches to treat kidney cancer. Embryonic stem cell research in humans attracted widespread attention from medical scientists, the healthcare industry and pressure groups opposed to research on human embryos. As in plants, adult stem cells do not have the same level of totipotency as embryonic cells. Controlling the differentiation of stem cells into cells, tissues and organs offers new vistas for repairing damaged or defective tissues and organs. As usual, there was confusion in public and political debates over the distinction between research and commercial application.

Plant scientists were intrigued by the current emphasis in the marketplace on herbal products, plant-derived dietary supplements, nutraceuticals and functional foods. In most instances, but not all, the efficacy, and sometimes the safety of the products were not known but assumed with little evidence (see www.consumerlab.com) and much wishful thinking. One feature of many products was the variation in the amounts of so-called active ingredients both between apparently similar products and batches of the same product. Some dietary products were also noted to contain dangerous contaminants. Other products, however, were efficacious. More science and regulation will have to be directed to this neglected facet of oral intakes (see also *SCRI Annual Report for 1999-2000,* pp 83-94).

The 'Snowball Earth' concept was reinforced by its originator J. L. Kirschviak and colleagues who presented evidence for two periods when the earth was more or less completely covered with ice, at around 2.4bn and 600-800 million years ago. These periods coincided with mass extinctions, and the ensuing global warming created favourable conditions for the surviving prokaryotic Cyanobacteria (blue-green algae, formerly Cyanophyta) leading to oxidising conditions for large-scale geological banded iron formations and postglacial cap carbonates. It was suggested that the enzyme superoxide dismutase (see *SCRI Annual Report for 1999-2000*, p93) may have had a key rôle in the adaptation of organisms to the changed environment. Fascinating hypotheses were presented by I.W.D. Dalziel (University of Texas) and colleagues, C.R. Scotese (University of Texas at Arlington) and others about the formation of the supercontinents Rodinia, Pangaea, and Pangaea Ultima (see www.scotese.com). Together with reports using geochemical analyses, greater understanding of plate tectonics revealed the nature and extent of continental drift. Continuous geophysical monitoring using the satellite-based Global Positioning System gave unprecedented insight into dynamic phenomena such as earthquakes, tectonic plate motion, and volcanoes, and aided more sophisticated predictive models to be generated.

In mathematics, prizes were offered for the solution of eight famous problems: (i) a proof for Goldbach's conjecture that every even integer greater than 2 is the sum of two prime numbers; (ii) P *versus* NP (are there

more efficient algorithms for computations?); (iii) the Poincaré Conjecture that if every loop on a compact three-dimensional manifold can be shrunk to a point, is the manifold topologically equivalent to a sphere? (iv) the Riemann hypothesis that all zeros of the Riemann zeta function lie on a specific line; (v) the existence of solutions for the Navier-Stokes equations, describing the motions of fluids; (vi) the Hodge conjecture on algebraic geometry; (vii) the existence of Young-Mills fields in quantum field theory and particle physics; and (viii) the Birch and Swinnerton-Dyer conjecture on elliptic curves. There were no equivalent prizes in the life sciences.

In organic chemistry, scientists at the University of Chicago reported that difficult-to-synthesise octanitrocubane may be the most powerful non-nuclear explosive, reflecting its highly strained 90° bonds and eight oxygen-rich nitro groups. Cubane derivatives may interact therapeutically with enzymes involved in Parkinson's disease. Relevant to many branches of life sciences was an automated oligosaccharide synthesiser reported by P.H. Seeberger and colleagues at the Massachusetts Institute of Technology. In nuclear chemistry, A. Türler of the Paul Scherrer Institute, Switzerland, and colleagues, reported that contrary to the belief of certain theoreticians that the periodic table of elements was unable to assist in the prediction of properties of extremely heavy elements beyond uranium in the table, the strangeness or relativistic effects associated with the interpretation of Einstein's theory of relativity, when applied to superheavy elements do not alter the predicted properties of element 107, bohrium. In applied chemistry, R.H. Grubbs and colleagues at the California Institute of Technology reported the development of a new family of nickel-based catalysts that could simplify the production of polyolefins, including polyethylene and polypropylene, and designer plastics with desired electrical, mechanical and optical properties. K.E. Sickafus and colleagues at the Los Alamos National Laboratory announced a new family of ceramic materials virtually impervious to the damaging effects of ionising radiation. By developing a fluorite-structured oxide of erbium, zirconium, and oxygen, the group may have generated an important class of compounds that could be used for the safe long-term encapsulation of nuclear waste, suitable for storage in geologically stable mines. The stability of plutonium oxide, used in commercial nuclear reactor fuels and as the storage form for plutonium from dismantled nuclear weapons, was called into question by the work of J.M. Haschke and associates at the same Los Alamos National Laboratory in New Mexico. They demonstrated that water can slowly oxidise solid crystalline plutonium oxide to a new less-stable phase with greater than 25% of the plutonium atoms in a higher oxidation state, releasing hydrogen gas and becoming relatively water-soluble. This phenomenon may explain the relatively rapid spread of plutonium from the nuclear tests in Nevada into groundwaters. The search for non-toxic, environmentally friendly 'green' solvents to replace organic solvents has highlighted the potential of supercritical carbon dioxide, which has fluid-like properties. Its utility, however, depends on high pressures and the presence of solubility-enhancing compounds termed CO_2-philes which are typically fluorocarbons. E.J. Beckman and colleagues at the University of Pittsburgh reported the synthesis of an environmentally effective series of CO_2-philes, co-polymer compounds termed poly (ether-carbonate(s)).

An international team of physicists at the DONUT (Direct Observation of the Nu Tau) experiment at the Fermi National Accelerator Laboratory provided in 2000 the first direct evidence for the existence of the tau neutrino, the only one of the 12 kinds of matter particles (fermions) yet to be confirmed in the current standard model. There are three kinds of neutrino; the electron, muon and tau; and there may possibly be a fourth type of neutrino – the sterile neutrino. Six of the fermions are termed quarks, two of which, the up quark and down quark, comprise the protons and neutrons, or nucleons, that constitute nuclei of matter. Quarks were confirmed within the nucleons, bound together by the exchange of particles called gluons. At the time of the formation of the universe, it was postulated that quarks and gluons existed freely in the form of a quark-gluon plasma. At the European Laboratory for Particle Physics (CERN), physicists reported evidence for a new state of matter akin to a quark-gluon plasma.

Advances in solid-state physics came from continuing development of semiconductor quantum dots – isolated groups of atoms with the crystalline lattice of a semiconductor coupled quantum mechanically such that electrons in the dot can only exist in a limited number of energy states. Accordingly, the dot has light-absorbing and emission properties that could be used in astronomical spectroscopy, optical communication, and quantum computing. Laser technology was advanced by the development at

Lucent Technologies's Bell Laboratories of the first electrically powered semiconductor laser based on an organic material. Here, a crystal of tetracene was placed between two different kinds of field-effect transistors which triggered a yellow-green light pulse when applied with a voltage. The speed of light as a fundamental speed limit, essential to the theory of relativity, was a topic for deep philosophical debate following the experiments of A. Ranfagno and colleagues of the Electromagnetic Wave Research Institute, Florence, who modulated a microwave pulse to send microwave-frequency radiation through air faster than that of light, and those of L. Wang at the NEC Research Institute, Princeton, who propagated a pulse of visible light through a chamber of optically excited cesium gas such that it exceeded the speed of light in a vacuum. The fundamental principle of causality would be undermined should usable information travel faster than the speed of light, thereby allowing a preview of the future that could be used to alter the present! Politicians could be interested in further developments of this work.

The year 2000 was also noted for evidence from detailed studies by J.M. Dohm and R.C. Anderson on the high-resolution images of Mars, taken by NASA's Mars Global Surveyor spacecraft in 1997, that liquid water may have flowed just beneath the Martian surface, raising interest in the possible existence of life on that planet. The largest of the near-Earth asteroids, 433 Eros, an odd-shaped s-type asteroid, was surveyed in close detail by the Near Earth Asteroid Rendezvous Shoemaker spacecraft. In orbit since 1995, the Galileo spacecraft continued to operate in its official extended mission to study Jupiter's large ice-covered moon, Europa: initial data may support the notion that the ice sheets cover liquid water, a prerequisite for life. New solar system objects were discovered. Nine new extrasolar planets were described, including one revolving around the star Epsilon Eridani, 10.5 light-years distant, and one of two planets orbiting HD 83443 likely to have a mass about 50 times the mass of Earth. It may be possible for the Hubble Space Telescope to make direct recordings. A planet about 30% larger than Jupiter was thought to orbit HD209458, a star similar to the Sun lying at a distance of 174 light years in the constellation of Pegasus. According to theory, elements heavier than iron can be formed in the centres of massive stars and spread into space in Supernova explosions. The Chandra X-ray Observatory, operating in Earth orbit since July 1999, provided evidence in 2000 for the detection of newly formed iron in the Supernova remnant Cassiopeia A., formed from a star that exploded in 1680, but the iron was ejected beyond the region where lighter elements such as silica were located. The Chandra Observatory also helped resolve the conundrum over the uniform glow of S-rays, radiation with energies 1 000 to 1 000 000 times that of visible light, apparently coming from all directions. About 80% of the radiation was produced by about 70 million discrete sources uniformly spread over the sky, a third of which appeared to be distant galaxies with black holes at their centres.

Based on the motions of stars in the neighbourhood of the Sun, W. Dehnen of the Max Planck Institute for Astronomy provided evidence in support of the view that the Milky Way Galaxy, which contains the Sun and all the stars visible with the naked eye, is a barred spiral in which the spherical central hub is replaced by a barred structure obscured by interstellar dust.

Manned space exploration was boosted by the ongoing assembly in orbit of the International Space Station and the start of permanent human occupancy. Associated with this was the flight testing of the Crew Return Vehicle, its lifeboat. Long-term sustainability of humans in space will require investments in R&D on recycling waste solids, liquids and gases; combating the effects of microgravity; and the supply of liquids and foodstuffs: plants and microorganisms will be crucial to this work. My own experience during the late 1970s and early 1980s, dealing with the European Space Agency and others, is that this type of research has very low priority in the UK but not elsewhere. As an aside, graviperception is a special feature of differentiated organisms, and although there is a useful pioneering literature on the topic, the advent of space travel means that greater attention will be required to elucidate the biophysical and biochemical factors underpinning growth and other physiological and biophysical responses to changes in gravity.

A computer model possibly explaining the formation of the Sahara Desert was generated by a team led by M. Claussen at the Potsdam Institute for Climate Change. The change from a fertile and inhabited region to a barren desert might be explained in part by the as yet unexplained change in the tilt of the Earth's spin axis about 9 000 years ago from 24.14º to 23.45º over a period of 3 000 years, to 23.40º currently. In addition, there was a movement in the perihelion (the nearest point of the Earth to the Sun), such that it

occurred in July, 9 000 years ago, and is now in January. These two changes were sufficient to modify the weather systems in the northern hemisphere, so that the African monsoons and the vegetation cover declined, altering the hydrology of the area. In turn, less rain fell, the rivers dried up and desertification ensued. The transition from fertility to aridity took place in just a few hundred years. Meanwhile, the changes in the tilt of the Earth's spin axis and timing of the perihelion continue. Computer modelling studies highlighted the close interrelationships between vegetation cover and composition, atmosphere, and ocean currents, with small changes leading to vast effects. This work is germane to the international Convention to Combat Desertification, and to predictions of the effects of climate change.

Experiments using liquid sodium in Riga, Latvia, and Dresden, Germany, confirmed the dynamo theory which proposes that the Earth's magnetic field is produced in the centre of the Earth by the movement of the fluid liquid outer core (consisting of molten iron and nickel) surrounding a solid inner core. According to the theory, a moving conductive fluid can generate and sustain its own magnetic field, but needs to be initiated by a disturbance such as a small electric field. This field can be stretched and distorted by the moving fluid giving rise to new currents and magnetic fields, and eventually a large stable magnetic field.

In previous editions of this *Annual Report*, I have described the essential characteristics of science and the societal need for research; both are fundamental to our appreciation of truth and progress. Reports of misconduct over the past two decades led to several investigations at institutional level and to the intervention of national government, and even to a definition of misconduct generated by the US Office of Science and Technology Policy (see also *Responsible Science,* US National Academy of Science, 1992, and *What Price Progress?* N. Steneck, *Times Higher Education Supplement*, March 16, 2001) Misconduct and behaviour that undermines confidence in science and scientists, and therefore compromise integrity, include falsification of results, wanton or reckless misinterpretation of results, plagiarism, bias in peer-review exercises, clogging the literature with insignificant work, failure to cite correct authorship attributions, misuse of statistics, failure to acknowledge the efforts of colleagues, lack of attention to detail, and inadequate supervision and mentoring. The setting of high standards should not be compromised whatsoever by the source of funding – public or private. Litigation will flush out misconduct or misleading work as it enters the marketplace, or becomes incorporated into public policy, so it is not in the interest of any organisation or company to tolerate bad practice.

A growing divide was noted in higher education between the well-endowed centres of excellence, almost exclusively in the USA, and the rest. A dependence on accessing public funding, which brings in its wake bureaucratic processes and liabilities to ensure public and political accountability as well as significant extra costs and enforced uniformity, caused problems in the UK and many other countries. The scale of the problems faced by the universities related directly to their financial reserves, the quality of their management, the economic well-being of the host country, its attitude to higher education, and fostering high-profile R&D. Measures to increase efficiency included increasing class sizes, creating popular low-cost courses, better utilisation of space, tight financial management, a focus on diversifying funding sources, a switch to profitable R&D, better publicity, and policies to recruit and retain key personnel. Traditional areas of scholarship, particularly in some of the expensive underpinning sciences such as chemistry, physics, and many areas of the life sciences including botany, were under threat. In contrast, distance and e-learning were regarded positively, as they offered the promise of greatly improved efficiency and quality. Tentative steps were made towards institutional mergers in some countries. Underlying the higher education sector was a growing awareness by administrations of students and prospective students as discriminating and vocal customers. The sector also was much more international in outlook, with almost universal interconnection to the Internet *via* institutional intranets.

Public education at the tertiary level (higher education provided mainly in universities and colleges of higher education) should not be assumed to be exempt from the negotiations surrounding the General Agreement on Trade in Services, part of the World Trade Organisation (WTO) agenda. Unless properly protected by robust legislation, this could result in the loss of domestic government control over Research Council funding, degree awards, and the restriction of education funding to public-sector providers. In the UK, the universities are legally regarded as essentially part of the private sector, albeit with heavy

dependence on public funding and strong central controls – only the University of Buckingham is truly independent. Advice to government on universities is provided by the Higher Education Funding Councils (HEFCs) for England, Wales, and Scotland, and by the Higher Education Council in Northern Ireland. The Councils receive block grants from central government for allocation to the institutions.

Libraries as repositories of knowledge as well as culture have been transformed by the Internet. Print materials were increasingly being scanned into digital form. Nonetheless, the costs were rising of maintenance of collections, new acquisitions, security, computer software and hardware, archiving, classification, and improving access to information. Scientific organisations, particularly in the public sector, found the costs of sustaining subscriptions to scientific journals burdensome, let alone subscribing to the stream of new journals. The numbers of on-line scientific journals increased. (See also *Publishers agree on deal to link journals on the web. Nature*, 402, 226, 2000).

Study of the major trends in the contemporary world, *i.e.* cultural anthropology, brings together science, public policy, cultural perceptions, attitudes to change and risk, non-empiricism, ethnography, immigration and identity, codes of ethics, perceptions of the built and natural environment, human rights, kinship and gender, and postmodernist writing. The reissue in 2000 of the 1998 *Handbook of Methods in Cultural Anthropology*, edited by H.R. Bernard, described quantitative and qualitative approaches and methods in important areas of human activity, many of which represent the interface between science, technology and society. More emphasis will have to be placed on this neglected interface, introducing much greater intellectual rigour.

Freedom of the press was actively curtailed in Angola, China, Iran, Malaysia, Swaziland, Zambia, and Zimbabwe. Elsewhere, newspapers and magazines moved to establish on-line readerships, and convergence of print, Internet and television journalism was starting to take place, most notably in Canada. The deaths of the influential cartoonists Jeff MacNelly and Charles M. Schultz depleted the newspapers they served so admirably and journalism generally. Magazines were reported as taking 12.9% of the world-wide expenditure for advertising in 1999. Similar to certain newspapers, and scientific magazines and scientific journals, book publishing began to explore 'e-publishing', the publishing of books in electronic format. There were no universal hardware and software standards for downloading and reading e-texts. Difficulties in safeguarding intellectual property (IP) rights in the new e-format, and taxation and royalty strategies, were not resolved.

Economics and Politics

In sharp contrast to 2001, the year 2000 witnessed the world economy growing at the fastest rate since 1988, largely as a result of consumer demand in the USA - the global economic dynamo, although a downturn was detected in the second half of the year. According to provisional data from the International Monetary Fund (IMF), real output in 2000 rose by 4.7%, compared with a revised 3.4% in 1999. Relative price stability was maintained for consumer products as a result of tight monetary policies world-wide, although there was volatility in the oil and stock markets, and inflationary hotspots in some countries. For countries undergoing transition from centrally controlled to market economies, consumer prices rose by 18.3%, unacceptably high but markedly less than the 43.8% level of 1999. In the economically advanced countries, consumer prices rose by 2.3%, up from the 1.4% level in 1999 which had then raised the spectre of deflation. Inflation in the less-developed countries (LDCs) fluctuated around an average of 6.2%. In African LDCs, the percentage change from 1999 was 12.7%, and 17.4% for LDCs in the Middle East and eastern Europe.

Growth, as measured by the annual change in real gross domestic product (GDP), was faster in LDCs (5.6%) than in the more-developed, advanced countries (MDCs, 4.2%). Provisional data from the Organisation for Economic Co-operation and Development (OECD, see *Economic Outlook*, November 2000) and the IMF (see *World Economic Outlook*, October 2000) indicated that growth in the USA (5.2%) and Canada (4.8%) significantly exceeded that in other major OECD economies (France 3.3%, Germany 3.0%, Italy 2.8%, Japan 1.9%, and UK 2.9%). By the end of the year, the current-account deficit of the USA was around $450bn. Foreign direct investment (FDI), one of the important features of globalisation, was aided by favourable changes in the regulatory environments of more than 50 countries. FDI outflows exceeded $1 trillion worldwide in 2000, some 20% more than in 1999. The number of companies classified as transnational increased to 63 000, with 690 000 affiliates and sales of $14bn. Transnational mergers

and acquisitions, leading to market consolidations, tended to be 'horizontal' rather than 'vertical', involving closely similar industries and commercial activities, and were valued at around $720bn. The principal mergers and acquisitions involved the automobile, beverage, chemical, food, pharmaceutical, and tobacco industries, and France, Germany, UK, and the USA were the chief beneficiaries.

In the UK, real GDP was estimated by the Bank of England to be 2.9%, compared with 2.1% in 1999. The RPIX changed by 2.1%, earnings growth was 4.6%, and the unemployment rate 3.6%, the lowest rate among the MDCs. After the withdrawal in 1992 of sterling from its ill-fated involvement in the European exchange-rate mechanism, the UK experienced its longest period of sustained growth since 1945. As in nearly all the strong economies, growth was led by domestic consumer demand at a rate (3.6%) that exceeded that of household disposable income (2.5%). An enhanced level of net lending to individuals meant that the household savings rate fell from 5.1% in 1999 to just 3.6% in 2000. The UK was expected to be the fastest-growing nation in the G-7 MDCs, with a relatively resilient, domestic-demand-oriented economy deriving benefit from an easing of monetary policy.

In Scotland, the growth in GDP in 2000 was 1.5% compared with 2.9% in the UK, a lesser performance attributed to its greater dependence on exports, principally to the EU. Even so, GDP growth was driven for the most part by an expansion in the service sector, with a strong reliance on public services. Consumer spending lagged behind that of the rest of the UK (see *Scottish Economic Report*, Scottish Executive, June 2001). Manufacturing exports declined, most notably in the electronics sector. Overall, there was a falling unemployment rate, although it still remained above the UK average.

In the euro zone (or euro area), growth increased from 2.4% in 1999 to 3.5%, aided by a weak euro which made exports more competitive. In the second half of the year, rising oil prices generated rises in consumer prices and falls in real income, aided by an almost doubling of interest rates imposed by the European Central Bank (ECB). As in the previous year, growth was most pronounced (8.7%) in the Irish Republic, compared with 3.5% in France, 3.1% in Italy, and 2.9% in Germany, the three larger euro economies. Elsewhere in the euro zone, growth ranged from 5.1% in Luxembourg, 5% in Finland, 4.1% in Spain, 3.9% in The Netherlands and Belgium, and 3.5% in Austria, Greece, and Portugal. Variations were also noted in inflation rates, reflecting constraints of a single euro-zone interest rate in diverse economies, and ranged from about 4.8% in Ireland to between 2% and 3% in the other countries. The average unemployment rate declined from 9% in 1999 to about 8.3%, but in Belgium, Germany, Greece, and Italy between 8% to 15% of the workforce were unemployed.

According to the IMF (*World Economic Output*, October 2000), the rate of growth in the LDCs was expected to increase from 3.8% in 1999 to 5.6% in 2000, and there were no longer marked differences on a regional basis. Individual countries, however, varied from the 6%-7% range in China and India, to 4%-4.5% in Latin American countries, 2.6% in South Africa or even lower in those African countries disrupted by conflict or political unrest. Zimbabwe was unique in suffering a 6% decline in output coupled to burgeoning inflation, as racially motivated interference by the Marxist Zimbabwe African National Union-Popular Front (Zanu-PF) government in the white-owned commercial farming sector – the mainstay of the economy - undermined confidence.

Another measure of economic activity is the measured increase in the volume of world trade in goods and services, estimated to have more or less doubled from 5.3% in 1999 to 10% in 2000. Thus, the difference in the rate of growth of production (4.7%) and trade was wider than hitherto. Compared with 1999, the dollar rise in global exports was estimated to have been $7 497bn, reflecting trading buoyancy in all regions, and the economic absorptive capacity of the USA. Sales of fuel, manufactured goods and primary products rose in volume terms in both MDCs and LDCs. Import volumes rose by 13% in Canada and the USA, 8.9% in the euro-zone, 8.2% into the UK, 6.8% in Japan, and 14.1% in the newly industrialised countries (NIC)s.

When considered in terms of value, the rise in the rate of exports from the LDCs exceeded 20% and their imports rose to 15% in 2000. From a figure of 17% in 1990, the LDCs attained a level of 27.5% in the share of world exports in 2000, as new manufacturing facilities were opened, and metal prices recovered somewhat. Contrasting with the globalisation trend as expressed in the internationalisation of economies, industries, trade, government policies, legal systems,

political movements, the World Trade Organisation (WTO), pressure groups, science, diets, publishing and broadcasting, terrorism and the Internet – regional trading arrangements were much in vogue in 2000. Although regional trading bloc arrangements shared with the WTO the same vision and processes of integrating trade and services, incompatibilities were seen in several crucial matters. Around 170 regional agreements operated in 2000, with another 70 under consideration. One potentially influential agreement enacted in 2000 was the two-decade partnership, the Cotonon Agreement, between the EU and the African, Caribbean and Pacific (ACP) group, replacing the Lomé Convention.

Globalisation created tensions in those anxious to sustain national sovereignty, preferences and prejudices, culture and independence. Institutions such as the IMF, World Bank, and WTO were subject to protests, sometimes violent in nature by those resentful of their influence, and who claimed that such institutions were unresponsive to domestic civil society and tended to be secretive. Protestors demonstrated at the WTO meeting in Seattle in November 1999, the IMF and World Bank meeting in Washington in April 2000, at the World Economic Forum in Melbourne on 11 September 2000, and at the Prague Summit Meeting of the World Bank and IMF on 26 September 2000.

Globalisation to some is an undesirable manifestation of the spread of international capitalism from the MDCs, but mainly from the G-7 nations, reinforced by the IMF, the World Bank, and the WTO. Free choice, the uptake and exploitation of technologies that improve efficiency and reliability, the free flow of information, the operation of free markets and individual choice which can develop the common good, and lightweight governance, will inexorably favour globalisation. Competition and the deployment of profit for social progress drive improvements, as do enlightened democratic processes that quell corruption and support strong legal systems. Opponents of globalisation, many of whom wished to target inequality, often presented feeble and dubious arguments which were couched in anti-business, anti-mixed-economy, anti-American, anti-technology, anti-capitalism terms and were based on the application of excessive market-distorting regulations, trade barriers, and taxation. International economic integration has become an anathema to others who wish to resist the loss of cultural diversity. Yet foreign direct investments (FDIs) mentioned above affect both the providing (outward) and recipient (inward) economies, sometimes seemingly adversely in the short term, but almost without exception there are net benefits for consumers, government taxation returns, and the higher-paid workers appointed to the new enterprises. Technologies are taken up quickly. According to the *Economist* (29 September – 5 October 2001), in these early stages of globalisation most outward FDIs tend to create exports and represent net complements because affiliates of multinational companies trade with each other. W. Dobson of the University of Toronto and G. Hufbauer of the Institute for International Economics, USA, noted that longer-term capital contributes to economic growth in emerging markets. Whereas there is little evidence that bank loans and trade credits contribute to higher GDP, for every 10 percentage point rise in the ratio of FDI stock to the economy, GDP rises by 4%. Clearly, and perhaps controversially, free trade should properly go hand-in-hand with mobility of appropriate labour.

Complexed with globalisation is the rôle of democratic governments, and the need for checks and balances that prevent democracies operating insensitively as monolithic tyrannies over minorities. General taxation levels have risen in the MDCs, largely to fund social protection, defence, infrastructural, and public-good programmes. Globalisation presents, however, a challenge for governments in the raised expectations of the populace (good public services with low taxes), diminished control over the flow of capital across borders, ownership transcending national borders, international comparators that raise malcontentment, and rapid surveys of public opinions (usually influenced by the media) capable of changing the direction of policy. Biologists at least realise that all forms of diversity affecting human behaviour – cultural, ethnic, linguistic, political, and economic, have their roots in differential gene expression. Governments are beginning to realise that a better-informed population tends to generate contradictory demands and expectations that in turn create political difficulties.

Much criticism during the year was directed at the 'Washington consensus'. This term, introduced in 1989 by the economist J. Williamson, encapsulates the promotion of trade and FDI, fiscal discipline, reduced subsidies, simplified and reformed taxation systems, liberalised financial systems, competitive exchange rates, privatisation, deregulation, and strengthened property rights. Concerns were

specifically expressed at the imposition of these policies on LDCs, leading to unsustainable debts, vulnerability to the excesses of economic cycles, and political instability. Regulatory failures, corruption, and unreasonable expectations undoubtedly caused problems in the inward economies. Although the IMF and World Bank have been justifiably criticised for their prescriptive and inflexible impositions and policy blueprints, and unwillingness to permit longer periods of economic transition, they are usually only called in as a matter of last resort (as did the UK, the last MDC to do so, in the 1970s). At least, it is the case that all countries now have access to the global capital markets, and it is the politics of a country that determine its fate.

Included in the criticism of the IMF and World Bank is the WTO, an organisation specifically mandated to promote international trade. Some believed erroneously that it overrode democracies through newly applied international quasi-judicial routes and was both unaccountable and unrepresentative. Yet the WTO is wholly intergovernmental, operating solely by consensus. All 142 members, soon to be joined by China after its 15-year quest, have a veto. The dispute-resolution rules were agreed unanimously, and require objective and open analyses, rather than subjective imposition. Small nations can participate actively in the struggles between the main trading blocs. With time, it is expected that the secrecy attached to trade negotiations will have to go, even though governments currently insist on the control of information. Eventually, politically tender areas of trade *viz.*: agriculture, textiles, exploitation of natural resources such as minerals and forestry, and corporate interests, look likely to be assimilated without special protection measures in all the remaining areas of trading interchange.

After six years of surplus, the overall current account of the balance of payments in the advanced economies moved into deficit in 1999, rising to a projected $176bn in 2000 and was mainly attributable to the deficit of $420bn in the USA. Of the Group of Seven (G-7) MDCs, only the USA and UK ($20.9bn) had significant deficits. The euro zone remained in surplus. Across Europe, significant surpluses were noted in France ($35.7bn), Switzerland ($24.2bn), Belgium/Luxembourg ($22.9bn) and Norway ($22.6bn). Deficits were posted in Spain ($12.6bn), Portugal ($11bn), Greece ($5.7bn), and Germany ($3.7bn). Outwith Europe, surpluses are projected to have been recorded in Japan ($110bn), Singapore ($22.1bn), South Korea (*circa* $12bn), Hong Kong ($11.2bn), and Taiwan ($6.6bn). Australia and New Zealand reduced their deficits to $18.6bn and $3.2bn, respectively.

An overall current account surplus of $21.1bn was expected for the LDCs, largely as a result of higher oil prices. At a regional level, the Middle East had a surplus of $43.9bn and Asia £39.4bn, but deficits were provisionally recorded for Africa ($3.6bn, a large improvement over $16.8bn in 1999), and Latin America ($58.7bn). Indebtedness of the LDCs rose slightly to $2 068bn, of which $270bn was short-term debt. The most heavily indebted region was Latin America ($775bn).

Investor nervousness and volatility characterised the world's stock markets in 2000. Although 'Y2K', the 'millennium bug', did not materialise to jeopardise trading, a raft of factors contributed to a generally bearish sentiment later in the year. Chief amongst these were the economic outlook of the USA and the bifurcation between 'old economy' and the fragile 'new economy' stocks, especially businesses in the information technology (IT) sector which had been encouraged to develop disproportionately high price-earnings ratios compared with all other sectors, such that the increased weighting of IT stocks in national indices in the early part of the year led to vulnerability as investor and analyst sentiment changed later on. Other factors included rising oil prices, the threat of conflict in various parts of the Middle East, and a weak euro. As several 'dot.com' or Internet-based companies collapsed - the 'Internet bubble' - throughout the year, the technology, media, and telecommunications (TMT) sector suffered, leading to a sharp decline in the National Association of Securities Dealers automated quotations (Nasdaq) composite index and related technology indices in other countries. One of the features of information technology and its close association with aspects of globalisation was the internationalisation of capital markets, cross-border correlation of stock prices and international trading. A debate yet to be resolved concerns the true weighting of stocks in the various key national indices to reflect accurately and openly those that could be bought and sold, as opposed to those constrained by corporate cross-holdings, government holdings or control, or other restrictive devices. Several blue-chip companies would be adversely affected by re-weighting. Attribution of company pension liabilities was also a lively topic of discussion related to true company valuations.

The collapse in technology stock and share prices in April 2000 cut a swathe through public stock offerings for Internet start-up companies. Valuations of existing dot-com and e-commerce companies began to relate more sensibly to their earnings and profitability in the short-to-medium term rather than an evanescent potential for the long term. Similar declines in investment and valuations were noted in media and biotechnology companies. Meanwhile, technological developments in computing and information systems included web-enabled digital wireless telephones, personal digital assistants (PDAs), and other hand-held computers, but limited screen sizes and modem speeds severely restricted their utility. Recordable and rewritable compact-disc drives were beginning to be built into personal computers (PCs) during a year when growth in sales started to tail off, prices declined but computer performance increased. Initial estimates by the Semiconductor Industry Association put global sales of semiconductors at $205bn in 2000, a 37% increase over sales in 1999. Demand for semiconductors came from the PC, data networking, wireless, broadband and optoelectronics (especially laser devices and image sensors) sectors. Rapid growth was noted in programmable logic devices, digital signal processors, microcontrollers, flash memory, and dynamic random access memory.

At a time when e-commerce companies were forced to retrench, raising prices and focusing on profits, the so-called 'bricks-and-mortar' conventional companies began to use the Internet for marketing. In the USA, legal status given to electronic signatures began to permit on-line electronic contracts. Business-to-business web sites also began to take shape, but globally the complex issue of Internet taxes and bartering challenged national and more locally based taxation centres.

Loss of privacy and confidentiality in cyberspace by the actions of commercial profilers of personal on-line activities, and other surveillants, became major concerns. The breaching of commercial confidentiality of financial information and intellectual property was a closely related issue. Internationally, there was no robust cross-border legislation to deal with Internet crime, and hackers and destructive software 'viruses' caused destruction of computer files, immobilisation of corporate computer servers, and extortion. One growing problem was the use of the Internet by people, sometimes anonymously, to criticise, vilify or even libel individuals and corporations, currently without proper redress.

According to the *Financial Times*, only the Toronto Composite (Canada), ISEQ overall (Republic of Ireland), Milan Banca Comm.Ital. (Italy), and SBC General (Switzerland) stock markets recorded increases above the levels at the end of 1999, whereas declines were noted in the remaining major global stock markets. The Morgan Stanley Capital International World Index declined by 15%. Cross-border mergers of European exchanges were entertained, and, by the end of the year, the outlook for equities was depressed.

A hotly debated topic was the rôle of hedge funds which, in the view of some, weaken stock markets by short-selling, break down exchange-rate pacts, and target shares leading to a collapse in share prices and thereby to bear markets. Hedge-fund managers, however, pointed out their rôle in the creation of balanced markets, as well as their investment potential in recent years as an alternative to traditional equity investments.

A dramatic rise in oil prices from relatively low prices to a high in September 2000, caused popular unrest in Europe and malcontentment in the UK of high fuel-tax impositions. The partial cartel operated by the Organisation of Petroleum Exporting Countries (OPEC) was mildly effective at stabilising relatively high prices, but a shortage of refinery capacity; low strategic reserves in importing, fuel-dependent economies; the threat of conflict; the increasing influence of non-OPEC exporting countries such that they more than matched OPEC output; and a downturn in manufacturing, all contributed to a non-stable situation. Low prices still afflicted agricultural commodities, and consequently the economies of those countries with large agricultural sectors. As input costs rose, and quality-control measures were becoming the norm, competitive pressures suppressed agricultural prices. In many MDCs, a combination of statutory controls relating to health and the environment, the influence of supermarkets, new technologies, pressure groups and marketing strategies led to bleak predictions for the future of their indigenous agricultural and horticultural industries.

Rural tourism interdigitates with agriculture and horticulture. It is reliant on the visual amenity and other free benefits, as well as paid benefits, provided by

these underpinning primary industries. Only when large-scale deleterious changes in the landscape take place, or when travel restrictions are introduced following pest and disease outbreaks - amplified by ghastly media reports as in the UK's 2001 foot and mouth disease outbreak, is this dependence revealed. The UN International Labour Organisation estimated that in 2000 the tourism industry as a whole employed 207 million people, equivalent to 8% of global employment. According to the World Tourism Organisation, international tourism expenditure in 2000 was *circa* $65bn in the USA, $46bn in Germany, $35bn in the UK, $32bn in Japan, $16bn in France, $156bn in Italy, and $11bn each in Canada and the Netherlands. International tourist arrivals were 75 million in France, 50 million in the USA, 48 million in Spain, 41 million in Italy, 30 million in China, 25 million in the UK, and around 20 million each in Russia, Mexico, and Canada.

In the forest products industry during 2000, pulp prices increased whereas lumber prices declined. The textile industries in the MDCs suffered from low prices and competition from the LDCs and NICs. Despite political attacks on the US pharmaceutical industry during the presidential campaign, and the threats posed by generic pharmaceuticals, the major pharmaceutical companies prospered. Even so, many politicians and pressure groups were beginning to regard the industry world-wide as a taxation milch-cow at best, or target for protest at worst, despite its massive investments in biomedical R&D. The tobacco industry also prospered irrespective of actual and threatened legal actions, anti-smoking initiatives in most MDCs, and the imposition of high taxes by certain countries.

Consolidation in the banking and securities industries reshaped the global banking and financial services sectors. Procedures were put in place to eliminate local currencies in the euro zone to replace them with euro banknotes and coins by 1 January 2002. Regulatory and supervisory relationships in the banking and securities industries exercised governments of most countries, not least in the light of the formation of highly complex international groupings, and the need to reduce unnecessarily convoluted restrictive processes without undermining confidence. Loan loss provisions, classification of assets, pension provisions, risk-management processes, financial-reporting practices, and the elimination of money laundering were the main common themes. In June 2000, the report of the international Financial Action Task Force on Money Laundering identified 15 jurisdictions operating with inadequate measures, including The Bahamas, Cayman Islands, Dominica, Israel, Liechtenstein, the Philippines, and Russia.

Comparative performance indicators of countries were (widely) used by analysts to evaluate their contributions to global and regional trade, their gross national product, labour force, the effectiveness of their governments and body politic, their educational and health and other social indicators, transport and communications, demographic indicators, taxation levels, military expenditure, and standard of living. Other indicators included the seaward claims for territory and fishing and economic rights, and land claims. These wide-ranging indicators were used extensively in 2000 for international negotiations in both the public and private sectors; they were important for inward-investment decisions. The principal indicators (i) were rarely up-to-date; (ii) were subject to methodological problems whereby data may be compiled on different bases; (iii) suffered from the fact that the sources of the data varied to a considerable extent; (iv) were difficult to compare because some data were classified as preliminary, final, revised or adjusted; (v) varied because the accounting interval may vary from Gregorian calendar year, a fiscal year, an Islamic or other national or religious year, a cropping year, a multiyear period or average, especially when a single year would be unrepresentative; and (vi) may use data sets that are discontinuous. Interpretation of these data to gauge national effectiveness, or even to present the data in a straightforward manner, are fraught with difficulty, and it is rare to access crisply presented authoritative global data comparable to the *Britannica World Data* published by *Encyclopaedia Britannica.* Other valuable sources of reference include the *World Bank Atlas*, and the associated *Global Development Finance*, and the *World Development Report*; the IMF's *Direction of Trade Statistics Yearbook, Government Finance Statistics Yearbook* and the monthly *International Financial Statistics*; *Keesing's Record of World Events*; the OECD's *Economic Surveys*, and *Financing and External Debt of Developing Countries*; Pennwell Publishing Company's *International Petroleum Encyclopaedia*; the UN's *Demographic Yearbook, International Trade Statistics Yearbook, Population Studies, National Accounts Statistics,* the quarterly *Population and Vital Statistics Report, Statistical Yearbook,* and the biennial *World Population Prospects*; UNESCO's *Statistical Yearbook*; UNIDO's

Global Report; the US Central Intelligence Agency's annual T*he World Factbook;* and the WHO's *World Health Statistics Annual*.

Increasing attention was given to membership and adherence to the precepts of the relevant premier international organisations, *viz*. the main UN organs and affiliated intergovernmental organisations (United Nations Conference on Trade and Development, UNCTAD; United Nations Children's Fund, UNICEF; International Court of Justice, ICJ; Food and Agriculture Organisation, FAO; International Atomic Energy Agency, IAEA; International Bank for Reconstruction and Development, IBRD; International Civil Aviation Organisation, ICAO; International Development Association, IDA; International Finance Corporation, IFC; International Labour Organisation, ILO; International Monetary Fund, IMF; International Maritime Organisation, IMO; International Telecommunications Union, ITU; United Nations Educational, Scientific and Cultural Organisation, UNESCO; United Nations Industrial Development Organisation, UNIDO; Universal Postal Union, UPU; World Health Organisation, WHO; World Intellectual Property Organisation, WIPO; World Metereological Organisation, WMO; and the World Trade Organisation, WTO); the Commonwealth of Nations; six regional multiple-purpose bodies (the European Union, EU; Gulf Cooporation Council, GCC; League of Arab States, LAS; Organisation of American States, OAS; Organisation of African Unit, OAU; and the South Pacific Commission, SPC), and finally nine economic organisations (African Caribbean and Pacific [Lome IV] Convention, ACP; Asian Development Bank, ADB; Asia-Pacific Economic Cooperation Council, APEC; Caribbean Community and Common Market, CARICOM; Economic Community of West African States, ECOWAS; The Franc Zone, FZ; Inter-American Development Bank, I-ADB; Islamic Development Bank, IDB; and Organisation of Petroleum Exporting Countries, OPEC).

Afghanistan was reported by the UN Office for Drug Control and Crime Prevention to be the largest opium producer in the world and becoming a major heroin manufacturer. Lack of funding and local political involvement in the trade closed the drug-control programme in that country.

Political turbulence affected several member countries of the Commonwealth of Nations at a time when it appointed a new Secretary-General (D. McKinnon). There was the military takeover in Fiji; the enforced removal of the Prime Minister of the Solomon Islands; the land-reform/land-seizure crisis in Zimbabwe mentioned above; a delay in the return to civilian rule in Pakistan, a developing country hosting large numbers of Afghani refugees and in dispute with India over Kashmir; and the civil war in Sierra Leone. Political advancement took place, however, with progress in adopting tighter rules of membership and stopping the attendance of military leaders at its meetings. In addition, pressure was put on the World Bank and the OECD to deal sensitively with small nation states.

Expansion of the EU into former communist countries in Eastern Europe was retarded by the slowness in reforming the Common Agricultural Policy (CAP) and the efforts primarily of France and Germany to engage in deeper political and economic integration. Disapproval of the election in Austria of a government coalition involving the far-right Freedom Party led to the unprecedented act by the other 14 EU partners of freezing bilateral contacts. By September, a review team concluded that the new coalition had not strayed from 'European common values', in effect rescuing the EU from deadlock in its reform programme which requires unanimity. Further internal political crises in the EU were spawned by the proposal floated by the German Foreign Minister, K. Fischer, of a fully fledged European government with a written constitution, elected President, diminished national parliaments, and therefore even weaker regional assemblies. The proposal was seized on by those opposed to seemingly inexorable further political integration or who wished to unwind the current level of central control. Similarly, there was debate as to whether the EU should run its own foreign policy and defence, thereby creating disharmony with the North Atlantic Treaty Organisation (NATO) and some of the more prominent member states. Plans were drawn up in the face of opposition by the staff unions to modernise the operation of the European Commission itself, tightening up staff training, discipline, and processes to permit 'whistle-blowing'. The disgraceful treatment in 1999 of P. van Buitenen, the auditor, led to the resignation *en masse* of the Commission on 16 March 1999 on the grounds that lax management had allowed fraud and nepotism in the Commission's services.

Throughout 2000, the euro was generally weak against the dollar and yen, leading to the stimulation of inflation in the euro-zone. A stated reluctance of

the European Central Bank (ECB) to intervene in the market place was thought to have undermined confidence.

Against this background of a slump in the value of the euro, and the rejection in a referendum in Denmark of adopting the single currency, reinforcing the views held by many in Sweden and the UK that adoption of the euro was not inevitable, European integration and enlargement were fraught issues. Preliminary and technical analysis continued nonetheless to prepare for the five economic tests to determine whether the UK Government should recommend entry to the euro (see www.hm-treasury.gov.uk/pdf/2001/p11901.pdf; for business implications of the introduction of the euro see www.euro.gov.uk; and www.europa.eu.int/euro;). Concerns were expressed about the disconnection between the public and politicians in the speed and direction of change. Plans were nonetheless advanced to admit 13 new countries to the EU: ten former communist countries, Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia; plus Cyprus, Malta, and Turkey. The Commission president, R. Prodi, announced that negotiations on the terms of entry of the "more prepared" nations (Cyprus, the Czech Republic, Estonia, Hungary, Malta, and Poland) should be concluded by the end of 2002, with full membership by 2004-2005. At the Nice Summit in December, national interests soon prevailed over European integrative moves. Vetoes were retained, *e.g.* over taxation policy, and there were disputes over voting weights.

Partnership and co-operation agreements based on regulating and improving political and economic relations, and mutual trade concessions, but which exclude any possibility of membership, have already been signed with Moldova, Russia, and Ukraine (1994); Belarus, Kazakhstan, and Kyrgyzstan (1995); and Armenia, Azerbaijan, Georgia, and Uzbekistan (1996). The procedure for accession to the EU is laid down in the Treaty of Rome. Thus, nation states must be stable European democracies, governed by the rule of law and with free-market economies. In essence, the procedure involves a study of the membership application by the Commission which leads to an Opinion which, if positive, leads to negotiations followed by an Accession Treaty. Approval of the Treaty is required from all member state governments and parliaments, the European Parliament, and the government and parliament of the applicant state.

The European Parliament expanded its influence through the Single European Act of 1986, the Maastricht Treaty (1991) and the Amsterdam Treaty (1997). It is deliberately biased in favour of multi-national political groupings, and has incrementally increased its degree of democratic control. The legislative process is formally described as a dialogue between the European Commission, the Council of Ministers and the European Parliament, but the European Commission and the European Central Bank (ECB) have limited legislative powers within their fields of competence. Funding of the European Community budget is derived from four sources from each member state : levies charged on agricultural imports into the EU from non-member states; custom duties on imports from non-member states; contributions based on the share of a notional Community harmonised Value-Added Tax base; and contributions based on the share of community gross national product (GNP). The latter is a so-called budget-balancing item and covers the difference between total expenditure and the revenue from the other three sources. According to the *General Budget of the European Union for the Financial Year 2000*, agriculture accounted for 44% of the total spend of 92.7 billion ECU, regional and social aid 35.1%, external action 5.1%, pre-accession aid 3.4%, research and technology 3.9%, other internal policies 2.6%, administration 5%, and reserves 1%.

Manifold difficulties were faced in 2000 by members of the Association of South-East Asian Nations (ASEAN, Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar (Burma), the Philippines, Singapore, Thailand, and Vietnam). Northeast Asia was clearly advancing economically faster than Southeast Asia; Indonesia faced political, religious, and separatist strife; concerns were expressed about the differences between North and South Korea, and between China and Japan, and China and Taiwan; the UN had reported that the region had 1.3 million new cases of HIV infection in 1999. The member states voiced their commitment to developing a free-trade area despite the desire of some members to protect sensitive industries. The free-trade theme was also shared with the Asia-Pacific Economic Co-operation (APEC; 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, and Vietnam). In

November, members agreed to begin negotiations to eliminate trade barriers, but did not address the fears of some LDCs that the EU and the USA would impose labour and environmental standards through the WTO and bilateral arrangements that would reduce the competitiveness of poorer nations.

The creation of any single market area requires a common patent system. At the European Council of Lisbon, a decision was taken to introduce a 'community patent' from the end of 2001. Three profound problems will need to be addressed, namely: (i) the choice of language; although English is widely accepted as a suitable technical language, cultural sensitivities mean that the ongoing enormous costs of translation are likely to continue; (ii) an intellectual property (IP) tribunal will have to be set up at the European Court of Justice in Luxembourg, and on grounds of cost it may have to set up decentralised channels, but the vested interests of many national patent lawyers will strongly oppose this aspect; and (iii) the bureaucratic processes to bring the common patent system into being are not fully integrated, and are unlikely to be changed in the short term, given the fact that the various national patent offices will have to concede power, and the essential services they provide users may suffer. Presumably, the European Patent Office in Munich will have to examine and grant new single patents.

Patenting costs, including associated litigation and licensing arrangements, mean that most public sector R&D bodies and all but the most affluent companies have to review constantly their patenting strategies and tactics. Failure to patent could mean that one or more competitors could gain the patent and protect it by closing off a market or demand licensing fees. On the one hand, failure to patent properly often means that incremental improvements and derivatives have to be patented too, or the original patent becomes surrounded or 'picket-fenced' by competitors. On the other hand, existing and potential competitors can be disqualified from patenting by 'defensive' publishing of information about the invention so as to create 'prior art'. In order to facilitate this defensive strategy, specialist journals such as *Research Disclosure*, websites such as *IP.com,* and its associated *Priorart.org*, and others act as public disclosure routes, with ready access to patent offices. Defensive publishing of incremental improvements could stop picket-fencing, but may have several drawbacks. Thus, it could be used to undermine or even dismantle the patenting system, adversely affecting investments in research-intensive organisations and technology-transfer companies, and quelling enquiry and investments more generally in innovation.

Agricultural biotechnology (agbiotech) experienced difficulties in IP matters internationally, mainly in restricted access to IP (or lack of freedom to operate), variable regulatory regimes, overlapping patents and patent claims, inadequate technology-transfer systems, and the burden of transaction costs associated with convoluted IP rights. Almost akin to orphan medicines, minor crops (especially horticultural crops) and many crops which are essential for life in LDCs are for the most part ignored in agbiotech R&D programmes in the MDCs. Helpful proposals to improve the situation were made in *IP Strategy Today No. 3-2001* (see www.bioDevelopments.org), including IP 'clearinghouses' to reduce the complexity and transaction costs of the 'patent thicket' and IP 'aggregators' for bringing together smaller interested parties, as well as for mutually interdependent patents over a common technology system scattered across multiple parties. As pointed out in *Slow Magic. Agricultural R&D a Century after Mendel* by P.G. Pardey and N.M. Beintema, International Food Policy Research Institute, 2001, there are 114 members of the Patent Co-operation Treaty administered by the UN World Intellectual Property Organisation. All 141 members of the WTO must comply with the terms of the Trade-Related Aspects of Intellectual Property by 2005. Moreover, 49 countries, including 28 LDCs, are signatories to the UPOV Convention (the International Union for the Protection of New Plant Varieties) that provides certain rights to plant breeders.

A measure of IP awareness in the UK was detailed in the *Annual Report and Accounts of the UK Patent Office (2000/2001)* (see www.patent.gov.uk/about/reports/index.htm). Patent applications (more than 31 000), registrations for trade marks (76 290), and design registrations (9 380) were substantially greater than in 1999. Most patents were granted in the telecommunication sector (1 110), civil engineering (535) and data handling (526) sectors. There were 6 856 applications published for scientific trade marks.

At a time when governments and individuals have become conscious of health costs and the efficiency of public and private health systems, the report from the World Health Organisation *The World Health Report 2000 – Health Systems: Improving Performance* was

timely. In an analysis of standards, effectiveness and responsiveness in 191 countries, it was recognised that it would be difficult to adopt a single healthcare model. Medical advances, ageing populations, rising expectations, and rapidly accelerating costs caused political and social problems in many countries, not least in publicly funded health systems such as that of the UK National Health Service (NHS). A 'socialised' medical system which purported to offer free access to high-quality healthcare, the NHS was under great pressure, rather like the public transport network, and despite increased funding and dedicated staff, was unable to meet expectations, denying expensive treatments to those that needed them and delaying treatments generally. Dissatisfaction was also voiced about public health systems in Canada, The Netherlands, Norway, and Spain. *Per capita* health expenditure in 1997 was greatest in the USA, $3 724, 41% of which was public expenditure, but in overall terms of efficiency was only ranked 37th as it did not cover uninsured people adequately. France was considered to have the best healthcare system, although its *per capita* expenditure, $2 125, 77% of which was public expenditure, was less than that of the USA, Switzerland ($2 644), and Germany ($2 365). The UK had a relatively lowly ranking at $1 193, 97% of which was publicly funded. Little R&D was supported by the NHS.

Many MDCs were concerned about the long-term funding and viability of their social security (protection) programmes. The rôles of private-sector providers, new technologies to enhance delivery, and policies to improve fairness but discourage dependency, were under continuing scrutiny. Combinations of insurance schemes, means-testing, payroll taxation, tax credits, involvement of charities, employer-based schemes, and a policy focus on the most needy were operated with varying levels of success. To this was factored in many MDCs a rapidly expanding proportion of older people in the population, early retirement schemes, healthcare and pension expectations, and pressure exerted by the broadcast and publishing media. In the newly emerging countries and LDCs, reform efforts were made against a backdrop of poverty and ill-health. There was disagreement in 2000 on the five main ways to alleviate poverty in the LDCs: loans, grants, debt-forgiveness, economic and market restructuring to improve productivity and wealth creation, and increasing the proportion of MDCs GDP to donate to LDCs to reach the UN target of 0.7%. Insufficient attention was given to confronting corruption and terrorism. International or globalised social security agreements operated only to a limited extent.

Globalisation strongly influenced the development of international law in 2000, and numerous international agreements were introduced. The establishment of a Caribbean Court of Justice was agreed in principle, to join three existing permanent international courts: the International Court of Justice, the European Court of Justice, and the European Court of Human Rights. Non-permanent bodies, such as the International Criminal Tribunal for the former Yugoslavia, the International Criminal Tribunal for Rwanda, and the Marshall Islands Nuclear Claims Tribunal, met during the year. By the end of 2000, 139 nations, including the USA and Israel, had signed, and 27 nations had ratified the treaty – the Rome Statute – to establish the permanent International Criminal Court, under the auspices of the UN, and first voted for in 1998. It would bring to international justice those individuals accused of the most serious violations of international humanitarian law or values. Harmonisation of national and international laws was particularly challenging in the functioning of the WTO, and in the imposition mentioned above of EU sanctions against Austria, a member state. During the year, there was settlement of the first cases under the new Uniform Domain Name Dispute Resolution Policy of the Internet Corporation for Assigned Names and Numbers. In May, the G-7 countries and Russia convened the first international gathering of law-enforcement agencies, civil servants and prominent private-sector individuals to combat computer crime. In January 2000, more than 130 countries signed the Cartegena Protocol on Biosafety, which requires notification if any transported material has been genetically modified.

International and local terrorism was evident, but at a relatively low level in 2000. Drug trafficking, however, was a significant factor in international conflicts, murder, terrorism, and other violence. Transparency International, a non-governmental organisation (NGO) based in Berlin and established to expose and prevent corruption, reported in September that Nigeria was the most corrupt country. The eight cleanest national administrative environments were Canada, Denmark, Finland, the Republic of Ireland, New Zealand, Norway, Singapore, and Sweden.

Conflicts and Populations

Population growth and changes in the age composition of the population can be predicted on the basis of (i) fertility and whether the number of births per woman exceed, match or fall below the level required for each generation to replace itself; (ii) mortality and life expectancy data; (iii) effects of migration on particular regions and countries; and (iv) age distribution, particularly the ratio between young and old. Global population projections by the UN and World Bank since the 1950s have been remarkably accurate, within 4% of the measured totals. Difficulties were noted for country projections, most notably for LDCs, not only in respect of acquiring reliable primary data, but there were inherent errors, arising from trying to quantify the uncertainty of trends. In recent times there has been a continuing decline in fertility in MDCs, a rise in life expectancy world-wide, and a persistence of migration to a number of major receiving countries. According to *Beyond Six Billion: Forecasting the World's Population* by the Panel on Population Projections, edited by J. Bongaarts and R.A. Bulatao, current world population projections to 2050 are based on reasonable assumptions but several improvements could be made to the forecasting methodology, principally by (i) reducing the assumed rate of fertility decline as fertility approaches the replacement level in countries now in transition; (ii) removing an assumed ceiling on life expectancy; (iii) maintaining net migration around current levels for several decades for receiving countries; (iv) using more reliable baseline data, requiring investments in censuses, surveys and vital registration; and (v) timely updating of projections. Beyond 2020 and in the absence of catastrophic happenings, uncertainty accumulates rapidly and nonlinearly. It is reasonable to estimate that the global population will grow from the current 6bn level to between 8 and 11bn in 2050. Nearly all of this growth will take place in the LDCs, and there will probably be population declines in several MDCs. All of the major agencies (the UN, the World Bank, the US Census Bureau, and International Institute for Applied Systems Analysis, and related institutions) accept that world population growth will continue at least to 2050. By this date, it is expected that the most populous countries will be India (1 529 million), China (1 478 million, USA (349 million), Pakistan (345 million), Indonesia (312 million), Nigeria (244 million), Brazil (244 million), Bangladesh (212 million), Ethiopia (169 million), and the Democratic Republic of the Congo (160 million). Thus, the USA will be the only MDC in the listing. Periurban and urban agriculture will become pressing topics for planners, scientists, and politicians. The European population is projected to decline markedly and the proportion of the elderly in the population will rise rapidly. According to *Encyclopaedia Britannica*, at midyear 2000 there were an estimated 6 080 141 683 people on Earth, some 77 632 256 more than in the year before.

The UN was involved in 15 peacekeeping operations, deploying more than 37 000 military personnel and civilian police from 88 countries. Africa was the most troubled continent, with wars affecting Burundi, the Democratic Republic of the Congo, and other countries in Central Africa as an aftermath of the 1994 genocide in Rwanda. A virulent, nine-year civil war in Sierra Leone was quelled by British special forces. Rebel forces disrupted the border areas of Guinea and Liberia. In December, Eritrea and Ethiopia signed a peace agreement after a prolonged series of offensive actions. Civil war persisted in parts of Asia. Afghanistan was racked by the efforts of the Taliban Islamic militia to seize overall control from an assortment of warlords. The separatist Liberation Tigers of Tamil Eelam fought with the government troops of Sri Lanka. Muslim separatist guerrillas fought the Philippine armed forces. China, an undemocratic country, blatantly threatened to use force to retake Taiwan, a wholly democratic country. The Middle East remained politically fragile, with little sign of peace between the Israelis and Palestinians. Israel terminated its occupation of southern Lebanon in May but the West Bank and Gaza witnessed scenes of violence. A suicide attack was mounted against the USS *Cole* in Aden. Enforcement of the no-fly zones in northern and southern Iraq was sustained by the UK and USA, and Turkish forces made an incursion into northern Iraq to combat Kurdish rebels.

Russia was engaged in attempting to take full control of Chechnya, virtually destroying its capital, Grozny, but failing to pacify the mountainous southern zone. Related in part to the activities of other militant Islamic fighters in the inhospitable mountainous region where Kyrgyzstan, Tajikistan, and Uzbekistan share common borders, the six member states (Armenia, Belarus, Kazakhstan, Kyghyzstan, Russia, and Tajikistan) of the 1992 Commonwealth of Independent States Collective Security Treaty agreed to create a joint rapid-reaction force to deal with any external aggression or terrorism.

Under the protection afforded by the Kosovo Force (KFOR) of over 40 000 troops in the Serbian province of Kosovo, and the 32 000 troops of the Stabilisation Force (SFOR) in neighbouring Bosnia and Hercegovina, the Balkans settled down to an uneasy peace. The profundity of the animosity between the communities would indicate that peacekeeping would be needed for several years.

In April 2000, the Russian government finally ratified both the 1993 Strategic Arms Reduction Talks (START-III) treaty and the Comprehensive Test Ban Treaty. START-III talks to make further cuts in the nuclear arsenals floundered on the claim by Russia that the development of a national missile defence system by the USA would undermine the Anti-Ballistic Missile Treaty, signed with the former Soviet Union. Even so, at the Review Conference of the Nuclear Non-Proliferation Treaty (NPT), the avowed nuclear weapon states (China, France, Russia, UK, and USA) unequivocally undertook to reduce and eventually eliminate their nuclear weapons; no timetable was set. India, Israel, and Pakistan were called on to become signatories of the NPT. Bioterrorism and biological warfare were beginning to be regarded as worrying as nuclear warfare.

There was an increase in the number of people classified as refugees and persons of concern to the Office of the United Nations High Commissioner for Refugees (UNHCR), from 21.5 million in 1998 to 22.3 million in 1999. The scale of the humanitarian crisis was that the latest figure represented more than 1 in 300 of the global population, and that more than 50% of the number were women, and 41% were children under 18 years old. Yet even the numbers cited did not record adequately those affected by conflict.

Africa was the continent of most concern. Almost half of the population of Sierra Leone, *i.e.* 2.5 million people, were not able to access relief aid because of the fraught situation and despite a cease-fire agreement. About 11 000 of the population had been displaced. Liberia was also unsettled although 38 000 Liberians were repatriated in 1999. The largest refugee population in West Africa, more than 500 000 people, was in long-suffering Guinea, largely unrecognised by MDC donors for its hospitality. Refugees also flooded into the Central African Republic from the adjacent Democratic Republic of the Congo. Instability persisted in the Great Lakes region irrespective of the 1999 Lusaka cease-fire agreement. Since 1998, over 90 000 Congolese refugees resided in Tanzania, and 25 000 in Zambia. Over 38 000 Rwandan refugees were repatriated, but by the beginning of 2000, Tanzania faced the burden of nearly half a million refugees from unstable Burundi, the Democratic Republic of the Congo, and Rwanda. UNHCR was involved in the repatriation of 100 000 Eritrean refugees in the Sudan, and large numbers of Somali refugees from Djibouti, Ethiopia, and Kenya. Angola was enmeshed in its 26-year civil war, leading to sub-populations of more than 2.6 million internally displaced persons, and tens of thousands of refugees in Namibia, Zambia, and the Democratic Republic of the Congo.

In Asia, the principle areas of concern were Afghanistan, Bhutan, Myanmar (Burma), parts of the former Soviet Union (Chechnya, Ingushetia, Georgia, and Kazakhstan), Indonesia, Kashmir, East Timor, and the Middle East. Millions of refugees from conflict and drought in Afghanistan sought refuge in Iran and Pakistan, and were the largest refugee group in the world. As of March 2000, UNHCR provided relief assistance to 180 000 displaced Chechens in Ingushetia. It was estimated that the violence in East Timor led to the displacement of 75% of its population, and the conflict in Sri Lanka caused the displacement of 700 000 people with an additional 70 000 refugees in India.

During the past two years, the UNHCR estimated that 600 000 people had been displaced within Colombia, joining 500 000 who had been displaced by earlier troubles. It was the area of most concern in South America.

Disruption continued in the Balkans with the return of displaced ethnic Albanians to Kosovo in July 1999. By mid-July 2000, 210 000 Serbs, Roma (Gypsies), and other ethnic minorities were forced to flee Kosovo. In contrast, large numbers of refugees and internally displaced persons returned to Bosnia and Hercegovina, and Croatia.

For most countries, repatriation was regarded as the preferred solution to the situation of refugees, rather than offer resettlement in their new host country. In 1999, 45 000 refugees were resettled in receiving countries; far fewer countries offered local full integration, an option dependent on the willingness of refugees to adopt the local culture and language. For many refugees, particularly Afghanis and Palestinians, their refugee status has persisted over decades. The

difficulties faced by returning displaced persons and refugees should not be underestimated. In many instances, their homes and livelihoods have been destroyed or taken by others, the infrastructure of the country or region has been damaged, their families broken up, and they are subject to a life of poverty, often in politically unstable areas. Feeding them is a challenge to the MDCs.

Failure to prevent the 1994 genocide of 800 000 people in Rwanda led to a panel from the Organisation of African Unity (OAU) to propose that nations and institutions such as Belgium, France, the UN, USA, and the Roman Catholic and Anglican churches were culpable and should pay reparations. The Panel asked the UN Secretary-General, K. Annan, to establish a commission to deal with the issue, and also requested that creditors cancel the international debts of Rwanda.

In *Deliver Us from Evil: Warlords & Peacekeepers in a World of Endless Conflict,* William Shawcross questioned the ability of the UN to solve the problems of local wars, refugees and genocide without the member nations fully implementing its Charter.

According to The World Bank, in *World Development Indicators 2000*, 2.8bn people, nearly half the global population, survive on an income of less than $2 per day, while 1.2bn live on less than $1 a day, 291 million of whom live in sub-Sahara Africa, and 522 million in South Asia. In the UNDP *Human Development Report 1999*, it was estimated that about 1.1bn people are rated as malnourished, 1.2bn do not have access to clean water, and for the poor, contaminated water, and diseases such as cholera, tuberculosis, and AIDS have become acute.

Agriculture and Food

According to the UN Food and Agriculture Organisation (FAO), total agricultural production increased by around 1%, in both MDCs and LDCs. Total food production increased likewise, but *per capita* food production fell in the LDCs because the increase in food output did not adequately match the increase in population, contrasting with an increase in *per capita* food production in the MDCs.

Particular problems in production were noted in the former Soviet Union and Eastern European countries undergoing transition from centrally planned to market economies, such that agricultural outputs remained depressed to levels some 30% lower than a decade earlier. Despite potentially highly productive land resources, a combination of poor infrastructural development, corruption, old-fashioned agronomic practices and cultivars, failure to take on board entrepreneurial approaches, and constraints on land ownership, impeded development, a situation made worse by the downward pressure on international commodity prices. Sub-Saharan Africa, including Central Africa, also suffered production difficulties, not aided by expanding populations leading to declining *per capita* food production. Many countries experienced drought. Mozambique had catastrophic flooding; other countries such as Ethiopia, Eritrea and Angola were embroiled in conflict.

Food aid, as measured by shipment in cereals, declined to low-income, food-deficit countries (LIFDCs) from 7 908 million metric tonnes (mmt) in the period July 1998-June 1999 to 6 779 mmt in the period July 1999-June 2000, but increased to other countries, such as Russia, from 3 126 mmt to 3 449 mmt. The primary source of food aid was the USA (6 693 mmt), followed by the EU (1 324 mmt), Canada (349 mmt), Japan (303 mmt), Australia (264 mmt), Norway (48 mmt), and Switzerland (40 mmt). Russia was the single largest recipient of food aid from the USA.

Trade liberalisation fostered by the WTO did not extend to matters agricultural, following the unproductive Seattle event in late 1999. Trade-distorting subsidies were criticised by the Cairns Group (Argentine, Australia, Brazil, Canada, Chile, Colombia, Fiji, Indonesia, Malaysia, New Zealand, Paraguay, Philippines, South Africa, Thailand, and Uruguay), highlighting the extraordinary protectionist measures adopted by the European Union, Japan, and South Korea, mainly on the basis that agriculture provides indirect, difficult-to-quantify benefits such as visual amenity, food security, and rural cultures. A raft of production-related subsidies, export credit and credit-guarantee programmes, peripheral subsidies, and import barriers seen in the protectionist countries is associated with complex bureaucratic processes and regressive attitudes to agriculture. Potential enlargement of the EU to include agriculturally dependent countries in Central and Eastern Europe would create enormous pressures on the EU total budget unless substantial reforms including subsidy downsizing were to take place.

In the EU, agriculture continued to enjoy relatively high levels of protection from the vagaries of the marketplace. Despite a series of reforms since its inception in 1957, including the reforms of 1984,

1988 and the MacSharry Reforms of 1992 and the modifications brought about by the Uruguay Round Agreement on Agriculture (1997-1999), the Common Agricultural Policy (CAP) absorbed a disproportionately large component of the EU budget. Born of a drive to increase agricultural production, provide a fair standard of living for farmers, and ensure the availability of food at reasonable prices, as well as protect small-scale, sometimes peasant-level agriculture and rural culture, the bureaucratically complex CAP distorted international trade and weakened the international competitiveness of EU agriculture. By maintaining a combination of (i) common pricing systems with associated market intervention; (ii) sustaining a dual-pricing system such that internal EU prices were kept above those in the rest of the world through direct intervention, import duties, and export refunds; and (iii) direct payments to farmers for production and output; the CAP was responsible for unfair trading, creating inducements for excess production, stultifying technological advancement, and generating anomalous actions such as 'set-aside', quotas, corruption, and overburdening paperwork. Transformation of the CAP requires unanimity of agreement between the Member States, so given the level of vested interests, it is unlikely that substantial changes will be brought about unless the deficiencies are likely to imperil the existence of the EU as a whole during enlargement or economic stress.

In 2000, France received the largest allocation (£5.7bn) of EU funds for agriculture, compared with Germany (£3.6bn), Italy (£3.2bn), UK (£2.6bn) and the Republic of Ireland (£1.1bn). The major net contributors to the EU budget were the UK, Austria, Germany, Luxembourg, The Netherlands, and Sweden, with Belgium and France as minor net contributors. Major net financial transfers were made to Greece, Portugal, Spain, and the Republic of Ireland - the so-called cohesion countries. Given the disparities in *per capita* standards of living, contributions, and receipts, the current distributions are not tenable in the medium term.

No progress was made in the undertaking (Article 10(2)) to develop "suitable" rules at international level on subsidised export credits specified in the Uruguay Round Agreement on Agriculture (URAA). According to the OECD, the total support for agriculture in the MDCs was $327bn in 2000, or 34% of gross farm incomes, a figure slightly below the proportion in the mid-1980s. At a special session of the WTO Committee on Agriculture in July 2001, the EU proposed (i) a single reduction mechanism to reduced expenditure on export credits whilst recognising the special needs of LDCs, and (ii) clarification of the EU's application of the precautionary principle (see COM(2000) 1 final of 2 February 2000). On the latter, reference was made to preventing the placing on the market of products that cause 'legitimate concern' and the obligation on signatories of the URAA to implement the Agreement on the Application of Sanitary and Phytosanitary Measures – the so-called SPS Agreement, permitting countries to set higher levels of health protection than the accepted international norms (Article 14 of the URAA, and Article 5(7) of the SPS Agreement). Debate will ensue on how these contributions from the EU will accord with the guidelines laid down by the WTO Appellate Body.

Enlargement of the EU will mean reconsideration of the CAP, and during 1999-2000 progress was made in four respects. First, screening of all legislation was undertaken as a prelude to transposing Community law into the national law of acceding countries. Thereafter, nine of the candidate countries submitted their negotiation positions (Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, and Slovenia). Following submission of their negotiating positions, the Commission will adopt a common position for the negotiation which is expected to be adopted unanimously by Member States prior to negotiating sessions, the preparation of a draft accession treaty to be approved by Council and given assent by the European Parliament. Ratification of the treaty by the Member States and candidate country leads to incorporation of the candidate country into the EU. Bilateral agreements between the EU and each of the candidate countries were signed in 2000, addressing agricultural trade liberalisation. Associated with these agreements was approval of Sapard programmes in ten central and eastern European candidate countries (notably Bulgaria, Romania, Slovakia, and Slovenia). About 530 million euros were allocated to prepare the agricultural sector and rural areas in those countries for EU membership. Other assistance programmes implemented included Phare (investments related to institution building and economic and social development) and ISPA (pre-accession support for transport and environment infrastructure projects).

In terms of international agricultural trade, the EU was the world's leading importer of agricultural

products, and the second leading exporter after the USA. Under the auspices of the WTO, the EU's position on agricultural trade liberalisation mentioned above was agreed by the General Affairs Council in December 2000. A largely defensive posture was taken. Thus, there was a commitment to an overall average reduction of bound tariffs, and a minimum reduction *per* tariff line, but EU advocated retaining the special safeguard clause to ease tariff reductions. The right to continue to use geographical indications (*i.e.* the current Protected Designation of Origin register, of special interest in Scotland), and a guarantee of consumer protection through the regulation of labelling (*e.g.* Traditional Speciality Guaranteed labelling) were proposed for world-wide adoption. The EU stated its willingness to negotiate further reductions in export refunds in tandem with firmer controls over other instruments used to boost exports. With regard to the domestic support of agriculture, the need for continuing reform was recognised, using the blue and green box framework of measures agreed in the Uruguay Round. More controversially, the EU wished to recognise the specific rôle of agriculture as a provider of public goods – which it is, incorporating the multifunctional rôle of agriculture in sustainable development, the protection of the environment, the sustained vitality of rural areas, and poverty alleviation. These less tangible aspects are seen externally as routes of special protection. Similarly, the EU proposed to use specific measures, including the precautionary principle, to address concerns which arose over food safety and animal welfare, again areas that might be used blatantly to distort trade, or pander to prejudice. Finally, the EU proposed measures to open up duty-free access to products from LDCs by provision of trade preferences and other forms of assistance.

Through the year, the EU interacted with Mercosur (a trade bloc established in 1995 comprising Argentina, Brazil, Paraguay, and Uruguay) and Chile, established an EU-Mexico free-trade agreement in July 2000, as well as the Agreement on Trade, Development, and Cooperation with South Africa, and was engaged in related talks with Israel, Morocco, and Tunisia.

Agri-environmental measures became obligatory in the programmes of the Member States in 2000, with the aim of compensating farmers for losses of income they will incur by using more environmentally friendly practices that are more labour-intensive and which may lead to lower yields than by other methods. The measures must be in addition to good farming practice and not circumvent or be used to comply with mandatory legislation such as the Directives on nitrates and habitats. Amongst the measures are water-resources management, protecting specific production techniques such as terracing, production techniques that encourage richer biodiversity and wetlands management, landscape conservation, less-intensive livestock farming, and developing the 'organic' sector.

Organic farming, as defined by the Codex Alimentarius Commission, involves holistic crop and livestock production management systems that emphasise the use of management practices in preference to the use of off-farm inputs. (see also www.ifoam.org, the website of the International Federation of Organic Agriculture Movements, and www.soilassociation.org, the website of the UK Soil Association). Thus, it is expected that cultural, biological, and mechanical methods are used in preference to synthetic materials. The stated aims of organic farming include the application of farming methods that do not "damage the environment", that encourage a "more respectful use of the countryside", promote "concern for animal welfare", and achieve "high-quality" products (see the *SCRI Annual Report 1998-1999).* By 1999, over 50% of the 121 055 holdings in the EU certified as organic or in conversion were in Italy (40.5%) and Austria (16.3%). None of the other countries had more than 10% of their holdings organic; the UK total was 1.9%. Claimed benefits of strict organic systems were under review, particularly animal welfare and commodity quality criteria, and there were trends in Austria and Denmark of lowered price premia as a result of supply exceeding demand.

More than 7 million hectares were committed to 'organic' farming world wide, a tenfold expansion over a decade, and dominated by EU countries. The global organic food market was estimated to be $22bn annually, a tiny percentage of the total food market (see *Organic Agriculture World-Wide* by H. Willer and M. Yussefi, 2000; and *Organic Food and Beverages*: *World Supply and Major European Market,* UN Conference on Trade and Development, 1999). Differences of some magnitude exist between practitioners of organic farming and conventional farming in the criteria distinguishing 'organic' from 'conventional', the relative rôles of profitability and lifestyle, the rôle of new technology, and vision for the future of organic production systems.

According to Eurostat *Economic Accounts for Agriculture*, the shares of the EU member states in final agricultural production were France (23.1%), Germany (15.4%), Italy (15.4%), Spain (12.1%), UK (8.7%), the Netherlands (6.8%), Greece (4%), Denmark (2.9%), Belgium (2.6%), Portugal (2.3%), Republic of Ireland (2%), Austria (1.8%), Sweden (1.6%), Finland (1.3%), and Luxembourg (0.1%).

Against a background of concerns about the spread of bovine spongiform encephalopathy (BSE) from the UK to five countries in mainland Europe (France, Germany, Portugal, Spain, and Switzerland), and its possible linkage to a new variant form of Creutzfeldt-Jakob disease (CJD), dioxin contamination of poultry in Belgium, continuing problems of *Escherischia coli* O157 and other food-poisoning microorganisms, a rapidly escalating foot and mouth disease outbreak, and a mistrust of scientists and regulators, genetically modified (GM) crops received bad – often hostile – publicity in Europe. Regardless of the proven safety of current GM crops in agriculture, their widespread cultivation outwith Europe, their potential contribution to wealth-creation and the quality of life - including their potential benefits to the environment, various non-governmental organisations (NGOs) such as Friends of the Earth and Greenpeace and other groups strongly opposed GM crop cultivation and utilisation in Europe. Demonstrations, sometimes violent, against GM foods took place, and meetings on the topic were frequently discomfited by implacably polarised views, prejudice, misinformation, inability to understand risks, and outright intolerance. Religious views on the inviolate separation of species (taxonomic taboos), attitudes on 'ownership' of genes by species, ingrained suspicions about multinational corporations based in the USA, opposition to market-based capitalist economies (anti-globalisation), anti-Americanism, anti-science tendencies, unwillingness to accept expert views or the opinions and actions of regulators, and urban-based perceptions on the rôle and functioning of agriculture as a business, all acted against a change in direction to adopt GM technology even on a gene-by-gene, crop-by-crop, place-by-place basis. Indeed, the actions and publicity engendered by the anti-GM groups created concerns about GM organisms (GMOs) in countries throughout the world.

Pressure was brought to bear on governments in Europe to retard the development of GM crops, a position aided by the results of opinion polls. Retailers and food producers in Europe and especially in the UK responded by withdrawing GM products, and insisting that such products were withdrawn by suppliers from the food chain. This tactic operated in tandem with the marketing impetus given to 'organic' produce and products, but will undoubtedly create problems for those organisations when a change takes place on the grounds of quality, cost-benefit studies, and supply regularity. Herbicide-tolerant GM oilseed rape, one of the first GM crops of general release, proved to be a public-relations problem in the UK in respect of its outbreeding, gene flow induced by widespread pollen movement, and the inadvertent appearance of GM types in a purportedly conventional cultivar (see section on Plant Biotechnology). Another highly publicised crop was StarLink maize, an animal-feed type with the potential to cause allergies in humans. Analysis of foodstuffs, principally taco shells, revealed StarLink contamination, some caused by cross-fertilisation with human-feed cultivars and also by inadequate segregation of grain stocks. There were estimates of the StarLink genes being detected in nearly 50% of the maize crop harvested in Iowa.

The debates in 2000 about gene flow from genetically modified (GM) plants spread beyond the EU, extending to discussions on the merits and disadvantages of gene-use restriction (terminator) technology sanctioned in August by the US Department of Agriculture (USDA), and the nutritional, environmental, and medicinal benefits of GM crops. Meanwhile, S. Padulosi of the Rome-based International Plant Genetic Resources Institute stated that of 5 300 species of food plants collected world-wide, more than 50% had but a single sample left in a seed bank, even though each species may have hundreds or even thousands of cultivars. The preservation, viability, and characterisation of many collections are neglected in most countries. It is ironic, therefore, that biotechnology will be central to the rescue of these genetic resources.

Massive investments in GM technology by companies such as Monsanto and DuPont, and by many governments in MDCs, and the utility of the technology to a wide spectrum of new industries in healthcare, nutrition, industrial feedstocks, and the environment, provided market optimism in North America, and to the mainstream international scientific community. Food safety standards in the highly litigious society of the USA, and the openness and independence in the USA of their Department of

Agriculture, the Environmental Protection Agency, and the Food and Drug Administration, coupled to the credibility of their investigative media, clearly reinforced confidence in GM crops specifically, and biotechnology in general. European opposition to the technology and importation of its products represented a trade barrier that was difficult to justify scientifically and in trade terms. Perhaps the resistance to GM crops was able to blossom in an environment of poor marketing strategies, incomplete data sets for the impacts of both conventional and GM-based agriculture, ignorance of gene flow in agriculture, horticulture and forestry, and the paucity of scientists able to present in debate their knowledge and opinions without complex jargon and concepts. By appreciating the slow incremental improvement of knowledge, recognising risks in all human activities, welcoming the heterogeneity of scientific opinion, having a high regard for peer evaluation, knowing the difficulty of generating 'soundbites' without leading to over-simplification, and having the good manners to avoid personal vilification led to a marked reduction in participation in public debates by scientists. Most biotechnologically based scientists were described by pressure groups as 'GM advocates', as opposed to the more correct description of scientists able to understand both 'sides' of GM debates but aware of the huge potential of their studies. Understanding and appreciation of the behaviour of the public represented a challenge to scientists, and were areas of study rapidly taken up by social scientists and a growing population of ethicists. 'Shaping' of views, 'avoidance of unwanted outcomes', political 'preferences', and dubious sampling and questionnaire processes were noted in some studies. The high-quality social science publications supported the view that the general public operated rationally and justifiably according to the information that was made available. With regard to GM crops, the introduction of tighter EU regulatory controls, overarching committees that are socially inclusive, wider consultation, and close monitoring of crops and their products post-release should give greater public reassurance, as the policy of crop-by-crop, gene-by-gene, place-by-place analysis continues, and the newer metabolic profiling, gene-flow measurement, and environmental impact technologies are introduced (see section on Plant Biotechnology). Even so, neither multinational corporations nor scientists *en bloc* seemed able to deal with well-orchestrated attacks on them.

Strident anti-science views, even in pluralistic, multicultural societies, had the capacity to destabilise the numerically expanding political classes who were noted for the scarcity of scientists in their ranks. There was widespread confusion over such straightforward distinctions between research for curiosity, serendipitous discovery, invention, development, and commercial application. Rarely has it been possible to suppress inquiry throughout the world; the major challenge is to foster its socially acceptable application. Ridicule of scientific aspirations and vision (*e.g.* feeding the world, curing disease *etc.*) - easy because for obvious reasons there are not many irrefutable examples in younger areas of science, and hostile questioning of well-intentioned motives, also undermined scientific endeavours. In the UK, both the Office of Science and Technology in the Department of Trade and Industry, and the Scottish Executive produced strategies that were aimed at strengthening the science base.

Repeated health scares also undermined the confidence of consumers in food-safety regulations and the integrity of conventional farming. The linking by the EU of agriculture and the environment in world trade discussions was essentially aimed at legitimising barriers to farm trade, based theoretically on one of many definitions of the precautionary principle, and was an approach largely refuted by virtually all the other WTO members.

Domestic gardening in many MDCs was a major leisure activity both participatory and as broadcast entertainment. Modern trends were evident of containerised growing, use of planting modules as opposed to rearing from seed, elaborate garden designs, a preponderance of floral rather than vegetable growing, and a willingness to seek new species and cultivar introductions. For most countries, the horticultural introductions were species alien to the area. As the horticultural industry adjusted to these trends, the challenge of horticultural plant breeding gained wider respect. The sheer diversity of species and types, growing systems, pests and diseases, and markets presents geneticists and breeders with great opportunity offset only by a paucity of medium- to long-term funding. It is likely that horticultural benefits in the form of new vegetable types will come indirectly as collateral benefits from the agricultural crop breeding and selection programmes.

The Environment

One of the most interesting sources of information and analysis on environmental matters is the annual *State of the World* report on progress towards a sustainable society. Such accounts give an overview of the scale of the challenge facing the human race.

Pollution of groundwaters has become a serious issue as 97% of the Earth's liquid fresh water is stored in aquifers, some of which are not recharged by incoming water, or which are recharged slowly over hundreds of years (see UNEP *Groundwater : A Threatened Resource*, 1996 and P. Sampat *Uncovering Groundwater Pollution* in *State of the World 2001*). Groundwater is the primary source of drinking water for up to 2bn people. Agriculture accounts for around 65% of the fresh water drawn from rivers and wells each year, and manufacturing industry consumes 22%.

Removal of water from an aquifer can magnify the concentration of pollutants, enhance the inflow of saline water, cause a collapse in the aquifer structure, and affect the hydrology of the area. The major threats are pesticides, petrochemicals, chlorinated solvents, arsenic, other heavy metals, radioactive materials, nitrates, fluoride, and other salts. In the UK, low-level but bioactive pharmaceutical pollution has become an issue. Strategies to overcome these problems include lessening the impact of agriculture so that it requires less water and agrochemicals, restricting the use and disposal of pollutants above aquifers, use of closed-loop systems, changed manufacturing systems, restricting wasteful use of water, use of end-of-pipe filters, attempts to clean or treat aquifers, use of other sources of water *e.g.* desalination of sea water, lakes, dams, *etc.*, and a search for new technological solutions.

Lester R. Brown, in one of his characteristically hard-hitting articles, *Eradicating Hunger: A Growing Challenge* in *State of the World 2001*, made the point that 1.1bn of the world's population are undernourished, and this goes in hand with poverty. With the exception of Africa, though, the proportion of the population that is hungry is diminishing in all regions. In recognising that malnutrition is for the most part a manifestation of rural poverty, the World Bank started to replace conventional agricultural development strategies largely centred on subsistence agriculture with rural development strategies. Population growth is a pivotal factor to consider in the ability of a country to meet its needs. Most of the world's poor live in countries with rapidly growing populations. Calculations based on farm size, area of cultivated or grainland, or fresh water *per capita* are sobering for most LDCs; millions are effectively landless and the statistics are worsening. Thanks to the efficiency of modern agriculture, global food production (see section on Agriculture and Food) has more or less kept pace with population growth, although there are signs of a growing mismatch. From a figure of 247Kg *per capita* in 1950, grain (mainly wheat, rice, and maize) production reached a peak of 342Kg *per capita* in 1984, declining to 308Kg in 2000. Intensive livestock protein production (principally beef, sheepmeat, and chicken) and fisheries are unlikely to contribute a great deal to the world's future food supply, although the demands for these products is increasing. Thus, to avoid damaging or eliminating large tracts of forests and other natural and semi-natural habitats, it will be necessary to raise productivity. This can be addressed by raising yields with improved cultivars and agronomic practices, multiple cropping, use of residues and eliminating waste, controlling pests and diseases, restoring damaged agricultural habitats, operating with better water-use efficiency, and planning for long-term sustainability. Competition for non-farm uses of water will shackle agriculture and horticulture in the future. Few individuals and organisations world-wide pay the true price for water. Reduction of animal protein production will be enforced under highly competitive conditions for access to foodstuffs. Livestock are poor converters of energy from fodder, and can degrade the environment, even in low-density, extensive systems. Competition for agricultural products could be accelerated in the short-to-medium term if there are major weather perturbations, rising sea levels that flood low-lying coastal lands and river basins which are major agricultural production areas, outbreaks of pests and diseases, and clearly, rapid population growth. (See also International Food Policy Research Institute *Fourth Report on the World Nutrition Situation*, 1999; the UN Food and Agriculture Organisation *The State of Food Insecurity in the World 1999* and *2000*; the UN *World Population Prospects: The 1998 Revision.*

S. Dunn in *Decarbonising the Energy Economy* in *State of the World 2001,* highlighted the fact that the release of carbon atoms has been the byproduct of the human harnessing of energy, from the combustion of wood, coal, lignite, oil and through to natural gas. He noted that carbon output can be decoupled from economic growth. From the reports of the Intergovernmental

Panel on Climate Change and others, it is estimated that 42 trillion tonnes of carbon are fixed in or circulate between the three main reservoirs: the atmosphere, oceans and biosphere (*e.g.* vegetation, detritus, marine and freshwater biota, terrestrial fauna, soil and other microorganisms *etc.*). Since the start of the Industrial Revolution, more than 271bn tonnes of carbon have been added to the atmosphere by the oxidation of fossil fuels (coal, oil, natural gas); present-day emission rates are *circa* 6.3 billion tonnes. The capacity of the main reservoirs is not known, as is a precise understanding of the social, economic and environmental impacts of the anthropogenically added greenhouse gases (carbon dioxide, methane, nitrous oxide, and halocarbons) able to trap infra-red radiation reflected from Earth. Renewable energy sources have the potential to substitute for fossil sources, and hydrogen as a fuel of choice is a promising line of enquiry. Rarely, though, is nuclear energy regarded by reviewers as an appropriate major source for generating electricity until the issue of nuclear waste is put to rest.

Carbon sequestration and storage could be achieved by technological routes such as its incorporation into inert and long-lived composite products, injecting it into oilfields which are thought by the International Energy Agency to be capable of storing 126bn tonnes of carbon dioxide, or locking up carbon dioxide by forming stable hydrates, or reacting it with naturally occurring mineral oxides to form carbonates. The most effective approach would seem to be a reliance on photosynthesis, whereby the carbon is bound into terrestrial and aquatic plants, but there are uncertainties as to the rates at which the carbon will be released by degradation processes, unless there are large-scale increases in the biomass of forestry plantations, the planting of perennial amenity and horticultural species, and iron-fertilisation of oceans to stimulate phytoplankton growth. Of course, the oceans with their ability to store carbon dioxide in the form of carbonates represents a major buffering reservoir, and perhaps the deep oceans could also store injected carbon dioxide, but again there are uncertainties as to the possibility of large-scale, uncontrolled releases. Many environmental activists are opposed to technological fixes, and advocate the termination of burning fossil fuels.

Renewable energy from biomass, wind, solar and geothermal energy, and hydroelectric schemes, the so-called 'green' energy, does have the capability to be

Title	Date	Number of Parties
Ramsar Convention on Wetlands of International Importance, Especially as Waterfowl Habitat	1971	123
Convention Concerning the Protection of the World Cultural and Natural Heritage	1972	161
London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter	1972	78
Washington Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	1973	152
International Convention for the Prevention of Pollution from Ships (MARPOL)	1973/78	112
Bonn Convention on the Conservation of Migratory Species of Wild Animals (CMS)	1979	70
UN Convention on the Law of the Sea (UNCLOS)	1982	135
Montreal Protocol on Substances that Deplete the Ozone Layer	1987	175
Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal	1989	141
Convention on Biological Diversity (CBD)	1992	178
UN Agreement Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks	1995	28 (not yet in force)
Kyoto Protocol to the 1992 UN Framework Convention on Climate Change	1997	30 (not yet in force)
Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (PIC convention)	1998	11 (not yet in force)

Table 1 A selection of international environmental accords.

operated on a smaller scale than conventional coal- and nuclear- and natural-gas powered stations. Around 70% of the world's carbon emissions in 1999 were produced by the USA (25.5%), EU (14.5%), China (13.5%), Japan (6%), Russia (4.6%), and India (4.5%).

Hilary French and Lisa Mastny in *Controlling International Environmental Crime*, in *State of the World 2001*, pointed out the existence of nearly 240 international environmental accords (see UN Environment Programme *Register of International Treaties and Other Agreements in the Field of the Environment*, 1999). The principal agreements (Table 1) may be regarded as expressions of good intentions, at least, but resources to police the agreements are limited.

There were countless incidents of illegal dumping and pollution world-wide. Phasing out production of some of the 95 ozone-depleting chemicals (CFCs, halons, HCFCs, methyl bromide *etc.*) was confounded by a sizeable illegal trade and fraud. Some environmental NGOs were constructively active in policing compliance to the international codes, others merely sought publicity for enrolment purposes. The book by the Danish statistician, B. Lomborg, *The Skeptical Environmentalist*, *Measuring the Real State of the World*, challenged the mantras and assumptions of the more aggressive members and organisations in the environmental movement, and pointed out the selective use of scientific evidence and exaggeration of environmental damage. His views were contested by the World Resources Institute (see www.wri.org).

Environmental issues were politically prominent in 2000. Settlement of the debate between the EU countries on one hand, and Australia, Canada, Japan, and the USA on the other, over the Kyoto Protocol was not attained. The reluctance of LDCs and rapidly industrialising countries to restrict their greenhouse-gas emissions and jeopardise their economic growth meant that targets were sidelined. Decarbonising the economy; supporting the Clean Development Mechanism in LDCs; supporting agriculture, forestry and sustaining or improving natural habitats; emissions trading; and enforcing low-emission domestic and industrial activities, were all reviewed, but the challenge remained of reaching an agreed, fair system. Closure of the Shenyang Smeltery in north-east China, which was responsible for Shenyang being classified as one of the 10 most polluted cities in the world, was a refreshing approach to tackling environmental degradation in China. The Environmental Protection Agency of the USA reclassified dioxins from 'probable' to 'known' carcinogens, and stated that the compounds were 10 times more likely to cause cancer than thought hitherto; but this opinion was contested.

In Germany, Russia, and Sweden, the nuclear industry came under political pressure on safety grounds. Mainly as a result of the efforts of 'green' political activists, the nuclear industry in Germany was given operating limits, and safety regulations were tightened on the transport of spent nuclear fuel. In Sweden, the closure of the Barsebäck 2 nuclear reactor was postponed as a result of the demand for electricity and the inability of the renewable energy sector to make good any shortfall. As a result of the attention given to climate change issues, there was evidence of a rethink on the future of the power-generating industries. Although the transport and custodianship of spent nuclear fuel and waste were of concern, as were catastrophic radiation leaks and terrorism, the huge potential of nuclear industry to generate carbon-dioxide-free power was becoming widely recognised. Gas- and coal-powered plants were seen to create difficulties for countries trying to meet their Kyoto obligations. Alternative energy strategies were seen to be attractive yet remained under-resourced in respect of R&D investment into the associated areas of science, engineering and technology. Complex energy taxation arrangements were, in contrast, starting to be introduced.

Early release of the draft of the third assessment report by the Intergovernmental Panel on Climate Change – a group acting under the auspices of the World Metereological Organisation and other sections of the UN – showed that three of the past five years had been the warmest in recent history, and dendrochronological records from the past millennium demonstrated that the abrupt twentieth century warming is unique. Human-induced (anthropogenic) warming was identified as the factor responsible for a climate warming of 0.6ºC over the past century. Predictions of future 'greenhouse' warming and their consequences were thought to have made little progress given the levels of uncertainty over climate models, cloud behaviour, use of fossil fuels, impacts of changing land use, solar activity, *etc.* (see Fig. 1).

In the USA, a panel of the National Research Council, an offshoot of the US National Academy of Sciences, noted in January 2000 that there was little or no warming detected in the upper atmosphere, but

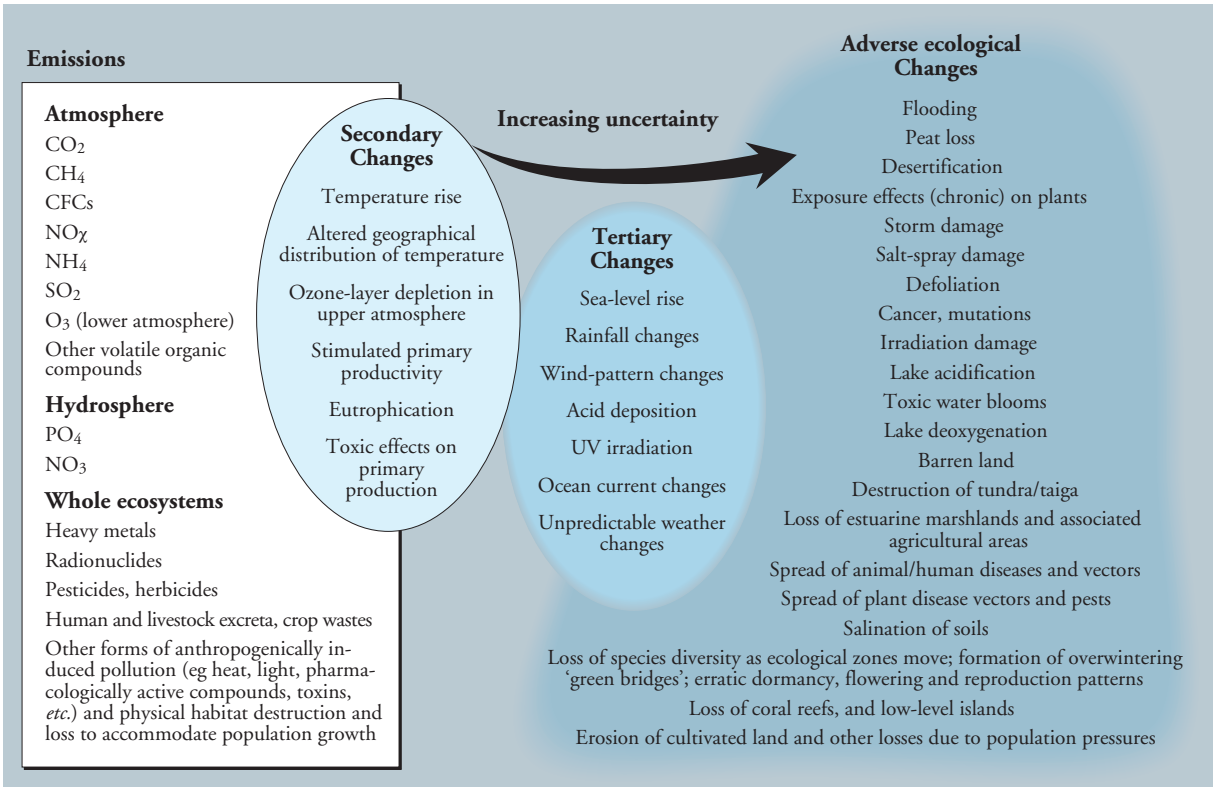

Figure 1 Principal global changes and their likely consequences.

confirmed warming at lower levels. The panel did not provide evidence to support the largely accepted view that the warming was a result of the accumulation of greenhouse gases, or would even continue.

Studies in the melting of the Greenland ice sheet, the retreat of glaciers, world-wide, melting of the Antarctic ice sheet, and the major depletion in the average thickness of summer polar ice in recent years, were all indicative of global warming. Any threat to the oceanic conveyor belt – specifically the Gulf Stream that accounts for the temperate condition of the UK, to the global flora and fauna, and to current weather patterns justifiably caused concern and raised questions as to whether global climate change can be favourably modified or, delayed anthropogenically, or is inevitable.

A combination of four governments (Finland, The Netherlands, Norway, and Sweden) and several companies funded a World-Bank global-market-based project to reduce greenhouse-gas emissions and to promote appropriate technologies in LDCs. It was envisaged that the World Bank would act as a broker, aiming at a price of *circa* $15 *per* tonne of carbon.

Notable pollution events in 2000 included (i) the failure in January of a containment dam holding water contaminated with cyanide and heavy metals at the Aural gold-tailings retreatment mine near Baia Mare, Romania; (ii) a series of fires during March in the forests of Sumatra, Indonesia; (iii) a damaging leakage from an oil pipeline into the Guanabara Bay in January; and (iv) in August, employees of the Shengli Chemical Company in Taiwan were charged with dumping dimethyl benzene into the Kqop'ing River, the principal source of drinking water in southern Taiwan.

In March, the European Commission and Norway persuaded the Marine Environment Protection Committee of the International Maritime Organisation, an independent specialised agency of the UN, to designate the North Sea as a low-sulfur-fuel zone *i.e.* to restrict fuels to no more than 1.5% sulfur as opposed to the 4.5% permitted globally. Implementation of designation, however, would require ratification by at least half of the world's fleet of an annex to the Marpol convention.

Effects of the lingering La Niña over the Pacific Ocean accounted for much of the unusual weather effects in 2000. The below-normal sea-surface

temperatures in the eastern and central equatorial Pacific, and above-normal temperatures in the western Pacific led to increased rainfall in the western Pacific, western USA and Indian Ocean basins, tropical storms in Australia, southeastern Africa, and the southern Indian Ocean.

Green architecture aimed at designing and constructing buildings that leave a small environmental footprint, consuming few resources and emitting few greenhouse gases, began to influence architecture and civil engineering in 2000. When the extent of ongoing construction world-wide of domestic housing, factories, airports, aquaducts, bridges, commercial centres, hotels, towns and villages, dams, roadways, railways and subways, tunnels, and harbours are taken into account, plus the costs of maintenance, it is clear that the pressures on the national environment and cultivated land are inexorable, and 'green' construction will need to become widespread.

UK Perspectives

Devolution developed during the course of 2000. The Westminster-based UK Parliament remained the supreme law-making authority, legislating for the UK as a whole, or for any parts of it. Sovereignty resides with the Queen in Parliament. The main functions of Parliament are to pass laws, to provide the means of carrying on the work of government by imposing taxes, and to scrutinise government policy and administration. All international treaties and agreements are presented to Parliament before ratification. Contrasting with most countries, the UK constitution is not contained in a single document but has slowly evolved, and been shaped by statute, common law, and by convention. Membership of the European Union poses constraints and overrides, however. Following its election on 6 May 1999, the Scottish Parliament exerted legislative power over all devolved powers, *i.e.* matters not reserved to Westminster; primary legislation can be introduced, and the Scottish Parliament has the power to raise or lower the basic rate of income tax by three pence in the pound. The areas of responsibility cover agriculture (including agricultural R&D), economic development, education, environment, financial assistance to industry, fire services, food standards, forestry, heritage and the arts, health, housing, law, planning, police, and some aspects of transport. A busy year was experienced by the Scottish Parliament (see *Scottish Parliament Annual Report 2000 to 2001*). Thirteen bills were passed, 14 bills received Royal Assent, 71 members' business debates were held, large numbers of questions were lodged, and answered either in Chamber or in writing. The Committees of the Scottish Parliament gained a higher profile. Of relevance to this report was the work of the Rural Development (formerly Rural Affairs) Committee which devoted considerable time to the controversial Protection of Wild Mammals (Scotland) Bill, but became increasingly involved in the alarming outbreak of foot and mouth disease. Other topics covered by this committee included an inquiry into the effect of changing employment patterns in rural areas. Following a petition, GM crops were considered in a report by the Transport and the Environment Committee; this Committee also considered a petition on the environmental effects of an oilseed-crushing plant in Arbroath. Petitions from the public were firstly reviewed by the innovative Public Petitions Committee, a noteworthy democratic initiative. Cross-party groups were also active. The National Assembly for Wales was also elected in 1999 and has the power to make secondary legislation in the areas where it has been granted executive functions. The New Northern Ireland Assembly elected in 1998 was due to be formally established by legislation in 1999. It was suspended in February 2000 and resumed sitting in June 2000, and had legislative authority in the fields administered by the Northern Ireland departments.

Alongside the changes taking place with devolution, the relationship with the EU came into sharper profile during the year. It is through the European Communities Act, 1992, incorporating the Treaty of Accession, that sovereignty is shared with the European Union, and it is assumed that the courts follow primarily the statute of Parliament. Potential expansion of the EU, sensitive issues such as taxation

and constitutional matters, Single Market laws and harmonisation, environment policy, health and safety, regional aid, transport policy, research and development, immigration and human rights, consumer protection, and overseas aid, generated both heat and light in the media. Eurostat, the official EU statistics agency, recorded a £20bn deficit on Britain's visible trade with the 11 original members of the eurozone last year, whereas Britain's Office for National Statistics estimated the deficit at just £1bn. This provided strong evidence of the over-valuation of the pound.

From an estimate of 59.8 million for the population of the UK in 2000, the Office for National Statistics in another of its functions forecast that the population will rise by 5 million in 2025, more than 3 million of whom will be immigrants arriving at a rate of 135 000 annually. Already immigration is responsible for more of the population increase than natural expansion by births in England, with slight increases in Northern Ireland and Wales, but the population of Scotland was projected to fall by about 200 000 to 4.9m. The average age of UK citizens will increase from 38.8 to 42.6 years by 2025, and more than 13 million people will be of pensionable age compared with less than 11 million in 2000. Life expectancy will rise from 76 to 79 years for men and 80 to 83 years for women of this time, raising questions on the quality of life in people in their final years and the need for companies to review marketing strategies. Under present arrangements, the tax take will decline, and the ratio of workers to pensioners will fall from 4:1 to 2.5:1 by 2025 unless attitudes to the elderly, retirement ages, and pension conditions change substantially in the interim.

Risk management is an intrinsic component of research organisations. It involves the removal of traditional barriers within the organisation, the application of vision and foresight, and the recognition of the rôle of risk tolerance – or risk appetite. The biggest risk to research organisations is risk avoidance. To capitalise on risk, and optimise opportunities, without endangering the future of the institution, there must be due levels of accountability, with measures to identify, quantify, and prioritise risk at the strategic and operational levels, bearing in mind reputation, regulation, and asset protection. Audit committees are a particular focus. Their oversight responsibilities and effectiveness were emphasised by the recommendations of the Blue Ribbon Committee and the O'Malley Panel Report. During the year, public-sector bodies were encouraged to emphasise the probity and process-checking rôles of audit committees. Corporate governance procedures were beginning to be widely applied in the public sector, codifying arrangements to deal with risk, responsibility, and communication. Decisions impacting on finances, effectiveness, and reputation were deemed to be best shared, rather than remain under the control of a single person. Disaster plans to enable rapid business recovery were widely discussed, with emphasis on protection of assets including IP, inter-institutional linkages, command chains, identification of choke points, and back-up processes. Institutional integrity, ethics and corporate values, and their relationship to stakeholders, were concepts beginning to be inculcated into the *modus operandi* of public- and private-sector bodies. Ethics represent a less-tangible concept in business terms, but relate to values, policies, and the behaviour of individuals. Honesty and integrity are needed at all levels, sustaining trust between and within businesses of all types; they inhibit illegality and failure to comply with regulations, and clearly diminish the risk of damaging litigation.

Investment in the future lies at the heart of the rationale for companies and countries to commit to a complex set of activities under the heading of R&D. Translation of the products, tangible or otherwise, into market or social advantage requires additional skills. In the UK, the Department of Trade and Industry has published for more than a decade, an annual *Research & Development Scoreboard* (see www.innovation.gov.uk/finance). The European Commission started to produce a related benchmark report – *The 2001 Innovation Scoreboard* (www.cordis.lu/scoreboard).

Rather like advertising, R&D spend is vulnerable during recessionary periods as short-term thinking pervades decision-making. Comparisons of sector mixes and intensity of spending on company R&D within and between countries, and between trading blocs give indications of future company, if not public sector, performance. Historical analyses show that R&D-heavy companies perform, on the whole, significantly much better than their competitors and are more likely to withstand successfully downturns in the economy. From the company reports and accounts of 597 companies received by 4 July 2000, as analysed by Company Reporting Ltd who prepared the 10th (2001) anniversary issue of the R&D Scoreboard in conjunction with the DTI Future and Innovation

Unit, it was possible to conclude that overall, the levels of business expenditure on R&D in the UK rose from 1.18% of GDP in 1997 to 1.25% in 1999. The overall total of R&D for the 597 companies was £15bn, excluding all the R&D carried out by UK companies overseas. The Scoreboard excluded R&D paid for by governments and other non-commercial sources. As always, there were uncertainties of definition and classification. The UK definition is contained in Statement of Standard Accounting Practice 13, and for international companies, the definition is that governed by International Accounting Standard 9. Both definitions are based on the OECD 'Frascati' manual, whose linear-thinking taxonomy of the spectrum of R&D has caused strong disagreement in the research practitioning communities concerned about subjective classification and complex inter-relationships between different components of R&D, disagreements not necessarily shared by those that administer R&D.

Some trends were obvious. R&D intensity (R&D/sales) in the USA rose from 1.9% to 3.5% during the 1980s, ostensibly at the expense of realisable profit because R&D intensity plus profitability remained approximately constant at around 7%. During the 1990s, however, R&D intensity increased further to over 5%, while R&D intensity plus profitability rose from 9-10% to 13-15%. At the start of the 1990s, UK profits exceeded the US level, but the R&D effort was much lower. By the end of the decade, UK company profits were less than 90% of US companies, and R&D expenditure was 60% less. The R&D intensive part of the economy, which includes 51% of the companies listed in the FTSE 100 and 39% of the FTSE 350 indices, was heavily biased towards what the Scoreboard described as chemistry-based industries, with over 39% of UK R&D in pharmaceuticals. In other words, in R&D terms, biotechnology is the UK's most important industry. Other advanced economies were, conversely, skewed towards physics-based industries, but the position is changing as the bioindustries grow in stature and integrate with the physics-based sector. That the overall R&D intensity in the UK was less than 50% of the US level, and that R&D intensity was higher in the UK than elsewhere for pharmaceuticals, aerospace and defence, means most other industries, the physics-based sector included, were underperforming. Almost 50% of the sales turnover in the UK Scoreboard was accounted for by sectors with R&D intensities of less than 1%, contrasting sharply with 22% of sales turnover attributable to low R&D-intensive companies for the US Scoreboard, and only 12% for the international Scoreboard. With the exception of the automotive industry, the UK subsidiaries of overseas companies invested at a lower R&D intensity than their UK equivalents, but some of the R&D supported was crucial to key sectors of the economy. In conclusion, overall UK profitability *per se* does not appear to be a constraint on R&D spend, if viewed in the medium term. Certainly, R&D intensity is positively linked to sales growth, and there is strong evidence to support the view that the amount of R&D per employee translates into sales per employee. Most UK companies in R&D intensive sectors are below international averages in these measures, a fact that indicates room for improvement in productivity and competitiveness. Concern was expressed in the Scoreboard that the proportion of medium-sized companies (over £60m annual sales) with R&D intensities of over 10% in the UK economy is about one sixth of the level in the USA. It is interesting that R&D is not greatly valued by the UK market, with the honourable exception of the pharmaceutical sector. Spend, of course, does not signal efficiency or effectiveness of the investment, or even how well the companies perform. Intellectual property owned or controlled in the form of patents or licences, and innovative power, measuring the R&D effectiveness of each employee – as is adjudged in visiting group and research assessment exercises in the public-sector – will surely start to be a part of the market analyst's armoury.

Distinct from the approaches adopted by the DTI R&D Scoreboard, the EC Innovation Scoreboard analysed relevant statistical data on 17 indicators in human resources; knowledge creation; transmission and application of new knowledge; and innovation finance, output, and markets. With the data available, there was evidence of declines in public-sector R&D, business R&D, and value added from high-technology manufacturing. The USA held a lead over the EU in tertiary education, business R&D, home internet access, and high-technology patenting. The EU led the USA in the supply of new science and engineering graduates, public-sector R&D, and information and communication technology (ICT). Compared with Japan, however, the EU led only in ICT expenditure. Of particular interest was a tentative national summary innovation index (S11) which scored performance within a range of whether all indicators were above average (+10) or all indicators were below average (-10).

The leading country was Sweden (+6.5), followed by the USA (+5.6), Finland (+4.7), UK (+4.4), Japan (+3.8), Denmark (+3.5), Netherlands (+3.0), the Republic of Ireland (+1.0), Germany, (+0.6), France (-0.6), Austria (-2.4), Belgium (-2.4), Luxembourg (-4.4), Spain (-5.9), Italy (-5.9), Greece (-7.9), and Portugal (-8.7). The UK gained from its educational system, the availability of high-technology venture capital, and Internet access. Two observations in the report were that the European innovation leaders managed to increase innovation performance and reduce poverty, as evidenced by the negative correlations between S11 and two indicators of social exclusion (percentage of the population living below the poverty line and inequality of income distribution), and that highly innovative countries tended to give high priority to sustainability.

Agriculture did not figure in the Scoreboard analyses. Its links with the international and top 300 UK listed companies would come in the beverages, chemicals, food processors, forestry and paper, general retailer, pharmaceuticals, and tobacco sectors. So, regardless of its underpinning rôle in the provision of foodstuffs and other aspects of civilisation, and the huge volumes and values of agricultural commodities in international, national, and regional trade, its once-high profile has been usurped by upstream and downstream industries.

UK Agriculture

As a consequence of the high levels of support to the agricultural industry, UK agriculture was with few exceptions uncompetitive in world markets. When compounded with animal health problems reflected in bans on exports, as well as dramatic falls in incomes and profitability, the industry had a bleak short-term future. The annual monetary support transferred to producers from taxpayers and consumers more generally is usually described officially as the Producer Support Estimate or Producer Subsidiary Equivalent, comprising direct payments (Budgetary Payments), and the indirect or invisible support (Market Price Support) leading to the elevated prices paid by EU consumers.

Despite a stream of reforms and external pressures to reduce Market Price Support measures, agriculture in Scotland was heavily supported. Reference to the keynote publication *Economic Report on Scottish Agriculture 2001 Edition* from the Scottish Executive Environment and Rural Affairs Department (SEERAD) reveals that CAP Budgetary Payments in 1999/2000 were estimated to have been about £473m, and Market Price support in the region of £293m. The bulk of the Producer Support Estimate in 1999 (£766m) was directed towards five sectors: such as beef (£115m) and wheat (£32m). Extensive grant and subsidy schemes have operated in recent times (Table 2).

Cattle
Beef Special Premium Scheme, including Top Up, Extensification Premium, and Agrimonetary payments
Suckler Cow Premium Scheme, including Top Up Re-Distribution, Agrimonetary, and Extensification payments
Extensification Payment Scheme
Hill Livestock Compensatory Allowance
Calf Processing Scheme
Veal Calf Slaughter Premium Scheme
Over Thirty Months Scheme
Sheep
Sheep Annual Premium Scheme, including Least Favoured Areas Support and Agrimonetary payments
Hill Livestock Compensatory Allowances
Milk
Dairy Agrimonetary Compensation
Arable Area Payments Scheme
Cereals
Oilseeds
Protein Crops
Linseed
Grain Legume Scheme
Other Subsidies
Arable Area Payment Set Aside
Chernobyl Compensation Payments
Environmentally Sensitive Areas Payments
Countryside Premium Scheme, including aspects of the Habitats and Heather Moorland Schemes, as well as the organic aid scheme
Selective Cull Compensation
Annual Diseases Compensation
Compensation for Milk Quota Cuts and Quota
Objective 1 (H1AP)
Objective 5B
Agriculture Business Development Scheme
Farm Business Development Scheme
Farm and Conservation Grant Scheme (EC)
Agriculture Improvement Scheme (EC)
Crofting Buildings Grants and Loans Scheme
Crofting Counties Agricultural Grants Scheme
FEOGA Processing and Marketing Scheme

Table 2 Agricultural grants and subsidies 1998-2000

The gross output at basic prices in 2000 was estimated to have been £1869m, the gross input (total intermediate consumption) £1043m, the gross value added (gross product) £826m, and the net value added at basic price £545m. The measure Total Income From Farming (TIFF) which estimates business profits plus income to workers with an entrepreneurial interest, decreased from £261m in 1999, to £230m in 2000.

The numbers employed in Scottish agriculture (working occupiers including working spouses of occupier, full-time employees, part-time employees, and casual and seasonal employees) was 26 808. Analysis of the data reveals that out of a total land area of 7 708 010ha, agricultural land accounted for 6 074 789ha. The areas devoted to various crops and other uses, with few exceptions, did not change substantially from 1999. Sole-right and common rough grazing (3 974 420ha) and mowing and grazing grass, under or over five years (1 187 792ha) dominated land use. Winter and spring barley (316 823ha), woodland (200 227ha), wheat (108 859ha), set-aside (77 875ha), 'other' land (*i.e.* farm roads, yards, buildings, excluding glasshouses, ponds and derelict areas, 60 826ha), rape for oilseed (36 410ha), potatoes (29 791ha), crops for stockfeeding (turnips, swedes, kale, beet, *etc.*; 24 245ha), oats (22 562ha), fallow (11 220ha); vegetables (excluding potatoes; 10 776ha); linseed (2 543ha); fruit (2 021ha); peas for combining (1 640ha); triticale (1 544ha); beans for combining (1 138ha); bulbs, other flowers and nursery stock (864ha); and all other crops (3 215ha) collectively accounted for Scottish agricultural land use, as estimated for June 2000.

In order to analyse UK agriculture generally, and the comparative performance of agriculture in Scotland specifically, reference has to be made to several publications produced by the Department for Environment, Food and Rural Affairs (DEFRA, derived mainly from the Ministry of Agriculture, Fisheries and Food); the Scottish Executive Environment and Rural Affairs Department (SEERAD, formerly Scottish Executive Rural Affairs Department, Scottish Office Agriculture, Environment and Fisheries Department, Scottish Office Agriculture and Fisheries Department, Department of Agriculture and Fisheries for Scotland), the Department of Agriculture and Rural Development (Northern Ireland), (formerly the Department of Agriculture for Northern Ireland), and the National Assembly for Wales Agriculture Department (formerly Welsh Office Agriculture Department). The principle document is *Agriculture in the United Kingdom*. Other valuable documents include *Agricultural Census Statistics in the UK,* the *Agricultural Atlas,* the *June Census Analyses, Historical Agricultural Data, Farm Incomes in the United Kingdom 1999/00, Economic Report on Scottish Agriculture, Agriculture Facts and Figures Scotland 2001* (http://www.scotland.gov.uk), *Agriculture in Scotland, Farm Incomes in Scotland 1999/00, Agricultural Census, Agricultural Sample Census Sheets by Geographical Area*, and *Abstract of Agricultural Statistics* (see http://www.defra.gov.uk and http://www.scotland.gov.uk).

Provisional data in the calendar year 2000 edition, at a stage prior to the 2001 Foot and Mouth Disease (FMD) outbreak, indicated that the contribution of agriculture to the total UK economy gross value added (GVA, at basic prices less intermediate consumption of goods and services, *e.g.* feed, seeds, agrochemicals) declined further from 0.9% in 1999 to 0.8% in 2000, contrasting with a figure of 1.5% in 1996. At current prices, the GVA in 2000 equated to £6 646m. About 2% of the UK work force was employed in agriculture (557 000), illustrating the rapid decline of around 100 000 in rural employment over a decade, a decline that has not received media attention in the same way as redundancies in the manufacturing and mining industries. Nonetheless, these figures do not reveal that there is a large tranche of the UK workforce involved directly with agriculture, namely parts of the public sector such as government departments, their agencies and institutes, Research Councils and their institutes, higher-education and further-education bodies, and various groups associated with the EU; the food-processing, distribution and retail sectors; and the industrial feedstock industry. Importation of food, feed, and drink amounted to £17.004bn compared with the revised figure of £17.385bn in 1999, possibly reflecting the decline in commodity prices, and amounted to 7.6% of total UK imports. Imports of alcoholic drinks from the EU amounted to £1.619bn, and £0.848bn from the rest of the world. Exports of food, feed, and drink declined from a revised figure of £8.948bn in 1999 to £8.720bn in 2000, of which exports of alcoholic drinks to the EU contributed £1.262bn, and £1.707bn to the rest of the world. These agriculturally related exports represented 4.6% of total UK exports, down from 5.4% in 1999, 5.6% in 1998, and 6.3% in the period 1989-1991. The UK was 66.5% self-sufficient in all food types in 2000, contrasting with an average of 72.8% in the period 1989-1991. For indigenous-type food, the UK was 79% self-sufficient, declining slightly from the revised

figure of 80.5% in 1999. Household final consumption expenditure on household food and alcoholic drinks at current prices was once again up from a significantly upgraded revision of £87.245bn in 1999 to £88.6bn in 2000. Some £33.2bn (over 37%) of that figure was attributable to alcoholic drinks! Household food and alcoholic drinks accounted for only 15% of total household final consumption expenditure, continuing a declining trend over several years and reflecting the remarkable efficiency of agriculture. In the period 1989-1991, the figure was 18.8%. Domestic food expenditure alone was only 9.4% of total household expenditure compared with 5.6% for alcoholic drinks.

In June 2000, the total area of UK agricultural land plus common rough grazing was 18 306 000 hectares, of which 4 665 000 hectares were devoted to crops, and 37 000 hectares were left fallow. In the period 1989-1991, an average of 18 887 000 hectares was committed to agriculture, 5 037 000 hectares of which were harvested for crops. More detailed analysis of the cropping data reveals that the area devoted to cereals rose from 3 141 000 hectares in 1999 to 3 348 000 hectares in 2000. This was mainly attributable to an increase in the wheat area from 1 847 000 hectares in 1999 to 2 086 000 hectares in 2000. Slight increases were noted in the area devoted to oats (92 000 hectares to 109 000 hectares), and triticale (13 000 hectares to 16 000 hectares), but the barley area declined from 1 179 000 hectares to 1 128 000 hectares and the rye and mixed corn area remained at 10 000 hectares. The potato area declined to 166 000 hectares, similar to that of 1997. Other arable crops, excluding potatoes, took up less land than in 1999, declining from 1 211 000 hectares to 979 000 hectares. Pronounced declines were noted in the area of oilseed rape (417 000 to 332 000 hectares), linseed (209 000 to 71 000 hectares) and sugar beet not for stockfeeding (183 000 to 173 000). Peas for harvesting dry and field beans increased from 202 000 to 208 000 hectares, and the area for other crops reduced from 197 000 to 192 000 hectares. Reflecting tough market conditions, the area of horticultural land continued its long-term decline, to reach just 172 000 hectares. Of this area, the bulk (119 000 hectares) was given over to vegetables grown in the open; commercial and non-commercial orchards accounted for 28 000 hectares, soft fruit (including strawberries, raspberries, blackcurrants and wine grapes) 10 000 hectares, ornamentals (hardy nursery stock, bulbs and flowers) 14 000 hectares, and glasshouse crops 2 000 hectares.

Without taking account of direct subsidy payments, the average price of agricultural products fell by 2.4% between 1999 and 2000, and inputs rose by 3%. The starkness of the situation is illustrated by the fact that agricultural product prices fell by 26% over the last five years.

In terms of production, the area of land devoted to cereals increased by over 6%, and with a slight improvement in yield, the volume of harvested production reached 23.98 mmt in 2000, an 8.3% increase over the 1999 figure. The value of production, however, only increased marginally to £2.35bn. Provisional cereal yields in 2000 were 8.01 tonnes per hectare for wheat, 5.76 for barley, and 5.87 for oats. Wheat production increased sharply from a revised figure of 14.87 mmt in 1999 to 16.7 mmt in 2000, valued at £1.545bn. Barley, one of SCRI's mandate crops, recorded a small decline in production, down from a revised figure of 6.58 mmt in 1999 to 6.49 mmt in 2000 and the value declined from £735m to £693m. Oat production increased over the same period from a revised 540 mmt to 640 mmt, and the value increased from £58m to £65m.

Potato production in the UK in 2000 was affected both by planting decisions arising from oversupply and poor return in the previous year, and by bad weather in the autumn of 2000. The volume of harvested production of this key SCRI mandate crop in 2000 was 6.611 mmt, 290 000 tonnes of which were attributable to the early crop, and the remainder to maincrop. A value of production of £501m, represented a major fall from the previous year. Processed potato products in the UK were valued at around £2.16bn. Potato imports amounted to 1 035 000 tonnes, the bulk in the form of processed potato product from the EU (727 000 tonnes raw equivalent), and exports amounted to just 369 000 tonnes, the bulk of which (173 000 tonnes) was as raw material. Total domestic use of potatoes in the UK (7.447 mmt) was divided into 5.724 mmt for human consumption, 452 000 tonnes for 'seed' for home crops, including seed imports of around 162 000 tonnes, and retained stockfeed, 'chats', and waste of 1.272 mmt. Oilseed rape production suffered a steep decline from a revised 1.737 mmt in 1999 to 1.129 mmt in 2000, valued at just £249m, less than the UK crop average of £289m in the period 1989-1991. The 32% drop in value from 1999 reflected the 25% decline in planting area, and lowered yields. Subsidy payments for the crop declined by 36%, even though subsidy and compensation payments were made to cover an area of

the crop inadvertently planted with unauthorised GM oilseed rape. Sugar beet production in 2000 was provisionally assessed at 9.335 mmt, adjusted at standard 16% sugar content, and was valued at £253m. Refined sugar production for the UK was 1.37 mmt, an 11% reduction from 1999; imports amounted to 148 000 tonnes from the EU, and 1 097 000 tonnes from the rest of the world. Total exports were around 700 000 tonnes. A decline was noted in linseed production during a year of lowered yields from 302 000 tonnes in 1999 to 43 000 tonnes (40 000 tonnes on a standard 9% moisture content) in 2000. The value of production fell by 74% to just £34m, with subsidies amounting to £30m. In the previous year, linseed was seen as a subsidy-dependent, financially safer, planting option than crops such as oilseed rape.

Horticulture, an industry dominated by financially stretched, small-scale producers without ready access to subsidies and with little market muscle, overall saw a small increase in the value of production from £956m in 1999 to £974m in 2000, despite a decline in cultivation area from 149 100 hectares to 144 500 hectares. Horticultural crops grown in the open in 2000 on an estimated 143 300 hectares were valued at £650m, and £324m for protected crops grown on an estimated 1 200 hectares. The highest value horticultural crops were mushrooms (£168m), followed by lettuces (£103m), carrots (£86m), tomatoes (£75m), cabbages (£57m), peas (£55m), and cauliflowers (£43m). Orchard (top) fruit production on an area of 25 300 hectares was valued at £101m, and soft fruit at £139m on an area of 8 900 hectares, mainly attributable to two crops of importance to SCRI and MRS Ltd, strawberries (£81m) and raspberries (£42m). Ornamental production on an area of 20 000 hectares was valued at £714m, a little down from the revalorised figure of £719m for 1999, representing £398m for hardy ornamental stock, £274m for ornamental protected crops, and £42m for flowers and bulbs, including forced flower bulbs, in the open.

Purchased livestock feedingstuffs, valued at £2.167bn, declined from 20.446 mmt in 1999 to 19.827 mmt in 2000, affected by reductions in milk and pigmeat production. Purchased seeds totalled 956 400 tonnes: potatoes (471 200 tonnes including farm-saved seed), certified cereal seed (413 400 tonnes), root and fodder crops (45 000 tonnes), vegetables, bulbs, seeds for hardy nursery stock, flowers, sugar beet and oilseed rape (15 600 tonnes), and grass and clover (11 300 tonnes). The total cost of all purchased seeds at £296m was an 11% decline from the position in both 1998 and 1999. A healthy seed industry that can offer a flow of improved cultivars is of prime importance to the revitalisation of the agriculture, horticulture and forestry industries; the poor financial returns bode ill for commercial plant breeding in the UK. The diminution in public-sector plant-breeding research also bodes ill for the future provision of plant breeders, and advanced germplasm, and access to modern technology and IP.

Total Income From Farming (TIFF) is a valuable if somewhat complex measure. It refers to those with a direct entrepreneurial interest in the agricultural industry (*e.g.* farmers, growers, partners, directors, sponsors and most other family workers). Official reports stress that TIFF is acutely sensitive to relatively small changes in the values of outputs and inputs, as well as the changes in statistical methodology and sourcing of data. It is derived by deducting interest, rent and paid labour costs from Net Value Added at factor cost, the best measure of value added by the agricultural industry because it includes all subsidies. According to *Agriculture in the United Kingdom,* TIFF was forecast to fall by 25% compared with its 1999 level, to £1 882m. In real terms, the fall was 27%, equivalent to a £696m attrition, prior to any judgements yet to come for 2001 from the impacts of the FMD episode afflicting UK agriculture. Productivity measures, based on volume indices with 1995=100, show that final output (that output leaving the industry *i.e.* gross output less transactions within the agricultural industry) has remained relatively static from 1989 onwards, varying between 97.2 to 100.1, On the other hand, labour productivity as given by the index of Net Value Added per annual work unit of all labour, increased from 117.4m in 1999 to 123 in 2000, as annual work units (*i.e.* the number of average full-time persons in agriculture) fell. There was a 2.6% rise in total factor productivity as given by the final output per unit of all inputs, including fixed capital and labour.

Across the Member States of the EU, there was great variation in the income derived from agricultural activity. Changes in income as measured by Eurostat's Indicator A (see Eurostat Statistics*: Statistics in Focus,* December 2000), which is based on Net Value Added per whole-time person equivalent, showed, provisionally, rises in Denmark (24.1%), Finland (22%), Belgium (12.2%), Germany (6.9%), the Republic of Ireland (6.5%), Sweden (4.9%), Spain

(4.6%), The Netherlands (3.7%), France (1.3%), and Luxemburg (0.4%). No rise was indicated for Greece but declines were noted for Italy (-4.3%) Austria (-4.8%), Portugal (-7.5%) and alarmingly most of all, the UK (-10.8%). Reasons for the poor UK performance may include the strength of sterling, weak commodity prices, poor weather, regulatory and bureaucratic impositions, lower subsidy regimes, lack of innovation, lack of market muscle relative to the supermarkets and processors, and changed political and public attitudes to, and perceptions of, agriculture.

Within the UK, the weakening economic, political, and social rôle of agriculture varied between the constituent parts. Thus, the Gross Value Added at basic prices in 2000 was £5.038bn in England, £824m in Scotland, £320m in Wales, and £464m in Northern Ireland. The TIFF estimates reflected the impacts of the different components of farming: England £1.552bn, Scotland £228m, Wales a remarkable and worrying £-2m, and Northern Ireland £98m. Estimates of the share of agriculture of total regional Gross Value Added at basic prices, revealed marked declines over time and that it was lowest in England (0.7%), followed by Wales (1%), Scotland (1.2%), and then Northern Ireland (2.6%). A slightly different pattern existed for the share of total regional employment by agriculture: England (1.6%), Scotland (3%), Wales (4%), and Northern Ireland (7.9%). This measure may well indicate future economic vulnerability to any continuing downturn in agriculture

The total UK public expenditure in agriculture was forecast to rise by £21m from £3.161bn in 1999-2000 to £3.182bn in 2000-2001. Of this, spending under the CAP regime was forecast to increase from £2.816bn in 1999-2000 to £2.869bn in 2000-2001, of which 39% was apportioned to the Arable Area Payments Scheme, 4% to sugar and 1% to cereals. Beef, veal and sheepmeat accounted for 45% of the spend. Unlike these sectors, the pig industry was subject to heavy regulation with little support. In addition to classical swine fever, the industry suffered from outbreaks of two linked diseases: post-weaning multi-systemic wasting syndrome, and porcine dermatitis nephropathy syndrome, both accounting for losses of about £21m a year.

Environmental accounting as a measure of the environmental impact of human activity is a rapidly developing field, with guidance issued by both the EU and sections of the UN on establishing assessment frameworks. Given the complexity of human activity and the nature of judgements of environmental impacts, such accounting methodology is still developing, but providing new insights, especially as the multipartite concept of sustainability gains ground. The environmental accounts for UK agriculture presented in *Agriculture in the United Kingdom* focused on the use of finite and renewable resources, the levels of damaging emissions to waterways and to the atmosphere, general indicators of phenotypic biodiversity on farmland, and details of public expenditure on environment schemes. A number of pesticides will have new residue levels which apply from 1 July 2001 through implementation of EC Directive 2000/42/EC (see www.pesticides.gov.uk). It was recognised that the finite resources consumed by the agricultural industry included fuels (petroleum, coal, gas), the generation and the direct and indirect consumption of electricity, metals used to manufacture machinery, and the synthesis of agrochemicals. Judicious management of soil and water is essential for sustainability of agriculture. In 1999, the energy used by agriculture represented less than 1% of overall UK energy consumption. It is clear that the Climate Change Levy and the prospects of agrochemical taxes (as well as existing downward pressure on input costs) will lead to increased energy efficiency, and lower emissions, inevitably by widespread cessation of hitherto profitable agricultural activity. Of relevant renewable energy sources, the combination of agricultural biomass, including straw, livestock wastes, and specific crops, particularly those used in short-rotation coppices, attracted attention. Agricultural biofuels were projected to contribute substantially to the policy of the generation of 10% of UK electricity from renewable resources by 2010. Wind farms on suitable agricultural land could offer another potential source of 'green' energy.

Quantification of agricultural emissions is difficult, given the diversity of sources (*e.g.* agrochemical leaching into groundwaters, atmospheric emissions from plant and animal wastes *etc.*). Nonetheless, integrated crop management (ICM) and integrated farm management (IFM) practices giving an holistic farm management system which is designed to balance normal measures of efficiency with minimising environmental impact, are being promoted by Government, especially in conjunction with the Linking Environment and Farming (LEAF) initiative (www.leafuk.org). Related to this is the European Initiative for Sustainable Development in Agriculture,

and *A Common Codex for Integrated Farming* detailing a set of common principles and practices to achieve sustainability. In addition, there are several agri-environment payment schemes to encourage the protection and conservation of the landscape and foster biodiversity (see section on Agriculture and Food). Agriculture's impact on biodiversity must not be regarded simplistically, however. Specialist farmland bird species, in particular, have declined in numbers over the past three decades, presumably as a result of changed agronomic practices, a reduction in the numbers of small-scale mixed farms, loss of habitats, natural population fluctuations *etc.* The rôle of weed species can be regarded positively and negatively in terms of biodiversity, food supplies for heterotrophs, soil structure, marketability of the produce, and visual appearance of the countryside.

Other important reports and documents relevant to agriculture produced by Government included *Environmental Regulations and Farmers* from the Better Regulation Task Force; *A Forward Strategy for Scottish Agriculture and Rural Scotland: A New Approach* from the Scottish Executive; the Rural White Paper *Our Countryside: the future, a fair deal for rural England*; the *BSE Inquiry Report*, and the Competition Commission's report on supermarkets. Helpful websites include www.defra.gov.uk, www.scotland.gov.uk, www.wales.co.uk, www.dardni.gov.uk, and www.foodstandards.gov.uk.

Plant Biotechnology

In previous editions of the *Report*, besides describing the range and potential of GM crops, the concerns surrounding GM crops and their regulation have been presented in considerable detail, although plant and agricultural biotechnology encompasses huge and dynamic areas of R&D and commercial activity beyond the generation and release of transgenic plants and animals. Nonetheless, in 2000, over 44 million hectares of GM crops were grown commercially in 14 countries. By the end of 2000, over 11 500 field trials of transgenic crops had taken place in 39 countries, including eight LDCs. The USA accounted for over 60% of the GM crop planted area.

Agricultural biotechnology encompasses modern crop and livestock breeding and pathology, aspects of agronomy, veterinary services, propagation, remediation of agricultural wastes and slurries, restitution of agricultural land, storage and processing of agricultural products, diagnostics, nutraceuticals, functional foods, alcoholic drinks and beverages, industrial feedstocks (non-food, see *SCRI Annual Report 1999/2000* pp.46-47), horticultural and aspects of forestry biotechnology, other areas of biotechnology, and service providers. The production of pharmaceutical and related compounds by plants is a fast expanding area of great interest. Series of mergers and acquisitions in recent times have given rise to powerful multinational groups and interlinked groupings, although it is noteworthy at this juncture that many largely national supermarket and retailer chains are substantially larger than some of the more prominent multinational agbiotech companies, and effectively shape their futures. Nearly all the agbiotech companies operate using molecular-genetics-based technologies in common with other biotechnology sectors *e.g.* healthcare, such that there are overlapping IP interests. All are noted for their rapid uptake of new technologies and collaborating with universities and research institutes. It is the advent of the new bioindustries which employ sophisticated scientific, technological, and engineering concepts and processes that are giving rise to quantum leaps in the precision, accuracy, sustainability, and cost-effectiveness of many areas of human endeavour, especially agriculture, environmental protection, and healthcare. All these sectors have yet to reach their zenith. All have been damaged to varying extent by individuals and organisations opposed to various aspects of biotechnology and globalisation, as well as by media accounts of regulatory failures on the control of livestock diseases that adversely impacted on consumers and the taxpayer. Some individuals and organisations have questioned the need for agricultural biotechnology, ignoring global trends in population growth and increasing consumer demands, and the need to mitigate the environmental impacts of food production on a steadily decreasing but precious global area of cultivated and cultivatable land. By about 2020, given continued freedom from catastrophic or cataclysmic events (*e.g.* war, diseases, asteroid strike *etc.*) and modest population growth, food production capacity will revert to being a political imperative. This position contrasts with the present rapid decline in importance and the negative perception of agriculture nationally and internationally.

An area of priority must be plant breeding which has an underpinning rôle in providing improved types of plant to resist the depredations of pests, diseases and adverse environments, to enhance yields, to meet ever-increasing customer demands, to provide livestock feed, and industrial non-food supplies (feedstocks). It is in

essence, even using the most advanced technologies, time-consuming, spanning decades. It requires strategic planning, access to parental material, crossing programmes, selection stages, and finally statutory testing and marketing. For species with long juvenile (ripeness-to-flower) periods, such as many forestry hardwood and softwood species, long-term planning is essential as of now.

Conventional and biotechnologically based plant breeding rely on access to parental material *i.e.* biological diversity. The Convention on Biological Diversity (CBD) specifically called for benefits flowing from the use of biological diversity to be shared with the country of origin of that material. As pointed out by R. Raymond and C. Fowler in *Sharing the non-monetary benefits of agricultural biodiversity*, Issues in Genetic Resources No. 5, 2001 published by the International Plant Genetic Resources Institute, the focus on monetary benefits has led to a downplaying or even disregard for significant non-monetary benefits, and to date there is no agreed definition of 'country of origin'. Non-monetary benefits were seen as access to a wide range of germplasm, improved material and genes, technology, training, information, joint projects, and sharing benefits and the burden of costs. Bilateral agreements between Ecuador and the USA, and networks such as the International Network for Genetic Evaluation of Rice, provide functional examples generating worthwhile non-monetary benefits. To identify the origin and value of individual and sets of genes in the complex genome of any commercial crop species would be a major undertaking, and would seriously impede the exchange of germplasm and the development of new cultivars. Institutions such as SCRI have rôles in maintaining, accessing and releasing germplasm. In 2001, a new international treaty on the use of plant genes was agreed by 116 countries in Rome after seven years of debate; Japan and the USA abstained on the basis that IP rights should accord with WTO rules.

Plants are special. They share characteristics (Table 3) that are fascinating and highly complex. Accordingly, agbiotech applications with respect to plants require specialised facilities and expertise.

Agbiotech is an integral part of the so-called 'knowledge economy'. It is dependent on integrating the skills and concepts of genomics, proteomics, metabolomics, analytical chemistry, information technology, agriculture, horticulture, forestry, and ecology. By deploying an array of fast-developing, generic technologies, it is able to address demands for food and non-food products, for both niche or mainstream markets, bringing in its wake detailed

- Eukaryotic organisms based on a cellular construction. More advanced forms show the phenomenon of alternation of generations.
- Autotrophic mode of nutrition arising from the possession of intracellular chloroplasts that are responsible for photosynthesis.
- Complex carbon metabolism giving rise to special type of squalene cyclisation and production of elaborate cell walls. Considerable cellular and metabolic heterogeneity. Living cells exhibit turgor.
- Lack of cell and organism motility: cells often joined by cytoplasmic bridges, the plasmodesmata.
- Open-ended development of modular growth habit by virtue of retaining apical and lateral meristems.
- Growth patterns subject to interacting influences of the environment with specialised detection systems and biological clocks. Light (spectral composition, intensity, temporal distribution/photoperiod), temperature (day/night and root/shoot differential requirements as well as various chilling and high-temperature requirements), gaseous composition of the atmosphere, magnetic fields, gravity, wind-speed, humidity, rainfall, edaphic (soil) factors, allelopathic and allelomediatory effects, pests, diseases, and grazing all affect growth patterns giving rise to considerable design plasticity, and modification of chemical composition.
- Unique positional signalling systems: no differentiated nervous system.
- Single parenchymatous cells able to generate whole plants (totipotency). The pattern of differentiation can be regulated by defined growth media.
- Reproductive strategies can be sexual and/or asexual, and may involve a juvenile or ripeness-to-flower period. Dormant dispersal units or structures may be produced to distribute progeny in time and space.
- Complex mass transport pathways: the xylem is dead when functional for transport of water and mineral salts: the living phloem transports the products of photosynthesis and nitrogen metabolism. Transport of solutes and growth factors may be apoplastic or symplastic.
- Cellular and physiological differentiation associated with vacuolation and susceptibility to senescence processes. No immune system.
- May have large genome sizes (e.g. *Lilium davidii,* DNA content of 43.2×10^{-12}g, per genome, and $2\chi=24$, compared with 6×10^{-12}g, $2\chi=46$, for humans. One picogram (10^{-12}g) is equivalent to 0.965×10^{9} base pairs).

Table 3 The general characteristics of plants.

product specifications, properly monitored quality-assurance schemes, improved habitats, lowered inputs, advanced waste processing, and IP protection offering competitive advantage. Current agricultural practice (both conventional and organic) will come under greater scrutiny as its outputs, including those affecting non-monetary goods, will not be able to compete with agbiotech production in the medium-to-long term, regardless of the efforts of certain organisations, governments, or groups of nations to retard the progress of technology. In broad terms, the six major factors suppressing the development of agricultural biotechnology at present are the weakened economic standing of agriculture and its commodities; a general downturn in technologically based investments; a much-reduced emphasis on agricultural and plant sciences in universities; food scares; the vulnerability to anti-technology pressure groups which focus on individual scientists, their organisations, companies, politicians, local and national governments; a risk-avoidance culture; and diminished public-sector investments in the sector. Perhaps the public sector should take the lead in introducing GM crops. Few investors currently consider the vast sizes of the commodity and food markets, the opportunities for wealth creation and improvement in the quality of life, and the societal needs for the products of agbiotechnology. As a consequence of these points, the market has not favoured merged agricultural, pharmaceutical, and environmental companies.

Closely associated with a portion of the agricultural biotechnology industry is the agrochemical industry. Collectively, the global turnover of the sector was *circa* $40bn, and it sustained a strong R&D base. Focused on by the naïve as an unnecessary imposition on agriculture and horticulture, in reality, the use of agrochemicals was instrumental together with improved cultivars and better agricultural engineering in the agricultural revolution that enabled global food production to match the growth in the human population. As the industry developed during the 1980s and 1990s, new products with lowered environmental impacts were released as it became subject to legislative and other controls. In parallel with this, a series of mergers and acquisitions took place leading to stronger vertical and horizontal integration. By 2001, there were only seven international R&D-based agrochemical companies, three of whom were headquartered in the USA (Dow Agrosciences, Dupont, and Monsanto), and the remainder in Europe (Aventis, BASF, Bayer, and Syngenta). Further mergers were mooted. Only Syngenta – the largest of the companies in 2000 - sustains a substantial research centre in the UK, contrasting starkly with the situation three decades ago, when the UK was a major international force in the agrochemical industry, reinforced by a strong public- and private-sector R&D base. As plant biotechnology, newer forms of synthesising and analysing bioactive compounds, and bioinformatics (computational genetics) developed, it was expected that the UK with its pioneering contributions in those areas as well as in agrochemicals would reach a dominant position, extending beyond agrochemicals *per se* into the generation of improved cultivars and wholly novel plants, industrial crops and feedstocks, bioremediation, and novel products for healthcare purposes. This was not to be. Fortunately, the position is recoverable with suitable investments in the public and private sectors, new attitudes and understanding, and crucially, political support.

In 2000, biotechnology companies *per se* generated revenues of nearly $50bn and sales were in the region of $15bn, mainly in the pharmaceutical, bio-medical, agriculture, food technology, environment, energy, chemical, and service sectors. By 2002, it is anticipated that the agbiotech company sector will have revenues of around $2.5bn. As distinct from revenues, the value of the herbicide-tolerant and insect-resistant GM crop market was estimated at $2.6bn, and was expected to reach $6bn in 2005. Ancillary applications of the technology were beginning to be introduced into the treatment of farm and urban wastes, the treatment (mainly phytoremediation) of polluted waters and land, generation of biomass plants to be used as an energy source, and diagnostics and biosensors. Likewise, substantial growth took place in bioinformatics to reach a market estimation of $250m in 2000, and is expected to reach £3bn by 2005. Analytical instrumentation for biotechnology applications was also a substantial market.

In the UK, the issue of GM technology was given prominence by the ongoing Farm-Scale Evaluations (FSEs) of GM herbicide-tolerant (GMHT) crops. These field-level investigations were undertaken at the behest of government and an industry body - the Supply Chain Initiative on Modified Agricultural Crops, and were based on spring and winter varieties of oilseed rape, fodder beet, sugar beet, and forage maize. Orchestrated hostility, campaigns led by some sections of the broadcast and publishing media, and

protests by individuals led to an analysis of the trials by the Agriculture and Environment Biotechnology Commission (see *Crops on Trial. A Report by the AEBC*, 2001) The Commission made 10 recommendations as follows. (i) The programme of FSEs should be completed subject to certain conditions *e.g.* witholding permission for commercial plantings meantime, operating with adequate separation distances from organic crops, and communicating with the public, especially local stakeholders. (ii) The Government should use clear and precise language in its press releases and publications. (iii) Policies should be developed on how to use the results of the FSEs in future decision-making. (iv) An independent review should be commissioned of all information that will complement the results from the FSEs *e.g.* from the Advisory Committee on Pesticides, the Advisory Committee on Releases to the Environment *etc.* (v) Ensure that the level of publicly funded research is such as to ensure an objective independent assessment of the potential impacts of both current practices and new technologies on agriculture and the wider environment. (vi) There should be commitment to an open and inclusive process of decision-making around whether the GM crops being grown in the FSEs should be commercialised, within a framework which extends to broader questions. (vii) Early attention should be given to the framework for post-commercialisation monitoring. Without prejudging the issue of whether GM crops will be approved for commercialisation in the UK, the Government should be prepared to publish and consult widely on its proposals for the post-commercialisation monitoring which would be needed, and for the action to be taken if adverse effects were discovered. (viii) There should be improvement of the understanding of the basis of public views by drawing on the work of social scientists in this field. (ix) Methods should be improved for dealing with risk and uncertainty in relation to the use of biotechnology in agriculture, by ensuring that all the regulatory processes incorporate the principles developed by Lord Phillips in his review on BSE and by Lord May when he was Chief Scientific Adviser to the Government, and that the regulators are publicly explicit about where areas of uncertainty occur in their deliberations and how they have tried to take them into account; and by developing and disseminating examples of best practice. (x) Specific consideration of the future of GM crops should be included in the discussions about the future of agriculture in the UK. The various strategic reviews of farming and food being undertaken by the UK administrations should explicitly address how to promote the co-existence of different forms of farming in the UK. There should then be a wider public debate involving a series of regional discussion meetings to consider what rôle GM crops might have in UK agriculture in the future. The AEBC stated its willingness to contribute to this process.

Missing from the recommendations was an analysis of the economic and social implications in the UK of not introducing commercial GM crops, of delaying the introduction of proven commercial GM crops, and costing the regulatory and review processes. No overt value judgements were offered on the validity or naïvety of the diverse arguments and concerns expressed to the Commission, but the evolution of consensus views was promoted.

Expansion of the global area of GM crops, penetration of the products derived from GM crops into global markets, tourism, consequential analysis of deliberate releases and inadvertant escapes, predictive studies on environmental impacts, development of beneficial gene banking and regenics, new GM crop types of obvious benefit to consumers, and eventual removal of the EU moratorium on the registration of GM crops may offer a boost to the European agbiotech industry, and will hasten decisions on the future of this branch of agriculture, horticulture, and forestry in the UK. The report of the New Zealand Royal Commission on Genetic Modification was an influential landmark analysis which favoured rational thinking for the benefit of society and industry. The tide is surely turning to a more balanced open-minded position, in line with confidence growing in the advisory and regulatory mechanisms.

Concluding comment

As in previous years, 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 Scottish, UK, and international plant and environmental science, launching major scientific initiatives, and we participate extensively in higher educational activities. I thank SEERAD and all our sponsors, public and private, and congratulate and offer my gratitude to my colleagues for their continuing loyalty, forbearance, and outstanding efforts. I thank especially our Chairman, Mr James E Godfrey, for his tremendous support, expertise, and dedication, and the rest of the Governing Body for their commitment and contribution to our development.