Report of the Director

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Global perspectives of factors influencing agricultural, biological, and environmental sciences, and their associated industries : 2001-2002*

Preamble

9-11 The world became politically and economically unstable in 2001. At 08.48h local time on September 11 2001, American Airlines Flight 11 from Logan International Airport in Boston, USA, flew into the north tower of the twin-towered World Trade Center (WTC) in New York City, followed at 09.03h by United Airlines Flight 175 also from Logan International Airport, crashing into the south tower. From images captured on film and magnetic media, the world witnessed the attack on the WTC. At 09.40h, American Airlines Flight 77 from Washington Dulles International Airport, crashed into the Pentagon building, the military nerve centre. At 10.10h, United Airlines Flight 93 from Newark International Airport crashed near Shanksville, Pennsylvania, apparently aiming at the White House or the Capitol Hill building in Washington. The following day, Osama bin Laden was identified by US officials as the chief suspect behind these acts of terrorism, by which time the North Atlantic Treaty Organisation (NATO) invoked Articles of its founding treaty, declaring that the actions constituted an attack against all NATO members. Australia invoked the ANZUS Pact, placing sections of its armed forces on a higher state of readiness to provide assistance to the USA. The four Boeing airliners were hijacked by 19 young Arab Muslim terrorists linked to the al-Qaeda terrorist network led by the Saudi-born Osama bin Laden, and linked in turn to the ruling Taliban in Afghanistan. Over 3000 people were murdered.

Democratic Modernity Arising from the "9-11" event were a series of precautionary actions, social developments, and a growing political and economic fragility. On October 7, military strikes led by the USA were launched against targets in Afghanistan. Hitherto-open but vulnerable democratic societies, politically if not intrinsically favourable to multiculturalism, questioned the accommodation of those violently opposed to secular modernity. Indeed, terrorism of all kinds was more rigorously opposed. Several member countries of the United Nations (UN) have yet to experience societies akin to those that arose from the enlightenment of the 17th and 18th centuries in the Christian world. G. Kerevan, the Scottish journalist, pointed out that the highly pragmatic Scottish Enlightenment associated with David Hume and Adam Smith onwards, rejected tradition, superstition, and subservience to religious authority, in favour of rational scientific thought,

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

learning, law, and property ownership, which in turn would lead to a rational, wholesome, and civilised society capable of economic progress. Sceptical of arbitrary top-down, utopian rules, these philosophers saw benefit in heterodoxy and reasoned that rules should arise from rational human conduct, tempered by social experience and education. Before that, Europe had become more or less unified through the Christian church, aided by the movement throughout the continent of scholars, communicating in Latin. P. Watson in *The Times* (June 13, 2002) singled out the

roles of three scholars: the Bolognese monk Gratian who upgraded ecclesiastical law; Robert Grosseteste (1186-1253) the inventor of the experimental method; and Thomas Aquinas (1225-1274) who made possible objective study of the natural order, and therefore the idea of the secular state. There was evidence of an increase in individuality, starting between AD1050 and AD1200, inside and outside the Church. Global exploration, international commercialisation, and agricultural technology improvements including horses replacing oxen and a change from the two-field to the three-field system, together began to transform Europe from a backwater compared with the Arab world and the Far East, into the condition of modernity, whereas, for example, intellectual innovation and mercantilism in China became suppressed by its bureaucratic feudalism (mandarinate) and in the Arab world by its Mukhabarat. No autocratic country anywhere has participated fully in the scientific, technological, economic, and social openness of the more-developed countries (MDCs). Modern communications, recreational travel, education, a wider diffusion of prosperity, and entertainment will continue to challenge all forms of fundamentalism throughout the world, inevitably creating an endogenous backlash against imposed inflexibility and intolerance. Whether or not the 9-11 event, which led to a declared war on terrorism by US President G. W. Bush, will cause the isolation and collapse of those regimes and organisations actively supporting terrorism, much changed on the global political and economic landscapes. Posterity will judge harshly those purportedly democratic and sophisticated governments that fail to address the consequences of appeasement and cowardice in the face of terrorists and terrorism, including ignoring situations which do not directly affect them on home territory. The twin counterbalancing dangers of racism and xenophobia will also have to be confronted.

Anti-Enlightenment P. Gross and N. Levitt, in *Higher Superstition : the Academic Left and its Quarrels with Science,* refer to an "anti-enlightenment", detecting the shift in contemporary non-science academic culture that now extends to a widespread suspicion of science. See also *The One Culture? A Conversation about Science* edited by J. A. Labinger and H. Collins. This trend in open free democracies has spawned not only a suite of social theories but stimulated radical movements that are hostile to scientific logic and sceptical of Western values and institutions. The UK is a rich source of environmental, animal-rights, anti-globalisation, anti-science, and anti-business activists. Fear of science and its products, pessimism about the future, interest in the occult, but total dependency on science, characterise a dumbing down of many societies, obsessed with entertainment of various kinds and worship of vacuous celebrity. Now, insecurity is added to this mix. Parenthetically, S. Jenkins, the journalist and broadcaster, and others suggested a post-democratic future of sovereignty by the media-savvy articulate, one in which politicians do not lead but simply represent media interests and pressure groups. Onora O'Neil, in the excellent and thoughtful Reith Lectures 2002 (http://www.bbc.co.uk /radio4/reith2002/onora.shtml) *A Question of Trust,* pointed out massive evidence of a pervasive culture of

suspicion that afflicts professionals and people in public life. She analysed (a) the human rights movement, reasoning that the promulgation of rights also requires the counterbalancing acknowledgement of responsibilities; (b) new conceptions of accountability that superimpose overburdening managerial targets on bureaucratic processes; (c) the drive towards 'transparency' processes, insodoing sidelining the fundamental obligation not to deceive; and (d) a public culture that is only credulous of its own standards of communication. The emphasis on a culture of accountability is leading to the destruction rather than support of trust, especially where the media have acquired unaccountable powers that others cannot match. She referred to that well-known botanical metaphor: "Plants don't flourish when we pull them up too often to check how their roots are growing".

Europabarometer, the polling organisation of the European Commission (EC), conducted a poll of 16,000 people in all 15 European Union (EU) member states in 2001, noting that Europeans have become distinctly sceptical about the contributions science and technology make towards European society. More than 45% believed that too much reliance is placed on science and too little on faith, but only 36% disagreed with this view. Over 61% of people believed science and technology changed life too quickly. More than 56% thought genetically modified (GM) food is dangerous, over 94% want the right to choose whether to eat it, and 52% doubt whether scientists can help solve world hunger. The report revealed that youth in the EU is being turned off science, perhaps an unsurprising observation given the rapidly deteriorating career prospects and working environment for scientists.

Engineering Prodigious engineering feats were completed in 2001-2002. These include the Birecik Dam on the Euphrates River in Turkey, the Mohale Dam (a phase of the Lesotho Highland Waters Project) on the Senqunyane River, and the Alqueva Dam on the Guadiana River, Portugal; all three dams will modify agriculture in their regions. Similarly, completion of phase 2 of the Great Man-Made River, an aquaduct for fossil waters linking the interior of Libya to the Tripoli region, and the completion of the Sheikh Zayad canal in Egypt providing irrigation for oases in central Egypt will aid local agricultural activity. Transport-related projects completed included in Incheon International Airport, South Korea; the Guangzhou International Airport, China; the Athens International Airport, Greece; the JFK International Airport, New York City; the Beijing-Shanghai Expressway, China; the Guangdong-Hainan heavy railway, China; the TGV Méditerranée high-speed railway, France; and the German High Speed railway linking Frankfurt and Cologne.

Libraries Traditional library functions of organising and classifying knowledge were advanced by improved networked computing, compact-discs, and bioinformatics, raising new challenges of storage and accessing text, genetic material, sounds, and the cultural heritage contained in museum collections. Important libraries were opened in 2001, including the extensive public library in Beirut, Lebanon, and the new Library of Alexandria in Egypt - the dramatically designed Bibliotheca Alexandrina. Both magazine and book publishing experienced difficulties in 2001, especially the electronic-book (e-book) market, and copyright issues were to the fore.

Scholarly communication through the market place has been subject to critical analysis, with concerns over the transfer of copyright to the publishers, the principle of charging for freely given – often, but not exclusively, publicly funded – material. Electronically published journals have yet to attain high citation impact values – a direct measure of popularity but indirect of quality, yet beloved of scientific assessment systems.

Internet Another form of communication and vehicle for globalisation, the Internet has become a crucially important tool for scientists, expanding both physically and in importance. In some respects, it has lived up to the term 'information superhighway' but in other respects – the equivalents of traffic jams, road closures, rush hours, and road rage – there are still technological improvements to be made. Text, graphics, data bases, music, video, games, and telephone conversations now co-exist on the Internet, utilising domain names (the set of words, numbers, and letters separated by dots used to identify an Internet server or group of servers), routers to select the most efficient route for information packets based on current system demands, and the Transmission Control Protocol/Internet Protocol (TCP/IP) which defines how information and requests generated by other protocols are transmitted and received over the Internet. Fibre-optic cable networks will assist in the transmission of telephone calls and video, and there is likely to be expansion of specific-user networks linking on to the Internet. In such an increasingly highly regulated world, it is remarkable that a system such as the

Internet on which much of modern society and science depends, has no central governing body, no legal jurisdiction, no formal censorship system, and thereby little opportunity for redress, no overarching planning, and is tax-free. It remains vulnerable to the malevolent, can be the source of misinformation or information for terrorist purposes (including bioterrorism), and especially in respect of e-mail, is insecure unless encrypted and comes with a digital signature. It also poses challenges to governments and organisations that wish to control information and apply taxes or charges. Both the British Computer Society and the Association for Computing Machinery oblige their members to operate codes of conduct and ethical behaviour.

Grids Grid computing initiatives are regarded widely as the next phase of Internet computing, linking high-performance computers capable of accessing and processing terabytes of data stored in global databases, to provide a single virtual source of processing capability. There are likely to be different kinds of grids for specific purposes, with interlinked consortia. In the UK, preparations were put in hand to develop the eDiamond grid in early 2003 to create an interactive national digital mammography archive for a group of specialist hospitals in Edinburgh, Glasgow, London, and Oxford.

Higher Education Higher education issues in 2001 included the use of educational and psychological tests for determining competencies of students and thereby the teaching performance of institutions. Very often the tests were standardised and cognitively related. Many of the measures of institutional performance were positively influenced by high levels of student intakes and the availability of short courses. Other issues were the trend towards international linkages, Internet-based learning, funding levels, value-for-money, the vocational utility of coursework, external audits, redress sought by students malcontent with the standards of tuition, and academic freedom. Against the tide of greater freedom of information, Cuba, Egypt, and Russia imposed restrictions on freedom of enquiry. In Cuba, four leaders of the independent library network were arrested because the libraries promoted parties hostile to the non-democratic government. The formerly prestigious Islamic Al-Azhar University in Cairo forbad any publications that "lacked respect" for God. Instructions were issued by the Russian Academy of Sciences requiring the nation's 53,000 researchers to report attempts by scholars to apply for foreign grants, to submit for inspection articles intended for publication outwith Russia, and to report visits by foreigners. Elsewhere, the implications of affirmative action programmes that favour ethnic, cultural, and social groups, rather than academic merit were debated in several countries. There was a growing demand for English as the preferred language of tuition and communication in science- and technology-based subjects, and management studies.

Many in the UK public-sector universities were unaware of the implications of the developing market in higher education arising from the General Agreement on Trade and Services (GATS), and were also unaware of the bilateral agreement between the European Commission and the USA on this topic. There is every likelihood that higher education will form part of the negotiations following the GATS talks scheduled in January 2005 unless prior agreements are put into place. Acquisition of formal accreditation roles and associated recognition, access to public funding, and greater competition for students and staff will undoubtedly open up opportunities for profit-making organisations. Presumably, non-degree-awarding research institutions such as SCRI will have a greater choice of affiliation partners, and new entrants to the market will be in a position to establish research capabilities themselves to compete for research and development (R&D) funding. Debate will ensue on the definition and involvement of 'public good' and reducing or eliminating privileged access to public funding by essentially centrally controlled, formula-funded quasi-nationalised universities and further-education bodies. In 1998, 3% (equivalent to $30 billion) of the total trade in services of the 30 countries of the Organisation for Economic Co-operation and Development (OECD) was the training and education of overseas students. Over 70% of these students were trained in Australia, France, Germany, UK, and the USA, the latter accounting for 28% of the total. When the data are analysed as a proportion of total enrolments, however, overseas students accounted for 17% of the enrolment in Switzerland, 11% in the UK, and only 4% in the USA. In the UK, about 1.1% of GDP is spent on higher education compared with 2.3% in the USA. A further problem for UK universities followed a sweeping ruling in June 2002 in the European Court of Justice that judged legislation in Germany exempting scientific research in universities from Value-Added Tax (VAT), did not comply with European Union (EU) law. It would appear that although grant

income from the higher-education funding councils and the research councils will remain exempt, research-contract funding from government departments, the National Health Services, and charities (which rarely pay overhead costs) will attract VAT.

Economics and Politics

Global Economy Contrasting with 2000, when the global economy grew by 4.7%, its fastest rate for 15 years, economic growth declined in 2001, beginning with a slowdown in the first six months that was more severe than projected. The terrorist attacks on the USA in September undermined confidence throughout the world's financial markets and echoed through the banking sector, international trade, business, insurance, and the political world. Growth in the economies of the 30 MDCs in the OECD was projected to have been around 1%. Deflation threatened several economies, raising prospects of the 'liquidity gap' when real investment is impossible as a progressive reduction takes place in the price level, in line with a collapse in confidence by consumers and investors.

Various factors contributed to the initial slowdown. For most Western European countries, a contribution of tight monetary policies, higher oil prices, weakening pension schemes, and falling corporate profits depressed growth. Falling demands for information technology products adversely affected Asian producer countries, with the exception of China which sustained a buoyant economy. After the September terrorist attack, the USA – engine of the world's economy by virtue of its domestic consumption – faltered with declines in output for the first time in 20 years. Redundancies and lay-offs, company failures, and a curtailment of world travel and tourism affecting airlines and hotels were all products of the year's events. Early in 2001, the US economy experienced an ongoing slump in demand for information and communications equipment leading to an 80% drop in telecommunications, media, and technology (TMT) shares. Nonetheless, strong household spending and an easing of monetary policies, coupled to relatively high employment levels, helped ameliorate the slowdown being experienced elsewhere. Following the 9-11 attacks, it was necessary for the Federal Reserve to cut the federal funds rate, bringing the rate down to 1.75% in December. Unemployment in the USA rose to 5.8% in December, the highest level in more than six years. A return to a federal deficit was projected in 2002 as the President, G. W. Bush, was allocated $40 billion to respond to the terrorist attacks. An additional $15 billion was granted to help US airlines, already in a financially precarious position before September. A package of $75 billion was planned to stimulate the economy.

UK The UK had one of the most resilient economies of the major advanced countries, with a forecast growth in output of 2.0-2.5%, making it the fastest growing of the industrialised Group of Seven (G-7) countries (Canada, France, Germany, Italy, Japan, UK, and USA). Declines in overseas demand severely reduced exports of goods and services. Agriculture and tourism were badly affected by the foot and mouth disease (FMD) epidemic (*see sections on Agriculture & Food and UK Agriculture*) and poor weather. The TMT sector showed signs of collapse. The competitiveness of UK goods and services was eroded by the relative strength of sterling against the euro. Even so, the UK economy benefited from strong domestic demand. Household spending and retail sales rose at rates similar to those in 2000. On a claimant-count basis, unemployment was the lowest for 26 years, and was estimated to be about 5.1% of the total labour force (declining to a seasonally adjusted 3.1% in 2002), compared with 8.5% in the EU, 8.1% in Germany, 8.9% in France, 10% in Italy, 5% in Japan, and 4.8% in the USA. Wage pressures were strong, and as a result of the priority given by the Government to the public sector, public-sector earnings rose faster than those in the private sector. Consumer debt stood at around £800 billion in 2002, including mortgages, and house-price inflation reached 24% in many areas of the UK.

Euro Zone The euro zone ("Euroland") showed economic weakness during 2001, as trade and business investment stagnated. According to the International Monetary Fund (IMF), *World Economic Outlook* October 2001, the estimated percentage annual change in real gross domestic product (GDP) was 1.8% in the EU. Unemployment remained high in most Euroland countries except Luxembourg and The Netherlands. Food and commodity price rises led to pressure on the rate of inflation for most of the year.

Countries in Transition In the former centrally planned economies – also referred to as the countries in transition – there was a 2% increase in output, down from 6.3% in 2000. Exports fell largely as a result of a drop in demand from Western Europe which takes about 50% of the region's exports. The Commonwealth of Independent States, in particular, suffered the greatest fall in regional economic growth, although domestic demand helped avert the worst

effects of the downturn. For most countries in the region, inflation rates declined to an average of 15%, although they were lower (*circa* 9%) in Central and Eastern Europe, and higher in Russia (*circa* 20%).

LDCs Growth in most of the less-developed countries (LDCs) was affected by economic weakness and reduced demand in and from the MDCs. The IMF projected that the annual change in real growth domestic product in all the LDCs was 4.3%, down from 5.8% in 2000. Most buoyant of the regional groups of the LDCs was Asia, where excluding the newly industrialised countries (NICs *e.g.* Singapore, South Korea, Taiwan) growth was around 5.6%. Public debt started to be regarded as a problem. Conflict in Afghanistan affected all its neighbouring countries, drastically disrupting trade and increasing external debt in Pakistan. By virtue of its relatively closed economy, India was not substantially affected by the global economic slowdown during the year, but was expected to be affected during 2002. Bangladesh benefited from an upturn in agricultural output. Growth in output from sub-Saharan Africa fell from 3% to 2.7%, but improved agricultural output in Ethiopia, Kenya, and Mozambique improved their domestic situations. Unstable regimes in Angola, The Sudan, and Zimbabwe impeded growth. In Latin America, there was negligible growth as demand from the USA weakened. Argentina, Brazil, and Mexico – the three largest economies – were markedly affected, and developing political and financial perturbations in Argentina started to undermine the economy. Lower oil prices, global downturn in the demand for goods and services, and the conflict between Israel and the Palestinians reduced growth in the Middle East from 5.5% in 2000 to no more than 2.3% by the end of the year, with projections into 2002 distinctly bleak.

Markets The September 11 event seemed to trigger worldwide loss of confidence in the financial markets, the most significant, and heralding a string of collapses in 2002, being the filing for Chapter 11 protection from bankruptcy in November 2001 of one of the world's largest conglomerates, the US energy trader Enron Corporation. An unprecedented analysis was undertaken of the rôles and practices of external auditors, and the veracity of company accounts, focusing on real earnings and profits. Large-scale job losses were announced such that over 97,000 workers were laid off in the EU during October alone. Markets fell heavily after the Spring of 2002 as further corporate accounting irregularities and excesses in the USA involved companies such as Xerox and WorldCom.

WTO Despite the worsening economic situation, or perhaps because of it, new agreements were reached at the World Trade Organisation (WTO) Conference in Doha, Qatar, in November 2001, enabling globalisation to continue and foreign direct investments to flow. It has been referred to as the 'development round', and the 'Doha development agenda'.

China became the 143rd member of the WTO in December, a decade and a half after first applying to join the General Agreement on Tariffs and Trade. Taiwan, a democratic country proper, was also approved for membership of the WTO, but to accede to the sensitivities of the leadership of China, it was designated as a separate customs territory together with its three offshore islands of Matsu, P'eng-hu, and Quemoy.

Globalisation Globalisation in respect of economic integration continued notwithstanding set-backs from the 9-11 event. Internationally integrated multinational companies have assisted in breaking down national differences; their employees usually have global interests and perspectives. Collaboration with trade unions to force through protectionist demands has been weakened, especially as the political influence of the unskilled and semi-skilled workforce has declined in relation to their proportion of the total workforce. Governments have become committed to multilateral and bilateral agreements. For Europe, the loss of large swathes of manufacturing, a steady increase in the numbers of retired people, and a willingness to purchase and use imported products, lessened resistance to globalisation in many sectors of the economy, even in the culturally relatively resilient areas of agriculture and food.

The previous year was notable for nearly 150 regulatory changes to be made by 69 countries in investment conditions to foster global trade. Although overall foreign direct investment (FDI) figures were expected to decline in 2001, in line with a sharp fall in merger and acquisition activity, in 2000 FDI had grown to an unprecedented level of $4,270 billion. Allied to this was around $15,680 billion in sales by the 800,000-plus affiliates of transnational companies. An investment boom into Hong Kong helped FDI into the LDCs of Asia rise, undoubtedly linked to the final stages of China joining the WTO, but there were a string of disinvestments in Indonesia. China, Hong Kong, and India were mainly responsible for an outflow of FDI from Asia amounting to $85 billion. Only Latin America and the Caribbean recorded declines in regional FDI levels in 2000 compared with 1999.

For the first time in recent history, the growth in world output during 2001 exceeded the volume in world trade. During the 1990s, the annual rise in the volume of merchandise exports had exceeded by three to one the growth of GDP, domestic growth was growing, and trade in services accounted for about 25% of all cross-border trade. Led by the recession in the TMT sectors, the economic slowdown in Europe, Japan, and the USA affected adversely the East Asia-Pacific region (principally Malaysia, the Philippines, Singapore, South Korea, and Taiwan), Latin America, and the countries in transition.

Overall, the current account of the balance of payments in the MDCs remained in deficit for the third year, falling to around $223 billion. Both the UK ($23 billion) and USA ($407 billion) had substantial deficits, as did Australia ($11 billion) and Portugal ($10 billion), but the euro zone progressed into surpluses, led by Germany and Spain with $14 billion surpluses. The four NICs had a total surplus of $48 billion. A surplus of $20 billion was sustained by the LDCs, falling from a level of $60 billion in 2000 as the deficit in Latin America grew to $58 billion and the surplus in the Asian LDCs reduced to $22 billion. There was only a slight easing of LDC indebtedness to £2,155 billion.

One manifestation of globalisation was the synchronised downturn in the economies of Europe, Japan, and the USA. There was no evidence that trade liberalisation adversely affected national economies, or that imports led in general to a widening of the gap between rich and poor, although there were many specific examples of inefficient industries and activities undermined by open markets.

Central Banks With the stark exception of the euro zone, central banks in the MDCs started to cut interest rates early in 2001 and fiscal policy was modified essentially to reinforce confidence in the household, corporate, and market sectors as the main strategy to prevent recession and an economic "hard landing". Eleven cuts to interest rates were made in the USA, reducing the Fed rate to 1.75%. In the UK, the Bank of England steadily brought down the rate to 4%. Japan had few options and room to manoeuvre; nominal interest rates had been below 1% since the mid-1990s, and the financial markets were already depressed. The Bank of Japan eased monetary policy, increasing liquidity and reinstated zero rates. In April, it also announced an emergency package that included a proposal to force its under-pressure banking sector to face up to its long-standing bad-debt problem. Later in the year, it engaged in extensive selling of the yen in an attempt to steady exchange rates. The European Central Bank (ECB) admitted Greece at the beginning of the year as the twelfth EU country to join the euro system. This was a time that the euro appreciated against both the dollar and sterling. By April, market sentiment turned against the euro, as interest rates remained unchanged reflecting the view of the ECB that it was constrained by high inflation and there were prospects of healthy economic growth. Soon thereafter, however, the ECB was forced into three cuts leading to an interest rate of 3.75% by December.

€ The euro zone is dependent on fixing interest rates on a continental scale, and reliant on the assumed authority of European institutions acting under a remit given by governments, rather than allowing its various citizens to act in a truly free market. These citizens currently live under differing political, educational, and legal systems; speak a wide variety of languages; and have differing attitudes to social and economic developments, influencing thereby the processes leading to wealth creation and the quality of life. Some of the nation states have undergone several currency changes as well as political traumas since the end of World War II in 1945. Political integration will be aided specifically by the adoption of the single currency, the euro, in turn further weakening national governments and their control of monetary policy, and lengthening the chain of contact between citizen and bureaucrat. Even more constraint to national governments comes from the Stability and Growth Pact that limits governmental borrowing and budget deficits, amplifying the effects of economic downturns. With extremely limited geographic and wage flexibility of its workforce, even though a one-size-fits-all economic policy has been adopted, there is also the undesirable possibility of protectionist anti-free-market policies coming to the fore, seen most clearly in agriculture, financial services, air travel, and the utilities. Under the guise of 'harmonisation', further anti-competitive stances could be taken as politicians try to curry favour with a voting public disillusioned with full-time politicians generating a flow of enterprise-quashing legislation on a massive scale. At this juncture, the European Central Bank and the relevant member states do not have large enough central budgets to offset economic shocks, a basic requirement of an optimal currency area. Regardless of intrinsic difficulties, a remarkable event took place in the euro zone

in that within a space of two months at the beginning of the year, the national currencies of the 12 euro zone countries were efficiently replaced by new euro notes and coins, with minimal disruption despite the logistic and security challenges.

Stock Exchanges Nearly all the stock-exchange indices in the MDCs declined in both dollar and local-currency terms. According to the *Financial Times*, declines of over 5% were recorded in the Brussels BEL20 (-8%), Brazil Bovesta (-11%), Toronto Composite (-14%), Denmark KFX (-13%), Finland HEX General (-32%), Paris CAC 40 (-22%), Frankfurt Xextra DAX (-20%), Hong Kong Hang Seng (-25%), Milan Banca Commerciale Italiana (-25%), Japan Nikkei Average (-24%), The Netherlands CBS AU Share (-21%), the Philippines Manila Composite (-22%), SES All-Singapore (-15%), Switzerland SBC General (-22%), UK FT-SE 100 (-16.2%), and the USA Dow Jones Industrials (-7%). The global Morgan Stanley Capital International (MSCI) was calculated to have reduced by –16.9%. In contrast, stock market performances were up in Austria, Mexico, Russia, and Taiwan. On a global scale, investor and business confidence fell, and greater focus brought to bear on the veracity of externally audited accounts, share earnings, and executive reward packages.

Agricultural Commodities With the exception of sugar to some extent, and cocoa which was influenced by disease and agronomic problems in Côte d'Ivoire – the main producing country – and market speculation, agricultural commodity prices remained largely depressed as supply more or less matched, or was capable of exceeding, demand. Newer technologies meant that there were greater guarantees of switching on high-quality production, and competition remained intense. Few producers had the market muscle of food processors and particularly the major international or dominant national retailers. The forest-products industry suffered from market volatility, falling prices, and collapsing markets. In contrast, the tobacco industry was resilient. Non-agricultural commodity prices were generally depressed, although oil prices were volatile, yet ended the year below $20 a barrel as non-OPEC producers did not cut back production in line with a decline in demand from the main importers. Gold retained its attractiveness as a precautionary investment irrespective of the large-scale sale of gold reserves by certain central banks. Most other commodities were depressed, even copper, the bell-weather metal which entered a so-called "absorbing state" well below its long-term average, the state which tends to persist until events lead to a reversion back to the long-term average price.

Surveillance Another outcome of the September 11 events was the rapid introduction of broad-spectrum investigative and surveillance powers primarily by the US Government which, in turn, brought international banking and financial services to the fore in the war against terrorists and terrorism. The relatively low profile of the OECD's aim to combat money laundering, the Financial Action Task Force, was raised as it identified jurisdictions that were regulated inadequately. Remedial action and improved reporting were introduced in Argentina, Bermuda, Canada, The Cayman Islands, Israel, Italy, Luxembourg, and Panama.

Banking National and international banking systems, and the legal and regulation framework in which they operate, continued to adjust to the reality of a globalised and integrated financial system encompassing banking, investments, securities, insurance including deposit insurance schemes, mortgages and similar types of lending, and other financial services. The World Bank released a report describing 112 episodes of systematic banking crises in 93 countries since the late 1970s. Reform of its domestic financial regulatory arrangements was considered by South Africa with consideration given to the Australian and UK model of establishing a single financial regulator outwith the central bank, yet there was no international consensus on structures. Changes to the Basel Capital Accord were proposed at the beginning of the year by the Basel Committee on Banking Supervision although there was no resolution of the key issues of (a) using an internal ratings-based approach to selling risk-based capital standards; (b) the possibility of incorporating measurements of operational risk into the standards; and (c) disclosure standards under designated market-discipline principles. Corporate governance was generally agreed to be a primary level of control, and best-practice codes were directly and indirectly supported by governments. Electronic banking and commerce, the associated legal framework for electronic signatures, Internet payment systems, virtual banking, and electronic funds transfers were all under legal and regulatory review in nearly all countries. In the UK, there was emphasis on risk-management processes (*e.g.* risk registers and risk management committees) in companies and organisations, public- and private-sector alike.

IT Compounding the retrenchment caused by the massive contraction in the so-called dot-com companies in 2000, the computer and information systems sector suffered badly from falling demand and investor sentiment in the 2001 recession, extending well into 2002. The 9-11 event triggered a sharp downturn in the whole technology sector. Massive downsizing of workforces took place worldwide. Although the Microsoft Corporation had been found guilty of violating US federal antitrust laws by actions designed to sustain a monopoly on the operating systems (OS) of personal computers, the US Department of Justice decided not to force a breakup of Microsoft, nor pursue the issue of bundling its Internet Explorer browser with the Windows OS. Rival companies and several States, however, contested the federal government's settlement.

Shipments of personal computers were estimated to have declined for the first time since 1986, yet the Gartner Group, a technology-market research company, reported that by 2002, a billion personal computers had been sold over 25 years. The marketplace was made more competitive by price wars, especially in the consumer sector, lowering revenues for the industry by around 10%, and leading to company closures, mergers, acquisitions, and modified supply agreements. Dell displaced Compaq at the world's largest manufacturer. Technological developments and releases included Windows XP with its controversial electronic fingerprint; Mac OS X and its upgrade OS X version 10.1; faster microchips; and improved hand-held personal digital assistants.

E-commerce At a time when electronic-commerce (e-commerce) expanded, e-commerce companies and e-commerce arms of traditional companies declined in both profitability and valuation, alternative high-speed digital subscriber line (DSL) Internet-access providers collapsed, and even the competing cable modem services and wireless high-speed networking companies were also under pressure. Internet advertising revenues declined, but there was a growing awareness that the Internet was being used for product research by prospective purchasers from 'brick-and-mortar' retailers. There was a rise in the number of business-process patents and lawsuits related to infringement of these patents.

Credit-card fraud, the sale of listings of potential customers that have accessed some e-commerce sites, malicious attacks by Internet viruses and worms, and Internet security and spying technology were genuine issues of concern. Governmental actions following the 11 September terrorist attacks included the tracking of Internet users, *e.g.* the Carnivore technology deployed in the USA; the development of improved security systems, especially for remotely controlled factories, power grids, and telecommunications, as well as for transport systems; and encouragement of computerised disaster-recovery strategies. Examples of potential large-scale fraud by company executives and investment analysts defrauding investors by falsifying accounts and earnings and valuation projections were becoming manifest throughout the year.

Semiconductors Evidence of the economic downturn in 2001 was seen in the dramatic 31% fall in sales of semiconductors, but the Semiconductor Industry Association optimistically projected a rise in sales through to 2004. A parallel decline in the sales of flash memory was also thought to be capable of rapid reversal, driven by demands of digital photography, and automotive applications. Digital signal processors, dynamic random access memory devices, microcontrollers, programmable logic devices, and the optical storage markets were all though to have excellent prospects for growth despite declining sales in 2001. The Americas were displaced by the Asia-Pacific area as the world's largest semiconductor market. As in 2000, the top three semiconductor suppliers on the basis of sales were the Intel Corporation, Toshiba Corporation, and NEC Corporation.

Bribes Transparency International surveyed 835 business experts in 15 LDCs that trade most with multinational companies and constructed the Transparency Bribe-Payers index for 2002. This survey is thought to give an indication of the bribery of public officials in LDCs by companies in MDCs and aspirant MDCs. Scores were awarded to countries indicating the level of corruption involving multinational companies from that country. The ranking from least to most corrupt was Australia (1), Sweden and Switzerland (2), Austria (4), Canada (5), Netherlands and Belgium (6), UK (8), Singapore and Germany (9), Spain (11), France (12), US and Japan (13), Malaysia and Hong Kong (15), Italy (17), South Korea (18), Taiwan (19), China (20), and Russia (21). All were far less corrupt than domestic companies in the 15 LDCs. A free press coupled to active anti-corruption investigations by government were regarded as the most effective ways of combating bribery, in line with the convention adopted two years ago by the OECD. The LDCs perceived as most corrupt in

increasing degrees of corruption were Moldova, Uganda, Azerbaijan, Indonesia, Kenya, Angola, Madagascar, Paraguay, Nigeria, and finally, Bangladesh.

IP Country-by-country translation and registration fees, annual renewal fees, the absence of a proper central court of patents (European Patent Judiciary), delays in processing applications and inconsistent decisions dog entrepreneurial and commercial initiatives in the EU. Patenting within the EU remained a protracted and expensive process compared with the USA. The 2001 statistics from the European Patent Office for 2001 are given in http://www.european-patent-office.org/epo/an_rep/2001/pdf/8_e.pdf . In order to safeguard public access to research innovation and ensure full exploitation of intellectual property (IP), the strategy of 'defensive publication' has arisen in which scientists disclose details about their innovation to the public, thereby preventing others from gaining patent protection. This strategy is not confined to the public sector; commercial companies use it to prevent or forestall competitors from gaining advantage. In *Defensive Publishing : A Strategy for Maintaining Intellectual Property as Public Goods*, by S. Adams and V. Henson-Apollonio, International Service for National Agricultural Research (ISNAR), Briefing Paper 53, 2002, the strategy is outlined (see also *On the defensive about invention*, by R. Poynder, Financial Times, September 19, 2001). Guidelines on how to provide a robust defensive publication include (a) a complete and comprehensive description of the entire innovation or concept, (b) description of the use of the research product or innovation, (c) the publication must be made available to the public – especially accessible by patent office examiners, (d) the essence of the work must be brought to the public quickly and/or predictably, (e) it must be possible to prove the date on which publication was disclosed to the public, (f) it may be possible to defer surrender of all or part of the property rights. There are two main routes to defensive publication: (a) self-publishing through company publicity materials, company report series including websites, occasional publications, and possibly ephemeral literature, or (b) more to be preferred, third-party publishing such as commercial public disclosure (*e.g. Research Disclosure* (www.researchdisclosure.com), the peer-reviewed literature, national publications (*e.g. Statutory Invention Registrations* of the US Patent and Trademark Office), and other IP titles, such as the utility model system (*e.g. Gebrauchsmuster* in Germany).

2003 IMF expectations of global growth during 2003 in the order of 3.7% appeared to some observers to be rather high, given the trend for growth of around 4% in recent times, and an estimate of 2.8% for 2002. Weak growth was expected, especially in France, Germany, and Italy, as well as but to a lesser extent in the USA and UK, recognising the acknowledged risks of (a) an overdependence on the USA as the locomotive of the global economy by virtue of its domestic expenditure and willingness to import goods and services; (b) pronounced rises and turbulence in oil prices reflecting political and security concerns and actions in the Middle East, especially in Iraq; (c) volatile equity markets during a period of rapidly declining company valuations and earnings; (d) risky emerging markets in countries with weak economies; and (e) growing imbalances in some of the major economies, most notably the USA's widening current-account deficit.

Conflicts and Populations

Afghanistan The most important global conflict in 2001 was the aftermath of the terrorist attacks in the USA on September 11. Allied air strikes in Afghanistan, led by the USA, were launched on October 7 to rid that drought-afflicted country of its al-Qaeda group and the Taliban that ruled most of the country. Using the anti-Taliban Northern Alliance as an ally to provide the bulk of the ground troops, the USA and allies forced the Taliban and al-Qaeda groups to abandon the major population centres and suffer massive losses. Neither Osama bin Laden nor the Taliban leader, Mohammed Omar, were located or captured. By December 2001, an interim administration led by Hamid Karzai was installed following a UN-sponsored conference in Bonn in late November. The Afghanistan crop of opium poppies had almost disappeared from the Taliban-controlled areas, welcome to an international community trying to control the drug trade, but economically devastating to many subsistence-level farmers. When the Taliban control was removed, poppy-growing resumed.

Elsewhere India and Pakistan, two antagonistic nuclear-armed nations, were close to war footing in their dispute over Kashmir. By the end of the year, there were signs that the government of Sri Lanka and the Liberation Tigers of Tamil Eelam would renew their cease fire that was broken in April 2001. As a country with one of the most culturally, ethnically, and religiously diverse populations, Indonesia suffered from communal violence and threats of successions:

Aceh, Irian Jaya, Kalimantan, and the Maluku archipelago have witnessed war-like conditions. War was declared by the Philippine government on Muslim extremists in Jolo. In the Balkans, there were armed clashes between the Macedonian security forces and ethnic Albanians. Chechen successionists continued to harass Russian forces in Chechnya. In Africa, there was fighting in Burundi, the Democratic Republic of the Congo, and the Sudan, but both Ethiopia and Eritrea respected the 2000 Algiers agreement which led in 2001 to the creation of a security zone. The Middle East was one of the most politically fragile areas with ominous global overtones. Iraq had continued to reconstruct production facilities for weapons of mass destruction, but had been territorially reined in by patrolling war planes from the USA and UK over the northern and southern no-fly zones. Israel and the poverty-struck Palestinian Autonomous Areas were engaged in an unequal war, pitting suicide bombers and small arms of the Palestinian militants against Israeli civilian targets, and unleashing retaliatory attacks by the Israeli armed forces which protected Israeli settlements in Palestinian lands. Peace in the Middle East would boost the global economy, and remove one of the major stated 'justifications' for terrorist acts.

Agreements After 13 years, the final inspection was carried out under the terms of the 1987 Intermediate-Range Nuclear Forces Treaty originally agreed between the former Soviet Union and the USA, thereby eliminating an entire class of nuclear missiles. In contrast, at the end of the year, the USA announced its intention to withdraw from the 1972 Anti-Ballistic Missile Treaty with Russia, regarding the Treaty as an impedance to the development of its National Missile Defense System. The USA opposed a treaty to control the illicit trade in small arms and light weapons as it failed to distinguish between firearms used for traditional and cultural purposes rather than for wars. In addition, the USA withdrew support for a protocol aimed at including verification processes based on international site inspections in the 1972 Biological and Toxin Weapons Convention.

Refugees According to the United Nations High Commissioner for Refugees (UNHCR), at the beginning of 2001, there was a decrease in the number of refugees and persons of concern, from 22,300,000 in 1999 to 21,800,000 in 2000. Thus, 12,000,000 were officially recognised refugees; 914,000 asylum seekers; 786,000 returnees; and about 8,000,000 persons requiring protection or assistance. R. Lubbers, the former Prime Minister of The Netherlands, succeeded S. Ogata of Japan as the UN High Commissioner for Refugees in January 2001.

Coinciding with the 50th anniversary of the 1951 Convention Relating to the Status of Refugees, the Global Consultations on International Protection initiative was launched to reinvigorate international protection mechanisms for refugees and persons of concern. The 'gold-standard' solution has always been regarded as repatriation followed by resettlement and integration at the local and national levels, but although this has been achieved (*e.g.* East Timor, parts of the Balkans), this is not the case in Guinea, Liberia, and much of Sierra Leone. There were expectations that 1,800,000 internally displaced people and 350,000 refugees from the Democratic Republic of the Congo would return following the installation of the new President and implementation of the Lusaka cease-fire agreement. Likewise, it was expected that there would be progress towards repatriating 567,000 Burundian refugees. Around 4 million people were displaced or directly affected by war and other problems in Angola, including 350,000 refugees mainly in the Democratic Republic of the Congo and Zambia. In Asia, the long-standing Afghanistan situation meant that the Afghans formed the world's largest refugee population. By late October 2001, around 1.2 million people were displaced within the country, and *circa* 7.5 million required humanitarian assistance. Well before the launch of the international effort to banish the Taliban, substantial numbers of Afghan refugees and asylum seekers were recorded by most of the best-known recipient countries. The severe drought, internal warfare, persistent human-rights violations, poor education, hostility to modernisation, low prices for agricultural produce and minerals, and relatively low levels of donor assistance all contributed to the large-scale crisis.

As in Afghanistan, resolution of the Balkans situation seemed elusive. By mid-2001, the Macedonian conflict contributed to a total of 140,000 displaced people in the adjacent Kosovo province of Serbia, and 12,000 others to southern Serbia; over 50,000 were internally displaced in Macedonia. By the end of the year, around 57,000 refugees had returned from Kosovo and southern Serbia under the auspices of a NATO-enforced cease-fire agreement. Elsewhere in the Balkans, there were signs of improving relationships that would lead to more settled conditions in Yugoslavia, Croatia, and in Bosnia and Herzegovina. In Kosovo, however, there was little evidence of

accord between ethnic Albanians and non-Albanians, especially with respect to the small remaining Serb community.

The two major guerrilla forces in Colombia – the Revolutionary Armed Forces of Colombia (FARC, apparently aided by the terrorist Irish Republican Army) and the National Liberation Army (ELN) contributed to a refugee problem that overspilled into many other countries, such that Colombians comprise a major portion of those seeking asylum throughout the world. Besides terrorist actions, the country was beset by problems of corruption, the drug trade, and a weak economy.

Many MDCs, especially the UK, experienced substantial increases in the numbers of asylum seekers and attempts by illegal immigrants to circumvent the proper entry procedures, sometimes using desperate measures. Post September 11, and the introduction of antiterrorist measures, there were widespread clampdowns on the asylum process, and a rising risk of both xenophobia and racism affecting the innocent and vulnerable. In the year that the term of office of the UN Secretary-General, Kofi Annan was extended by five years, and both he and the UN had been awarded the Nobel Prize for Peace, the General Assembly was able to approve by the end of the year an increase of nearly 4% for the next two years, essentially to support peace-keeping operations. The budget authorised $2,625 million for regular operations in 2003. Coincidentally, the UN was also able to collect $4.2 billion in current and overdue payments by the end of the year. Earlier in 2001, China ratified the International Convention on Economic, Social and Cultural Rights but resisted the obligation to allow workers to form and join free trades unions. LDCs were responsible for the USA losing its seat on the UN Commission on Human Rights, a seat it has held since the foundation of the UN in 1945. Ill-tempered debate took place in the UN World Conference Against Racism, held in Durban, South Africa from August 31 to September 7.

Populations According to *Britannica World Data*, in 2001, the world's population was estimated to be 6,130,169,000, with a population density of 45.1 *per* square km. The population was estimated to increase to 7,477,335,000 in 2020, by which time the urban population is expected to double, giving rise to an increasing demand for convenience foods and meat products. Around 40% of the demand for meat products in the LDCs, which is expected to reach 213 million metric tonnes (compared with 114 million metric tonnes in MDCs) will come from China. Life expectancy in 2000, the latest date for which data are available, was estimated to be 64.7 years for males and 68.9 years for females. Infant mortality in 2000 was estimated to be 53.6 *per* 1,000 births. Only 76% of the global population had access to safe water in the period 1989-1998. In 1998, there were 4,270 people *per* 1,000 hectares of arable land. During the period 1995-2000, the fertility rate declined from 5.4% to 3.1% annually, and the population growth rate declined from 1.9% to 1.4% annually, according to the United Nations Development Programme (2002).

The populations of Africa (816,524,000): Anglo-America (317,195,000-USA, Canada, Greenland, Bermuda, St Pierre and Miguelou); Latin America (524,099,000 – Caribbean, Central America, Mexico); South America (350,514,000 – Andean group, Brazil and rest of South America); Eastern Asia (1,503,611,000 – China, Japan, South Korea, other Eastern Asia); South Asia (1,378,341,000 – India, Pakistan, other South Asia); Southeast Asia (1,378,341,000 – Indonesia *etc.*); Southwest Asia (312,679,000 – Central Asia, Gulf Cooperation Council, Iran, other Southwest Asia); Eastern Europe (375,196,000 – Russia, Ukraine, other Eastern Europe); Western Europe (391,637,000 – the EU countries and non-EU countries); and Oceania (31,377,000 – Australia, Pacific Ocean Islands) vary greatly in their growth rates, densities, life expectancies, infant mortality, access to safe water, and Gross National Product *per capita*.

Africa's population is expected to grow to 1,163,522,000 by 2020; its current population density is 26.9 persons *per* square km, life expectancy is 51.1 for males and 53.2 for females, infant mortality was 86.9 *per* 1,000 births in 2000, and in 1989-1998 only 57% of the population had access to safe water. The population per 1,000 hectares of arable land was 4,300, and the GNP *per capita* was only $700. The AIDS epidemic and other endemic diseases pose enormous threats to Africa's population and the quality of life. The recent experience of sub-Saharan Africa has illustrated the Malthusian (after Thomas Malthus 1766-1834) problem of *per* capita incomes being driven down to subsistence level by the tendency of the population to grow faster than output. Elsewhere, the combination of technical advancements in agriculture, falling birthrates, and exploitation of new natural resources has averted the problem. Anglo-America's population is expected to reach 369,868,000 by 2020;

its current population density is 14.8 persons *per* square km; life expectancy is 74.4 for males and 80.2 for females, with infant mortality of just 6.7 *per* 1,000 births in 2000, and 91% of the population having access to safe water (1989-1998). The population *per* 1,000 hectares of arable land was 1,350, and the GNP *per capita* was $30,750. Comparative data for Latin America are a projected population in 2020 of 645,387,000; population density of 25.5 *per* square km; life expectancy of 65.2 for males and 72.2 for females; infant mortality of 32.6 *per* 1,000 births; 78% of the population had access to safe water; the population *per* 1000 hectares of arable land was 3,720, and the GNP *per capita* was $3,850. For South America, the 2020 projected population is expected to expand to 424,569,000; current population density is 19.6; life expectancy is 63.8 (male) and 71.5 (female); infant mortality 33.0; 76% had access to safe water; there were 3,450 persons *per* 1,000 hectares of arable land, and the GNP *per capita* was $4,030. In all, the current population of the Americas is estimated to be 841,294,000, and projected to grow to 1,015,255,000 by 2020.

The population of Eastern Asia is expected to grow to 1,673,386,000 by 2020; the current population density is 127.7 *per* square km; life expectancy is estimated at 70.3 (male) and 74.6 (female) years; infant mortality was 26.5 *per* 1,000 births in 2000, and 71% of the population had access to safe water; there were 10,930 persons *per* 1,000 hectares of arable land, and the GNP *per capita* was $3,970. South Asia's population is expected to reach 1,783,298,000 by 2020; the current population density is 274.4 *per* square km; life expectancy is 61.3 (male) and 62.4 (female) years; infant mortality was 70.3 *per* 1,000 births in 2000, and 80% of the population had access to safe water; there were 6,520 persons *per* 1,000 hectares of arable land, and the GNP *per capita* was a lowly $440. Southeast Asia's population is also expected to increase sharply, to reach 651,001,000 by 2020; the population is presently 115.1 *per* square km; life expectancy 64.5 (male) and 69.5 (female) years, infant mortality was 40.3 *per* 1,000 births, and 70% of the population had access to safe water; there were 8,050 persons *per* 1,000 hectares of arable land; and the GNP *per capita* was $1,160. Southwest Asia's population is expected to reach 431,929,000 by 2020, increasing the current population density of 29.6 persons *per* square km; life expectancy is 65.8 (males) and 70.3 (female) years; infant mortality is 52.3% *per* 1000 births, and 79% of the population had access to safe water; there were 3,010 persons *per* 1,000 hectares of arable land; and the GNP *per capita* was $2,740.

Europe shares many characteristics with the Americas with the exception of population growth. The population of Eastern Europe is expected to decline to 322,138,000 by 2020, thereby leading to a decrease in the current population density of 17.4 persons *per* square km; life expectancy is 64.1 (male) and 73.9 (female) years; infant mortality was 18.1 *per* 1,000 births, and 95% of the population had access to fresh water (1989-1998); there were 1,570 persons *per* 1,000 hectares of arable land in 1998; and the GNP *per capita* was just $2,380. These data contrast with Western Europe, including the EU, where the population is expected to increase slightly to 398,507,000 in 2020, such that there will be only a small effect on the current population density of 105.6 persons *per* square km; the life expectancy in 2000 was 75.0 (male) and 81.5 (female) years, with just 5.1 infant mortalities *per* 1,000 births in the same year; all the population have access to safe water; there were 5,040 persons *per* 1,000 hectares of arable land in 1998; and the GNP *per capita* was $22,990. Scotland's population stood at 5,064,200 in June 2001, down from its peak of 5.24 million in 1974. By 2010, its population is predicted to fall below 5 million. At present there are fewer people aged under one than in any other age group up to the age 60, and life expectancies were 73.4 (male) and 78.8 (female), according to the Registrar-General. Oceania's population is projected to increase to 38,299,000 by 2020, and with a current population density of only 37 persons *per* square km there is clearly little relative pressure on land, other than in the Pacific Ocean Islands were the population *per* 1,000 hectares of arable land is already 5,530. Life expectancy in 2000 was 73.2 (male) and 78.8 (female) years; infant mortality was 24 *per* 1,000 births (just 5.0 in Australia), and 86% of the population has access to safe water. The population *per* 1,000 hectares of arable land in 1998 was 540, and the GNP *per capita* was $15,510 ($20,950 in Australia and $6,370 in the Pacific Ocean Islands).

Clearly, within each of the regions or blocs there is wide diversity in economic and social indicators, perhaps best illustrated by a comparison of GNP data. Thus, in Africa, the GNP *per capita* varied between $3,040 in Southern Africa and $280 in East Africa. In the Americas, the GNP *per capita* of the USA was $31,910, contrasting with $1,690 in Central America. In Asia, the GNP *per capita* of Japan was $32,030 whereas that of India was $440, similar to that of

Pakistan, and that of China $780. In Europe, the GNP *per capita* of Germany at $26,620 ($23,500 for the UK), contrasts with $14,800 for Spain, and just $2,250 for Russia, and just $840 for the Ukraine. The GNP refers to the total value of the final goods and services produced both from within the country, or averaged for a region, and from relevant foreign transactions in a given accounting period, usually a financial year. Thus, GNP is equal to the Gross Domestic Product (GDP) adjusted by net factor income from abroad (*i.e.* income residents receive from abroad for factor services - labour, investments, interest - less similar payments to those non-residents who contribute to the domestic economy). Unsurprisingly, GNP data closely align with other economic and social indicators in a country or region. It so happens that the 25 worst-nourished countries are the worst-governed countries.

Agriculture and Food

Production According to the United Nations (UN) Food and Agriculture Organisation (FAO, http://apps.fao.org), global agricultural and food production in 2001 increased slightly above the level in 2000, although *per capita* food production declined by 1.1%. Of the major MDCs, only Japan, South Africa, and some of the so-called transitional countries in the former Soviet Union and Eastern Europe experienced increases in agricultural production, although the countries in transition and Japan have yet to restore production to the levels of 1989-1991. Total food as opposed to agricultural production in Canada, Japan, South Africa, and the USA declined, and declines in *per capita* food production were recorded in Australia, Canada, the European Union (EU), Japan, South Africa, and the USA.

In contrast, agricultural production increased in many LDCs, such as Argentina, Brazil, China, Indonesia, Malaysia, and Mexico; but declines were noted in Bangladesh, India, Turkey, and Vietnam. Total food production in the LDCs increased marginally, and principally in Argentina, Brazil, China, Indonesia, Malaysia, and Mexico. *Per capita* food production in the LDCs declined on average, reflecting rising populations although increases were posted in Argentina, Brazil, China, Malaysia, and Mexico. In the Democratic Republic of the Congo, Ethiopia, Turkey, and Venezuela, *per capita* food production was significantly lower than in 1989-1991.

The low-income food-deficit countries (LIFDCs), particularly in sub-Sarahan Africa, received the bulk of food aid in 2000. A total of 8,464 million metric tonnes (mmt) of cereals were shipped between July 2000 to June 2001 to LIFDCs and other countries such as Afghanistan and North Korea, a marked decline from 11,168 mmt the previous year (1999-2000), but more than the 6,241 mmt in the period 1997-1998. Most of the reduction in food aid was attributable to a 35% decline in shipments from the USA to 4,697 mmt, a reduction from 1,387 to 707 mmt from the EU, and a reduction from 421 mmt to 192 mmt from Canada. Japan increased its shipments from 331 mmt to 720 mmt, however. Both currency devaluations and food aid can distort agriculture and agricultural trade.

WTO Attempts were made at the World Trade Organisation (WTO) meeting in Doha, Qatar in November to open a new round of negotiation on trade liberalisation, recognising particular difficulties in agricultural trade and associated export and production subsidies. Some argued that negotiations were less about trade liberalisation than justifying trade distortions. Agriculturally related trade disputes heard by the WTO included barriers against the importation of bananas, hormone-treated beef, bovine hides, wheat gluten, and lamb meat.

USA Despite its criticism of countries that distort trade by subsidies, tariffs, and other barriers, the USA consistently made supplementary payments to its agricultural producers since 1998, culminating in the early summer of 2002 with a new farm aid bill, the most expensive farm support programme in US history. Later in the year, an additional $6 billion was voted by the Senate in aid for farmers affected by the worst drought since the 1930s. Unsurprisingly, the level of support was heavily criticised by a raft of other agricultural exporting countries, justifiably by the Cairns Group of free-trading nations (Argentina, Australia, Bolivia, Brazil, Canada, Chile, Colombia, Costa Rica, Fiji, Guatemala, Indonesia, Malaysia, New Zealand, Paraguay, the Philippines, South Africa, Thailand, and Uruguay).

Subsidies Farm subsidies in the period 1998-2000, according to the European Commission and the OECD, were complex. One measure is the producer support estimate *per* farmer, which strictly refers to total transfers to total transfers including subsidies to producers, ranged from over $30,000 in Iceland, Norway, and Switzerland; over $20,000 in Japan, South Korea, and USA; over $15,000 in the EU; over $10,000 in the countries of the OECD; but less than

$5,000 in the Czech Republic, Hungary, Australia, Poland, Mexico, and New Zealand. The ministerially controlled European Agricultural Guidance and Guarantee Fund in 2000 ranged from around €9 billion in France; around €5 billion in Germany, Italy, and Spain; €4 billion in the UK; around €2.5 billion in Greece; and less than €2 billion in Ireland, Netherlands, Denmark, Austria, Belgium, Sweden, Finland, and Portugal; with a relatively small amount of spend on the Community Initiative Programme.

Livestock diseases Livestock diseases dramatically depressed rural economies in several countries, particularly the UK where after the expensive episode of bovine spongiform encaphalopathy (BSE), the cloven-hoofed livestock sector was afflicted with foot and mouth disease (FMD). Five years after the public declaration of a link between BSE and new variant Creutzfeldt-Jakob disease (CJD), continental Europe suffered more cases of BSE than the UK. Early in 2001, however, an outbreak of FMD spread over large areas of the UK, devastating an already weakened industry. The implementation of a large-scale slaughter policy that received an international profile of ghastly images of burning pyres of dead livestock; closure of rural footpaths; a ban on livestock movements and meat exports; and massive public-sector expenditure on veterinary services and compensation, served to highlight the largely unrecognised rôle of agriculture in underpinning several key areas of the economy such as tourism. Field research of all kinds was badly affected. Over 100 farmers committed suicide. The potential of other kinds of disease control, such as ring vaccination, was debated furiously, and a variety of enquiries were launched. By mid-January 2002, the UK was declared officially free of FMD. Without proper import controls on unsterilised meat and animal products, and in the absence of enforced related biosecurity protocols, the UK remains vulnerable to future epidemics (see UK Agriculture section). Meat consumption in Europe fell. FMD in Argentina, BSE in Japan, and poultry influenza in Hong Kong disrupted the international meat trade.

Trade Spreading global recession was rapidly expressed in shrinking values of agricultural trade, but not volumes. A relatively strong US dollar rendered many US agricultural products uncompetitive, other than the technologically advanced genetically modified (GM) soybean and maize commodities. World grain production increased from 1,836 mmt to 1,843 mmt. Coarse grain production increased by 2% but trade declined by 4%. For the second year, global rice production declined but its trade remained at 24 mmt; wheat production fell but its trade rose 4%. Grain prices remained at depressed levels even though consumption rose and reserve stock levels fell to levels last experienced in the mid-1990s.

Record levels of oilseeds were recorded in 2001, continuing the trend since 1991, particularly in soybeans from Argentina, Brazil, and the USA. With trade growing by nearly 6%, ending stocks declined by nearly 2%. As in the cereals sector, prices were depressed.

A 2% decline in global sugar production to 34.2 mmt largely reflected a remarkable decline of 12.5% in EU production, and with growing consumption there was a modest firming in prices. Enhanced coffee production and increasing exports from countries outside the Association of Coffee Producing Countries led to low prices for already hard-pressed growers.

Roadmap Agriculture is the single most important activity for human existence. The efficient production of crops and livestock for food supplies and industrial feedstocks has released humanity from the hunter-gatherer treadmill. Scientific, engineering, and technological advances have removed the drudgery in many countries. World food production has quadrupled since 1950, using just 1% more cultivated land; the world's population has grown and has the capability to expand further; less than one in ten people do not have enough to eat whereas 50 years ago, that figure was one in four. Civilisation has been allowed to proceed. Food-supply security is no longer a political priority in the UK and many other countries. The global economy, human health, and societal development have been, for the most part, positively influenced by agriculture, but there are debates about the environmental costs of certain types of agriculture, although large portions of the terrestrial environment have been shaped by mankind. Drawing on *A Science Roadmap for Agriculture* (cited as *Task Force on Building a Science Roadmap for Agriculture*, National Association of State Universities and Land-Grant Colleges, Experiment Station Committee on Organization and Policy, "A Science Roadmap for the Future". November 2001 (www.nasulgc.org/comm_food.htm)) there are huge challenges in defining the needs of agriculture and the future direction of the various strands of agriculturally relevant science. The Science Roadmap was designed for the USA, but it has resonance for the EU and the UK. It followed a conceptual framework of needs to (a) be competitive

in a global economy; (b) add value in future harvests; (c) adjust agriculture to a changing climate; (d) be good stewards of the environment and natural resources; (e) make agricultural enterprises profitable; (f) make families and communities strong; and (g) modify foods for improved health and safety. From these needs arose seven challenges which align closely with European agricultural perspectives, addressing common points in the background information and rationale, the consequences of failing to address these needs, the specific objectives of the research programmes, and potential impacts of the research. These challenges should take precedence over the negativity ingrained in the recommendations of the recent Curry Commission report on the Future of Farming and Food, not least because of the extensive and expert analyses devoted to the US study.

Challenge 1 refers to the development of new and more competitive crop products and new uses for diverse crops and novel plant species - logical in the light of the fact that the US farm community is responsible for record harvests but suffers economic losses despite its relative efficiency, and fails to capture value-added benefits. By a combination of gaining social acceptance of continued biotechnological R&D, increased investments in plant and microbial genomics that are combined with plant breeding and bioinformatics, crop biomass production, and precision and low-tillage farming – efforts that may extend over 20 years – US agriculture would generate great profitability, offer more options, have reduced reliance on fossil fuels, and release new products for consumers.

Challenge 2 is the development of new products from and new uses for animals. Interestingly, the focus is on production efficiency and lessening the impact of livestock intensification on animal and employee welfare, and on lessening the undesirable impacts of manure and its disposal. Consumer issues are relevant in respect of coaxing society to accept the practices and products of modern livestock farming. Specific objectives include expanded R&D programmes in functional genomics, proteomics, bioinformatics, utilisation and preservation of germplasm, value-added products, animal behaviour, animal handling systems, and systems to increase food safety. From these areas would arise a sustainable food-animal industry with reduced environmental impacts. Within the UK, disposal of animals and their byproducts is an urgent policy matter brought to a head by the FMD and BSE debacles, and new environmental regulations.

Challenge 3 – lessening the risks of local and global climatic change on food, fibre, and fuel production – mixes medium- to very long-term R&D objectives. It was noted that "crop and livestock production in the USA has shifted to states where climate conditions are more favourable than in others. For example, the four major US crops (corn, wheat, soybeans and cotton) now are grown in just four or five states. Similarly, the livestock industry, including beef cattle, dairy, swine, poultry, and fish, is moving toward concentration in just a few states. Further shifts in climate conditions may accelerate this pattern and affect both food and fibre production". This pattern has, is, and will occur in the UK and the EU, regardless of sociopolitical manipulations. Soil conditions, availability of water, climate, transport, skill base, and access to profitable markets will ultimately determine location of agricultural and horticultural activities. The Roadmap expects rain-fed crop acreage to decline dramatically in the face of climate change, while irrigated-land acreage should increase modestly in areas where water will become more readily available and affordable. It also refers to research that suggests the economic impacts of climate change could exceed those due to population growth. Vindicating a part of SCRI's research portfolio, Challenge 3's needs highlight the development of accurate mathematical models, simulation models, expert systems, and decision-support systems that will help assess and adapt to short- and long-term effects of climate change in crop and livestock systems. Interactions between plants and soil microbes, and the regulation of nutrient and water uptake were prioritised, as were the development of stress-resistant crops and livestock, and strategies to prevent the loss of biodiversity. New crops, conservation tillage, soil amendments, and land reclamation should be investigated. Most telling was the stated need to develop new institutions that allow scientists and policy makers to work together to design and implement flexible agricultural and environmental policies for land use and crop production.

Integral to Challenge 3 is Challenge 4 – provision of the information and knowledge needed to improve environmental stewardship, which recognises the critical role of R&D on ecosystem goods and services. This means the conceptual shift from considering only fields or farms to the management of complete ecosystems (*e.g.* whole watersheds), sustaining the natural resources base essential for its existence. Seven topics were listed. (i) More environmentally friendly crop and livestock health protection programmes

building on new opportunities from genomics research leading to a replacement of chemically based plant and animal health strategies with biotechnological solutions. (ii) More scientifically sound natural resource preservation strategies, noting the threat to a sustained agricultural production posed by urban developments. (iii) Fertilizer management, reining back nitrogen- and phosphorus-based fertilizers. (iv) Better environmental pollution prevention and management schemes, mitigating the effects of agriculture, and considering GMOs for bioremediation. (v) A greater dependence on science-based environmental regulations, so that understanding is gained of the trade-offs involved and alternatives can be developed as well as providing the necessary freedom to farm. (vi) Technology-based waste management solutions, helping to handle and dispose of the vast volumes of waste generated in food production and processing. It was noted that ignoring this latter topic could result in serious public-health hazards and environmental pollution, and increased public opposition to modern food production and processing practices. New understanding is also required of pathogenesis and resistance mechanisms.

Challenge 5 deals with improvement of the economic return to agricultural producers, noting that the focus may either be on the global market place or local or regional markets, and that there are several factors that lead to a competitive advantage. One of the primary objectives of conventional agriculture is to produce as much food and fibre for the least cost, capitalising so much on industrialisation to shift from subsistence requirements to meeting the needs of commerce. Inevitably, farm sizes have increased, the numbers employed have fallen leading often to rural depopulation, yields increased, capital investments increased, and the processing and retailing companies aggregated. As in Europe, small farms, usually family farms, barely make ends meet, collectively occupy a large land area, but account for a disproportionately small part of the total value of agricultural production, having less market muscle and little access to technology. The range of farm types, scale of operation, ability or willingness to take risks, markets addressed, and management capability vary such that there is not a single research thrust that will meet the needs of the marketplace. Diversity of operation will diminish unless there are improved decision-support systems for risk-based management in farming. Market analyses, novel and value-added products, strategies for community-supported food-production systems, and focusing on local and regional markets and consumers, were deemed essential components of a national strategy, leading to food and fibre security and economic viability.

Challenge 6 – strengthening communities and families – is an extension of Challenge 5, and in the light of national and international competition, the situation in the USA is affected by the mobility and diversity of the population at large, inadequate community structures, and inadequate workforce competencies. Europe is somewhat different, with relatively little workforce mobility, relatively static communities, and a markedly ageing workforce. Relatively few young people wish to enter agriculture with its poor rewards. The Roadmap document noted the need for community vitality which is affected by both globalisation and technological change. Entrepreneurship reinforces communities, and thus support of the self-employed was recommended. Unintended consequences of Federal policies adversely affecting rural communities translate all too readily to EU policies. Mechanisms to buffer against the adverse effects of globalisation seem to rely on a mixture of a supportive infrastructure, sustaining a farmland base, and giving access to technology. Proposed research in Challenge 6 is less tangible than in the other sectors, relying on documenting, surveying, and defining communities undergoing change.

Finally, Challenge 7 concerns food safety and health through agricultural and food systems, with the intention of lengthening the period of healthy life and eliminating health disparities (*e.g.* cardiovascular disease, obesity, diabetes). Specific foods are known to influence certain health conditions, and new experimental tools are beginning to unravel the mechanisms involved. Although much of the research is in its infancy, the public has "enthusiastically embraced some health claims that science has yet to prove, while neglecting others that have been proven for years". Throughout the world, food safety has improved markedly over time, and more than 200 known pathogens are transmitted by food. The R&D needs include improved understanding of the components of human health and wellness; how nutrients relate to physiological function; interactions between food components; and new methods to deliver foods to people to meet individual needs. Biomarkers for nutrients and phytochemicals; creation of healthier foods by using conventional and molecular methods; pathogen detection, identification, and characterisation; toxin levels in foods; food treatments to control

pathogens; and modification of behaviour in food handlers, preparers, and consumers were noted, all of which figure in the UK's Food Standards Agency operations. All in all, the Roadmap has a buoyancy of purpose and positivity missing from most European exercises looking at the future of agriculture.

CAP Reform Reform of the CAP is long overdue. Its origins lie in the original common market that reduced tariffs on industrial products from Germany in exchange for financial support for French small-scale farmers. CAP was largely designed to protect German small-scale farmers from French competition. Expansion of the system to incorporate other European countries with their own agricultural systems gave rise to bureaucratic complexities, opportunities for large-scale fraud and corruption, surpluses, waste, trade distortion to the detriment of agriculture in LDCs, the idiocies of unstructured set-aside, and a massive downturn in the wellbeing of UK agriculture. From a position of strength in 1973 when the UK joined the European Community, UK agriculture lost its competitive edge, disadvantaged by its support system relative to its European partners, the strength of the pound, political pressures to suppress consumer prices, and the effects of being swathed in regulations. Pressures for change are manifold: the sheer cost of CAP for the European Union, problems with the WTO and other countries, and trading blocs, the likelihood of bankruptcy for the EU if enlargement of the EU takes place without major changes to the CAP, the low profitability of agriculture and poor competitiveness of European agriculture in world markets as supply exceeds demand, and lack of political sympathy. Amidst discussion on the future direction of the CAP, notwithstanding the proposals by Franz Fischler, the EU Agriculture Commissioner, there is still the need for politicians properly to understand the original essence of support mechanisms for agriculture and horticulture – the provision of mechanisms to improve efficiency and access to low-cost, high-quality food supplies, cushioning the vagaries of the weather, pests and diseases, and volatility in world markets. This surely represents a food-access protection mechanism for poorer members of society. Trade distortion is a consequence of this underpinning support, thus exceptional care is needed to lessen its impact. There is little documented evidence of profound thinking about the impacts of the main proposals: linkage of payments to animal welfare, health and safety, and environmental laws and regulations; increasing support for rural development, however defined; compulsory long-term set-asides on arable land; mandatory inspections; capping of direct subsidies at €300,000 *per* year. In essence, the European Commission aims to complete the process of decoupling CAP aid from farm production, a process started in 1992. If the proposals are agreed, there would be a single integrated payment for each holding, but that would be conditional on meeting certain animal-health and welfare, environmental, and food-safety standards. These conditions would operate under a common framework with basic implementation criteria enforced through an as-yet-to-be-clarified auditing system for farms receiving over €5,000 *per annum*. Starting in 2004, it is proposed that there would be "dynamic modulation" – a compulsory cumulative annual levy of 3% on direct payments. Together with capping payments, the savings will go to the "Second Pillar" rural development budget to be distributed from intensive cereal- and livestock-producing countries to poorer and more extensively farmed and mountainous countries, with the expectation of bringing about "positive environmental effects". Support will be given for assurance and certification schemes, producer groups, the farm audit scheme, and for livestock farmers using politically acceptable animal-welfare systems. Long-term set-aside (10 years) will be compulsory on arable land and will be subject to the same standards required of land in production. A 'carbon credit' of €45 *per* hectare will be given for non-food crops produced with a view to carbon-dioxide management, with a maximum guaranteed area of 1.5 million hectares. (see http://europa.eu.int/comm/agriculture/mtr/comdec_en.pdf). It is a moot point as to whether tax payers will want to pay for many environmental goods. Large-scale efficient farming units, especially those in the UK, will be penalised. Assumptions that small-scale "organic" farmers are needed in greater numbers will be tested on the rack of the market place. The UK would be a substantial loser in respect of the return from its contributions to the EU; food imports will increase. Agriculture would become even more centralised through regulation and monitoring even though direct payment support for product would decline. The overall cost of the CAP would not decline, however. Research and development to improve agricultural efficiency and product diversification would diminish, and the competitive position of EU agriculture would be weakened.

Market manipulation comes at a high price in the medium-to-long term. The opportunities for fraud and corruption will still exist. Applicant countries

rightly perceive that they will not receive the benefits of the CAP they originally understood would come their way. Nevertheless, there is resistance to change, principally from France, the Republic of Ireland, and the Mediterranean EU countries. France had 679,000 farmers in 1998, occupying 30 million hectares; its farmers and farmworkers represented 3.9% of the workforce, and agriculture accounted for 2% of French GDP. Possible advantages of the proposals would be a better matching of supply and demand – food production would pay due regard to market conditions and environmental impacts. Export subsidies would be scaled back. Encouragement to form co-operative groupings may assist in negotiation with the small number of powerful supermarket retailers, and develop confidence in investing in the future.

In 2000, 5% of farmers in the EU received over 50% of the CAP funding. With the exception of Greece where data were not available, 4,450,000 claimants received €22.37 billion in direct payments but only 1,880 farmers received more than €300,000, the proposed capping level for payments in the mid-term review. Germany had 1,260 farms of this size, the UK 380, and Spain 130. Half of the EU's farmers received less than €2,000 on an individual holding basis, and 70% less than €5,000, reflecting the small size of the individual farming operations. In the UK, there were 166,500 claimants that each received an average of €19,256, but 47% received less than €5,000, and 24% less than €1,250.

EU Enlargement Enlargement of the EU by accession is dependent on applicant countries being stable European democracies with free market economies. Any Accession Treaty must be approved by the Governments and parliaments of all the member states, as well as by the European Parliament as well as the government and parliament of the applicant state. Agreements have been signed with 10 countries; Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia. Those agreements commit both the EU and the applicant countries to long-term political and economic integration and thereby EU membership. Chiefly in response to the intended enlargement of the EU, a 105-member European Convention was established on December 2000, and headed by V. Giscard d'Estaing. Its remit is to propose "a framework and structures for the EU which are geared to changes in the world situation, the needs of the citizens of Europe and the future development of the EU."

So-called association agreements which initially offer EU financial assistance have been signed with Cyprus, Malta, and Turkey. Partnership and co-operation agreements that foster political and economic relations but exclude the possibility of membership have been implemented with Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Ukraine, and Uzbekistan; those agreements with Belarus and Turkmenistan are not in force. The European Economic Area (EEA) which came into effect in January 1994 from the members of the European Free Trade Area negotiated preferential access for their goods, services, labour, and capital to the European Commission Single Market. After Austria, Finland, and Sweden joined the EU in January 1995, only Iceland, Liechtenstein, and Norway remain as the non-EU EEA members, but they agreed to adopt the EU's *acquis communautaire*, apart from the sections dealing with agriculture, fisheries, coal, and steel.

CAP Budget Agriculture plays a major rôle in the EU and its budget. The EC is limited to a percentage (currently 1.27%) of gross national product (GNP) it can raise from its member states, and budget revenue and expenditure must balance. Only four sources of funding are permitted: customs duties on imports from non-EU states; levies charged on agricultural imports from non-EU states; contributions based on shares of a notional Community harmonised Value-Added-Tax (VAT) base; and contributions based on shares of Community GNP, a budget-balancing item meant to cover the difference between total expenditure and the revenue from the other three sources. The "Mrs Thatcher's Rebate" initiated in 1984 (comprising 66% of the difference between the UK contributions to the budget and what it receives), represents compensation for disproportionate contributions by the UK caused by its high levels of agricultural and other imports from non-EU countries and its relatively small receipts from the CAP component of the budget. One impact of the rebate is that the UK Treasury is resistant to spending on EU schemes in the UK as this would reduce entitlement to the rebate, and agriculture in particular is disadvantaged.

In the *General Budget of the EU for the Financial Year 2001*, Agriculture represented 45% (€43.3 billion) of the total (€96.2 billion), Regional and Social 34% (€32.7 billion), External Action 5.1% (€4.9 billion), Administration 5.1% (€4.9 billion), Research and Technology 4.1% (€3.9 billion), and Pre-accession Aid 3.3% (€3.2 billion). In the *Official Journal of the European Communities C series 1.12.2000*, the major

contributors to the EC budget in 1999 were Germany (€21.07 billion; 25.5%), France (€13.99 billion; 17%), UK (€11.08 billion; 13.4%), Italy (€10.77 billion; 13.0%), Spain (€6.23 billion; 7.5%) and the Netherlands (€5.09 billion; 6.2%). The net recipients were Spain (+€6.66 billion), Greece (+€3.64 billion), Portugal (+€2.67 billion), and the Republic of Ireland (+€1.82 billion). The main "losers" were Germany (-€11.36 billion), UK (-€5.29 billion), the Netherlands (-€3.36 billion), Italy (-€1.76 billion), Belgium (-€1.28 billion), Sweden (-€1.23 billion), and France (-€1.16 billion); the remaining countries had "losses" less than €1 billion.

As agricultural markets, political imperatives, and production technologies evolved, reform of the CAP was inevitable, but as in most walks of life retarded by vested interests. A particular series of reforms to the CAP took place in 1984, 1988, 1992, 1997, and 1999. Co-responsibility levels and national quotas for certain products were established in 1984. The glorious set-aside grants to take land out of production started in 1988. The 1999 reforms were designed to reduce surpluses of cereals, beef, and milk by cutting intervention prices and compensating producers through area payments. Agenda 2000 was introduced to prepare the EU for the accession of new member states but has increased the cost of the CAP by around €1 billion *per annum* in compensation payments. The CAP is a major factor in the development of the concept of the Single Market, as codified in the EC 1985 White Paper on completing the internal market and the Single European Act which came into force in January 1993. The Act has not yet been fully implemented in respect of eliminating frontier controls and harmonisation of taxes. Budgetary and WTO pressures, improving transparency of process, and public debate will drive more reform of the CAP.

Influences Overarching influences on European agriculture include not only the CAP, decisions of the WTO, global weather systems, and pests and diseases, but population and social changes. According to the 1994 UN report *The Sex and Age Distribution of the World Population*, the population of Europe will shrink from 729 million in 2000 to 677 million in 2050, whereas there will be increases in Africa (831 million to 2.14 billion), and Oceania (30,651 to 46,070) (see also Conflicts and Populations section). Urbanisation and suburbanisation, an increase in single-person households, increased demands for convenience foods and recreation, demands of food processors and retailers, and development of non-food agricultural and forestry outputs including industrial feedstocks, will shape the quantity and nature of supplies and various types of demand. Ownership of relevant intellectual property will become a major issue.

Nutraceuticals Datamonitor recorded 204 launches of neutraceutical-type products in the world's major markets a period of 18 months up to October 2001. Most products were "probiotic" types, followed by products claimed to reduce the risk of heart disease, including those that lowered blood cholesterol levels. The Datamonitor report predicted a weakening demand for simple vitamin dietary supplements as consumers switch to food products that target specific ailments.

Pesticides Pesticide usage will be severely curtailed in the EU in 2003. The EC will withdraw 320 pesticides, including fungicides, herbicides, and insecticides, in the light of manufacturers declining to defend their products for economic reasons, a process arising from notification procedures introduced during 2000-2001. There is the possibility that a further 150 substances could be withdrawn in July 2003. Thus, more than 60% of the substances on the market in 1993 will have been withdrawn; safety assessments on all the remaining defended substances should be completed by 2008. The current state of plant breeding, and the known propensity of pests and diseases to circumvent resistance mechanisms, ought to engender a search for new-generation crop-protection agents, but the European agricultural scene is generally not favourable to widespread investments in this area.

In January 2001, the EC adopted the *Communication on the Sixth Environmental Action Programme* together with a proposal for a Decision of the European Parliament and the Council of Ministers for its adoption in June 2002. This stated in Article 7 that the impact of pesticides on human health and the environment must be reduced, and that there is a need to achieve a more sustainable use of pesticides as well as a significant overall reduction in risks and of the use of pesticides consistent with the necessary crop protection. Moreover, there was a need to ratify both the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, and the Stockholm Convention on Persistent Organic Pollutants.

The generic term 'pesticides' includes all substances or products that kill pests including but not exclusively

those deployed in agriculture, horticulture, and forestry. Related to those products are plant-protection products (PPPs) used specifically to protect plants or plant products against organisms deemed to be pests, or to prevent the effects of these harmful organisms; they act in diverse ways, such as by killing (*i.e.* true pesticidal action), repulsion, physical barriers, providing alternative attraction sites, modifying reproduction of the pests, or modifying the growth or composition of the host plant, *etc.* The term 'biocide' is widely regarded as substances that kill or control pests in the non-agricultural sectors *e.g.* wood preservation, domestic uses; see Directives 98/8/EC and 91/414/EEC. Most concerns in the EU are directed towards PPPs, according to Eurostat and the European Crop Protection Association. In 1999, the EU represented around 25% of the world market in PPPs, amounting to *circa* 320,000 tonnes of active substances sold *per* year, with fungicides (43%), herbicides (36%), insecticides (12%), and other pesticides (9%) as the main products. Non-agricultural deployment of pesticides amounted to only 2% of total use, according to *Environmental Pressure Indicators for the EU*, June 2001, Eurostat. Data on the volumes of pesticides used offer little related information on their environmental impacts. Applications vary according to the type of crop (vines, cereals, vegetables, and potatoes receive the largest quantities); pest, weed and disease frequency; seasonal factors; and agronomic practice. Data are scant on costs of pesticides and their application; in-field variation; and country or region where applied. The highest application rates are apparently noted in The Netherlands. The PPP industry in Europe employs around 35,000 people, and the crop protection market in the EU is estimated to be in excess of €6 billion *p.a.*

A particularly contentious area – bedevilled by strong opinions unfounded on fact, intolerant opinions expressed by certain farming and environmental pressure groups, unprofessional behaviour, and lack of understanding of agriculture – is that of a risk-benefit analysis of the use of PPPs. R. Bates, former head of Pesticide Registration and Surveillance Department in the former Ministry of Agriculture, Food and Fisheries noted that the public perception of the nature and magnitude of the health risks associated with pesticides is so at odds with available facts that it has become increasingly difficult to distinguish fact from fiction. Many have noted the disconnection between market demands for zero or low usage of pesticides with the maintenance of food supplies all-year round, with healthy and safe produce. Pesticides are used in organic and conventional agriculture with the aim of preventing yield losses from weeds, pests, and diseases; to protect or improve the visual appearance, quality and safety of harvested agricultural produce; to protect plant products in storage; and to improve agronomic efficiency and competitive position. Efficiency gains in agriculture have led to the availability of relatively low-priced, high-quality plant products throughout the EU as well as lessen the demand for cultivated land, reduce energy-demanding erosion-inducing tillage, reduce waste, and sustain profitability. The consumer-led marketplace decides on the acceptability and value of plant material. For very good reasons – the presence of anti-nutritional compounds and the depletion of vitamin C levels – consumers avoid diseased and blemished produce. Some of the attacking microorganisms themselves produce toxins. Losses due to pests and diseases, both in the field and the store, can amount to 40% of total food production. The level of safety testing of modern pesticides if applied to many staple foods would cause them to fail. Some of the chemicals permitted for use in organic-farming systems would also fail, and the various plant extracts that are allowed (*e.g.* neem, pyrelthrins, rotenone, tobacco), do not have established maximum residue levels in crops. B. Ames and colleagues have noted that 99.99% by weight of the crop protection products in the American diet have been synthesised by the plants themselves. Only 52 of these naturally occurring compounds have been tested in high-dose cancer tests and about half are rodent carcinogens. They estimate that Americans eat 1.5g of natural crop protection compounds *per* person *per* day, some 10,000 times more than any synthetic crop protection compounds they might consume. Syngenta Crop Protection UK Ltd. have produced a useful booklet on this topic, *Gaining Consumer Confidence : Residues of Crop Protection Products in Food*, by N. A. Atreya, C. Turner, and P. Parsons, May 2002.

Nonetheless, most PPPs are intrinsically dangerous (see Directive 67/548/EEC), Health and Safety Executive (HSE) *Agriculture and Wood Sector. Pesticide Incidents Report 2000/2001*) but it has proved difficult to quantify in monetary terms the actual adverse effects of PPPs. Human health can be affected acutely or chronically by direct exposure of those producing, applying, or consuming pesticides, or advertently coming into contact with them. According to the UK HSE, in the year 2000-2001

there were 170 pesticide incidents, 71 of which were alleged to have caused ill-health. Particular emphasis has been placed on those categories of the population regarded as sensitive, namely the elderly, the sick, and children, as well as those likely to encounter prolonged exposures. Drinking, surface, ground, and irrigation waters are subject to monitoring procedures. The most commonly identified pesticides in groundwater are the broad-spectrum herbicide atrazine and simazine. Persistence of active compounds and their bioaccumulation on the food chain, leading to possible adverse effects on human health (*e.g.* carcinogenicity, mutagenicity, genotoxicity, endocrine disruption) and indirect effects on the environment (principally loss of biodiversity) are active areas of research and monitoring, but there are remarkably few reports globally on pesticide-induced ill-health in consumers of agricultural products. Bad practice in the production and selection of pesticides, applications that lead to diffuse pollution or excessive doses, contamination after applications often through the cleaning of equipment, and disposal of surplus pesticides, their containers, and protective clothing pose risks. These are exacerbated in LDCs where there may be less strict monitoring systems, reliance on old-fashioned, broad-spectrum toxic compounds, imprecise application technologies, lack of protective equipment, and poor training, all manifestations reflecting financially stressed circumstances.

Reduction of risks associated with PPPs over their life cycle hinge on several factors, not least regulation, monitoring, packaging, and labelling, continual R&D, phasing out of pesticides with unacceptable effects, proper disposal systems, modified farming practices, and plant breeding to introduce new forms of resistance to pests and diseases. Risk assessments and their limitations are discussed in the *Communication from the Commission on the Precautionary Principle* (Com (2001)1 final). Complexity arises, however, from the formulation of active ingredients with other active ingredients, various adjustments, carriers, diluents, and supplementary fertilisers, leading to poorly understood additive or synergistic effects.

The Council Directive 91/414/EEC over-optimistically initiated a 12-year programme to review all bioactive substances in the EU marketplace, but the *Report from the Commission to the European Parliament and the Council on the evaluation of the active substances of PPPs* (Com(2001)444 final of 25.7.2001) recognised the enormity of the task and requested a postponement of the deadline to July 2008. The request was approved.

Maximum Residue Levels (MRLs) in foodstuffs are often cited in terms of toxicologically acceptable. Acceptable Daily Intake (ADI) measures using Good Agricultural Practices (GAP). Directives 76/895/EEC, 86/362/EEC, 86/363/EEC, and 90/642/EC relate to the fixing of MRLs derived from the standpoint of application. These Directives are connected to Good Farming Practice (GFP), which refers to the standard of farming adopted by a reasonable farmer in the region concerned. Member States are required to set out the standards which entail compliance with general mandatory requirements. Thus, GFP is mentioned in Council Regulation (EC) 1257/1999 in respect of support for rural development from the European Agricultural Guidance and Guarantee Fund, and the related Commission Regulation 1257/2002/ The potential cumulative effects of different PPPs have yet to be considered in the setting of MRLs. Most important, there is strong evidence from national monitoring exercises that residue levels in plant products have decreased over recent years. The overall picture is given in *Monitoring of Pesticide Residues in Products of Plant Origin in the European Union, Norway and Iceland*, 1999 Report (SANCO/397/01-final), in which 64% of fruit, vegetables, and cereals in 1999 were without detectable residues, compared with 60% in 1994. MRLs were exceeded in 4.3% of samples in 1999, but actual consumer exposure to pesticide residues remained well below ADI levels.

Among the various international initiatives and regional co-operation initiatives, on pesticides, the Codex Alimentarius has an influential role, with its recommendations having benchmark status upon which the WTO evaluates national food measures and regulations. Within the EU, there is a drive to set EU MRLs more rigorous than those of the Codex MRLs, an action that could be seen by importers as a contrivance to distort world trade. Discussions will be needed with other trading blocs, the European and Mediterranean Plant Protection Organisation (EPPO), and FAO, especially with regard to the FAO International Code of Conduct for the distribution and use of pesticides.

Water quality in the EU is controlled under the aegis of the Water Framework Directive (WFD); Directive 2000/60/EC, October 2000, establishing a framework for community action in the field of water policy; OJ

L 327 of 22.12.2000), based on Directives 91/414/EEC, 75/440/EEC, 76/464/EEC and 80/68/EEC encompassing surface water, discharges of dangerous substances, and groundwater. Member States are expected to prepare comprehensive river basin management plans by 2009, including measures to tackle pesticide pollution.

CAP and the Environment Fundamental to the future of agriculture in the EU is the way in which the CAP shapes land use, intensification, crop choice, the economic viability of farming, and the direction of rural development. Bureaucratic systems have been introduced to lessen the environmental impact of CAP-influenced agriculture *e.g.* Council Regulation (EEC) No 2078/92, Agenda 2000, Council Regulations (EC) 1257/1999 and 1259/1999. The latter Regulation links environmental protection requirements and direct support to producers from the CAP, giving flexibility to Member States to take the environmental measures they consider appropriate, if necessary to cut direct payments as a sanction to support the enforcement of environmental requirements. Less-favoured areas receive special attention. At present, though, less than 3.5% of total CAP spending is devoted to agri-environmental measures, but affect more than 20% of the total EU agricultural area. Policy makers favour various "environmentally friendly" (*i.e.* no-pesticide) systems. Thus, integrated agriculture, integrated production, integrated crop management (ICM), and integrated pest management (IPM) systems include different minimum requirements for the protection of the environment or for pest control, and the various measures permitted to bring about control. In essence, these systems aim to balance finances, pest and disease control, product quality, public health and food safety, working conditions, and environmental impact. Often, they are conducted in tandem with certified production schemes to provide a transparent, audited, due-diligence-related assurance to food processors, retailers, and consumers. Many producers do not receive adequate recompense for the cost of the assurance schemes.

"Organic" production is defined and regulated in Council Regulation (EEC) 2092/91 of June 1991, and operates under several bodies characterised by the use of relatively few pesticides, some of which, however, are controversial. Overall, it is a moot point as to whether there will be a downward trend in the use of PPPs in agriculture in the EU.

Directive 2001/18/EC of the European Parliament and of the Council of Ministers on the deliberate release into the environment of genetically modified organisms (GMO) repealing Council Directive 90/220/EEC (Commission Declaration. OJ L 106 of 17.4.2001) takes into account possible adverse effects of the widespread cultivation of GM crops. With regard to PPPs, several EU countries are conducting field trials on GM crop releases, and the EC has set up a Working Group on Herbicide-Tolerant Crops based on Directives 90/220/EEC and 2001/18/EC, considering also the use of herbicides. Gene flow and potential long-term effects of GMOs are also under review.

In COM (2002)17 final, the EC adopted a proposal in January 2002 for a Directive on environmental liability with the intention of establishing an environmental liability regime to assist in the prevention and remediation of environmental damage to waters, biodiversity, and land. This would cover the manufacture, use, storage, transport, and disposal of PPPs.

The UK has already stated its intention to follow Belgium, Denmark, and Sweden in introducing taxes on PPPs as a method of rationalising their use. Even so, statistics on the utilisation of PPPs throughout the EU are incomplete, but members of the European Crop Protection Association have provided Eurostat with their data on the use of pesticides for the major crop groups in the EU. In absolute terms, the highest consumption of pesticides takes place in those countries with the largest areas under crops (France, Germany, Italy, and Spain), but in terms of pesticide use *per* hectare, Belgium, Italy, France, and the Netherlands are the most intense users.

The EC proposes to introduce a thematic strategy to achieve sustainable use of pesticides, involving consultations, harmonisation of existing statutory instruments and initiatives, and the development of new instruments and initiatives to address the risks associated with the use of PPPs. This would involve the establishment within two years of national plans to reduce hazards, risks, and dependence on chemical controls (including a ban on aerial spraying); improved controls on the use and distribution of pesticides; substituting the most dangerous active substances with safer, possibly non-chemical, alternatives; encouragement of low-input or pesticide-free farming systems but not punitively by imposing an EU-wide scheme of levies on PPPs; and finally improved data-gathering for reporting and monitoring progress in achieving strategy and policy objectives. Of course,

much hinges on funding replacement strategies for the existing PPPs in an expeditious way, lest EU agriculture is sacrificed. Conventional plant breeding is too slow and the European plant breeding industry too unprofitable to provide resistant cultivars within the anticipated deadlines. Unreasonable demands will either simply switch off production, possibly increasing dependence on imports but satisfying the whims of certain pressure or retail groups, or provide the necessary stimulus to introduce high-speed modern breeding systems capable of matching the challenges arising from the fascinating adaptability of pests and diseases. Analysis of human life expectancies show an interesting correlation between the introduction of agrochemicals into farming systems and increasing life span. Better data are required on the biological effects, persistence, and degradation of the PPPs, and crucially, on their alternatives; altogether this represents a massive task. Crop-spraying specialists, farm advisory services, UK Levy Boards, research institutes, colleges, and government agencies provide informative briefings on current best practice and likely trends. It is axiomatic that the present level of R&D is wholly inadequate to address the scale of the exercise to review all PPPs, not least because data sets are discontinuous, science albeit advancing worldwide at a phenomenal rate is under-resourced in Europe, practices differ from country to country, agriculture is an economically frail industry, and politicians continually fall prey to food scares.

Non-Food Crops Non-food uses of crops would seem to be an attractive area of agricultural activity, creating new types of investment, income, and employment mainly in rural areas. Strategies to encourage the use of alternative fuels to lessen the dependence on oil-based and fossil fuels have been proposed over the past four decades. Biofuels, predominantly bio-diesel and bio-ethanol, but including bio-methanol, bio-oils, and bio-gas could displace fossil fuels but will not be able to establish a proper market foothold unless there are changes to fuel taxation, introduction of more emission controls, and encouragement to meet Kyoto targets. Major scientific, engineering, and technological advances are possible, focusing on the generation of improved cultivars, agronomy, harvesting and processing, storage, combustion, and energy conversion and storage. The topic is a potentially rewarding area for innovation and creation of intellectual property (IP), but requires multidisciplinary effort. To date, most effort in the UK has been expended by the public sector with little focus on encouraging the creation of IP. A pertinent source of reference in this topic is *The Technology Roadmap for Plant/Crop-Based Renewable Resources 2020 : A Vision to Enhance U.S. Economic Security Through Renewable Plant/Crop-Based Resource Use* (http://www.oit.doe.gov/agriculture/), prepared by Inverizon International Inc. on behalf of the Renewables Vision 2020 Executive Steering Group, published in January 1998.

According to the Department of Trade and Industry (DTI), biofuels represented 82.3% of the UK's renewable energy sources in 2000, hydroelectricity 14.6%, windpower 2.7%, and active solar heating 0.4%. Biofuels comprised landfill gas (24.4%), refuse combustion (21.2%), wood combustion (16.8%), other biofuels (12.1%), sewage gas (5.4%), and straw combination (2.4%). Total renewable sources accounted for 3 million tonnes of oil equivalent of primary energy use, with about 2.2 million tonnes used to generate electricity, and about 0.8 million tonnes to generate heat. With a stated intention of achieving 10% of electricity needs from renewable sources by 2010, the UK government introduced a renewables policy in February 2000 imposing an obligation on electricity suppliers (including nuclear power) to supply a specific proportion derived from renewables, but exempting renewable electricity sources from the Climate Change Levy. Coupled to this policy were expanded support programmes for new and renewable energy, including capital grants and an expanded R&D programmes, as well as the development of a regional strategic approach to planning and targets for renewables. The Non-Fossil Fuel Obligation (NFFO) Renewables Orders are the main UK mechanism for developing renewable energy sources; the fifth such Order was made in September 1998. A separate system of Scottish Renewables Orders operates north of the border. (*See section on UK Agriculture*).

CGIAR Since its inception in 1971, the Consultative Group on International Agricultural Research (CGIAR) has conscientiously addressed its aim to deploy modern science to promote sustainable development by reducing hunger and poverty, improving human nutrition and health, and protecting the environment. It now has a membership of 62, including 23 developing countries, 23 industrialised countries, and four foundations. A network of 16 'Future Harvest' Centers are supported (Table 1), and there are more than 8,500 CGIAR scientists and staff working in more than 100 countries. All of the research is in the public domain and subject to regular, rigorous

CIAT	International Center for Tropical Agriculture (Centro Internacional de Agricultura Tropical)
CIFOR	Center for International Forestry Research
CIMMYT	International Maize and Wheat Improvement Center (Centro Internacional de Mejoramiento de Maiz y Trigo)
CIP	International Potato Center (Centro Internacional de la Papa)
ICARDA	International Center for Agricultural Research in the Dry Areas
ICLARM	World Fish Center (International Center for Living Aquatic Resources Management)
ICRAF	World Agroforestry Center (International Center for Research in Agroforestry)
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
IWMI	International Water Management Institute
IPGRI	International Plant Genetic Resources Institute
IRRI	International Rice Research Institute
ISNAR	International Service for National Agriculture Research
WARDA	West Africa Rice Development Association

Table 1 'Future Harvest' Centers of the CGIAR.

scrutiny. In 2001, its budget was $337 million. See also *Food Systems for Improved Human Nutrition : Linking Agriculture, Nutrition, and Productivity*, edited by P. K. Kataki and S. C. Babu, *Journal of Crop Production*, 6, Numbers 1/ 2, 2002.

Genome Mapping Following the publishing at the end of 2000 of the DNA blueprint (the genome map) of *Arabidopsis thaliana* (thale cress), an achievement representing the first published genome sequence of a plant, the genome sequence of *Oryza sativa* (rice) was published in early 2001. The larger rice genome (430 million basepairs) was unravelled by Syngenta International AG and Myriad Genetics Inc., whereas the smaller *Arabidopsis* genome (115 million basepairs – about 28,000 genes, 17,000 of which have evidence of expression) involved around 300 scientists of various affiliations worldwide. Complete DNA sequences have been determined for over 60 microbial species, most recently the plaque bacillus, *Yersinia pestis* (4.65 million basepairs); about 4% of the genome comprises pseudogenes whose open reading frames (ORFs – hence the term 'ORFeome') are incomplete and therefore silent in respect of protein expression. Great interest was shown in the 13.8 million basepair DNA sequence of fission yeast, *Schizosaccharomyces pombe*, a eukaryote with 4,824 ORFs, 43% of which contain introns, non-coding regions that have to be spliced out when the DNA is transcribed to RNA prior to protein synthesis. SCRI is involved in unravelling the *Erwinia* and *Phytophthora* genomes, amongst others.

Patents The US Supreme Court ruled in December 2001 that new plants developed by genetic engineering or other breeding techniques could claim protection under a section of federal patent law. The law incorporates newly developed plants reproduced from seeds, and reaffirmed the 1980 Supreme Court ruling that cited the principle that "anything made under the sun made by man" – including living things – could be patented. In previous Reviews in this series, I have described the Union Internationale pour la Protection des Obtensions Végétales (International Union for the Protection of New Varieties of Plants) (UPOV) convention which is widely regarded as a reasonable mechanism of bringing conventionally bred cultivars to the marketplace, protecting the rights of breeders, researchers, and farmers.

Transgenic Crops Much cited, the annual review series *Global Review of Commercialized Transgenic Crops*, published as Briefs by the International Service for the Acquisition of Agri-Biotech Applications, and authored by Clive James, provides a valuable and authoritative oversight on the global status of commercialised transgenic (genetically modified or GM) crops. Brief 24 presents data for 2001. Despite the unprecedented level of anti-GM activity stemming largely from activists of various kinds in Europe, the estimated global area of GM crops for 2001 was 52.6 million hectares grown by 5.5 million farmers, three quarters of whom were resource-poor farmers planting Bt cotton in China and South Africa. This represents

an increase of 19% over the 2000 level, equivalent to 8.4 million hectares. Over 25% of the global transgenic crop hectarage was in LDCs.

Four transgenic crops dominated production : soybean (63% of global area); maize (corn, 19%); cotton (13%); oilseed rape (canola, 5%). Four countries grew virtually all these crops: USA (68%), Argentina (22%), Canada (6%), and the country with the fastest expansion in GM cropping, China (3%). Bulgaria, Germany, Indonesia, Mexico, Romania, Spain, and Uruguay also grew GM crops. The principal traits deployed were herbicide tolerance and insect resistance, with herbicide tolerance, deployed in soybean, maize, and cotton, accounting for 77% of the global area. Of the remainder, 15% were planted with insect-resistant GM crops, and 8% with crops engineered with stacked genes for both herbicide tolerance and insect resistance. The competitive advantage conferred by the technology was manifest by the portion of the global area of the major crops down to GM cultivars: 46% of the global 72 million hectares of soybean; 20% of the 34 million hectares of cotton; 11% of the 25 million hectares of oilseed rape; and 7% of the 140 million hectares of maize. C. James states that the adoption rates for transgenic crops are unprecedented, and are the highest for any new agricultural technology. Cautious optimism was expressed that the global area and the number of farmers planting GM crops will continue to increase in 2002. It was estimated that the global direct and indirect economic benefit of GM crops in 1999 alone was in the order of $1 billion or more. Analysis of the literature shows that by early 2001, more than 187 crop events involving nine basic phenotypic characteristics have been deregulated or approved for planting, feed, or food use in at least one of 13 individual countries plus the EU (M. C. Marra, *Agricultural Biotechnology : A Critical Review of the Impact Evidence to Date*. In *The Future of Food Biotechnology Markets and Policies in an International Setting*, edited by P. G. Pardey, International Food Policy Research Institute, 2001).

> "Governments, supported by the global scientific and international development community, must ensure continued safe and effective testing and introduction of transgenic crops and implement regulatory programs that inspire public confidence. Leadership at the international level must be exerted by the international scientific community and development institutions to stimulate discussion and to share knowledge on transgenic crops with society that must be well informed and engaged in a dialogue about the impact of the technology on the environment, food safety, health of producers and consumers, sustainability and global food security. Societies in food surplus countries must ensure that access to biotechnology is not denied or delayed to developing countries seeking to access the new technologies in their quest for food security, because the most compelling case for biotechnology, more specifically transgenic crops, is their potential vital contribution to global food security and the alleviation of hunger in the Third World. In summary, we must ensure that society will continue to benefit from the vital contribution that plant breeding offers, using both conventional and biotechnology tools, because improved crop varieties are, and will continue to be the most cost effective, environmentally safe, and sustainable way to ensure global food security in the future."
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> Clive James : *Global Review of Commercialized Transgenic Crops: 2001*

Food Crops Plant breeding is central to the success and efficiency of agriculture, horticulture, and forestry. In a succinct and timely analysis of the rationale for exploiting novel germplasm in plant-breeding programmes, J.S. Heslop-Harrison (*Exploiting novel germplasm*; Aust. J. Agric. Res., 2002, 53, 873-879), pointed out that of the 250,000 species of flowering plants, 12 species provide 75% of the food eaten, and only four species account for half of all the food eaten (Table 2). All the listed crops are capable of being biotechnologically modified.

Cartagena Protocol *The Cartagena Protocol on Biosafety : Reconciling Trade in Biotechnology with Environment and Development* edited by C. Bail, R. Falkner, and H. Marquant, Royal Institute of International Affairs, 2002, details the background and outcome of the adoption of the Cartagena Protocol on Biosafety to the Convention on Biological Diversity (CBD) in January 2000 after nearly four years of international negotiations that were themselves founded in biosafety meetings in the early 1970s. Although the nub of the Protocol was how to protect the environment and human health from the potential danger of GMOs or Living Modified Organisms (LMOs), the negotiations were conducted without firm evidence of any environmental damage caused by the release or LMOs, and sharp divisions over the potential risks involved. The Protocol is essentially a precautionary instrument, and emerged during intensifying politicisation of the GMO debate. Unfortunately, scientists did not play a

Crop	2001 production (Mt)
Sugar cane	1254
Maize	605
Rice	593
Wheat	579
Potato	308
Sugar beet	234
Cassava	179
Soybean	177
Barley	139
Sweet potato	136
Oil palm fruit	119
Tomato	100
Banana & plantain	98
Watermelon	77
Grape	62
Orange	61
Apple	60
Sorghum	58
Cabbage	55
Coconut	51
Onion	47
Yam	39
Rapeseed	36
Groundnut	35
Cucumber & gherkin	31
Millet	29
Oats	27

Table 2 The world's major food crops for human consumption ranked by production (from FAO Statistical Database, http://apps.fao.org, 2002). Banana and plantain have been combined, and the pooled category 'Vegetables Fresh not elswhere specified' has been omitted (between positions 6 and 7).

major role in the negotiations, contrasting with the involvement of environmental and other non-governmental organisations (NGOs). There were discussions about the outcrossing of GM oilseed rape, the potential development of resistance in target insects and the potential effects on non-target organisms from the cultivation of Bt maize, the 'Pusztai' case, and a few other high-profile science-related developments.

The key elements of the Protocol are wide-ranging. Article 4 states that the Protocol applies to the transboundary movement, transit, handling, and use of all LMOs that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health although there are other international routes for this aspect. Article 5 exempts pharmaceuticals for humans. Article 6 notes that the Advance Informed Agreement (AIA) procedure does not apply to the movement of LMOs for contained use or to LMOs in transit. The AIA procedures were thought to be at the centre of the biosafety talks that led up to the formal Protocol, with a 'need to know' and 'prior informed consent' deemed to be necessary by LDCs, and essential to build up confidence in biotechnology. Risk assessments (Article 15 and Annex III; level of detail, costs, scope, transparency, *etc*) and management, explicit *versus* implicit consent, the issue of precaution, and minimal national standards were considered in detail. LMOs intended for direct use as food, feed, or for processing (LMO-FFP) – agricultural commodities – were a key issue in the Protocol negotiations, as the area devoted to GM crops increase year by year. Unique identifiers will be required for a central database in the Biosafety Clearing House so that the transgenic crops agreed for release in the marketplace (many are already in international trade) can be employed for monitoring supply chains and usage. Socio-economic considerations for importing countries are dealt with in Article 26, allowing them to protect their biological diversity. Issues of liability and redress (Article 27) were contentious, similar to the situation when the wording of Articles 19(3) and 19(4) of the Convention on Biological Diversity (CBD) were discussed and eventually adopted at the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil (known as the Earth Summit) in June 1992. In the absence of any specific known cases of damage caused by the transboundary movement of LMOs, the Protocol is pre-emptive. Time scales for liability and insurability, impact assessments, definition of 'damage', identity of the person or organisation to be held liable, the relationship between the Protocol and Article (14)2 of the CBD remain to be resolved.

Principle 15 of the Rio Declaration states "In order to protect the environment, the precautionary principle shall be widely applied by States according to their capabilities. Where there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimise such a threat". This influenced the role of the 'precautionary principle' (or properly precautionary approach) in the Cartagena Protocol (see Articles 10 and 11) but there is in Annex III, general principles, point 4 a counterbalancing statement: "Lack of scientific knowledge or

scientific consensus should not necessarily be interpreted as indicating a particular level of risk, an absence of risk, or an acceptable level of risk". Importantly, the Protocol refers to 'potential adverse effects' as a precondition for possibly triggering precautionary measures. The question then arises as to the extent which the precautionary principle represents a principle or possible a customary rule of international law. Thereafter, the WTO Agreements on Sanitary and Phytosanitary Measures (SPS), and on Technical Barriers to Trade (TBT) need to be analysed in the context of the Cartagena Protocol and trade in biotechnology products. At the present time, the WTO's case law is uncertain, and the criteria of unilateral risk assessment and risk management, taking into account also socio-economic factors, would allow for extensive trade restrictions in GMOs and LMOs. It likely that the WTO dispute resolution mechanisms will be under pressure.

GM Crop Debate In previous Reviews, I have dwelt at length on the debate about GM crops. The surreal situation in Europe and the UK has occupied the broadcast and printed media in sensationalist outpourings. In the absence of "bad" actual accounts of GM crops, scare tactics have been used based exclusively on scenarios that are concocted to be damaging to biodiversity and nature, human health, agriculture and horticulture, and international trade. D. L. Kershen, Earl Sneed centennial Professor of Law in the University of Oklahoma, released in 2002 a landmark article *Innovations in Biotechnology – Public Perceptions and Cultural Attitudes : An American's Viewpoint* (dkershen@ou.edu). He argues cogently that the debate about agricultural biotechnology is of equal importance as Galileo *versus* Ptolemy, or Darwin *versus* Lysenko, drawing on the examples of China, Europe, India, and the USA. It should be obligatory reading for European policy makers. Not unrelatedly, the reading should also extend to *In Defence of Global Capitalism* by J. Norberg (ISBN 91-7566-503-4) published in 2002. As pointed out by J. D. Gwartney, R. Lawson and D. Samida, in *Economic Freedom of the World Annual Report 2000* (088975 202 8, Vancouver, B.C. Fraser Institute, see also reports for 2001 and 2002, J. D. Gwartney, R. Lawson, W. Park and C. Skipton, at http://www.fraserinstitute.ca/publications) , the most-free countries with open economies had the highest *per capita* incomes, the highest percentage growth through the 1990s, rapid technological uptake, and the lowest number of poor people as a percentage of the population based on the UN Human Poverty Index. They are also the least corrupt.

Around 14 million people in southern Africa are threatened with starvation, a figure likely to rise throughout 2002. On the eve of the UN World Summit on Sustainable Development in Johannesburg in August 2002, a major dispute erupted when the EU rejected a plea by the USA to offer reassurance to the affected southern African countries about the safety of GM emergency food relief. Mozambique, Zambia, and Zimbabwe turned back food shipments of GM grain – the USA supplies over 50% (500,000 tonnes) of the region's humanitarian aid – evidently preferring death by starvation than a theoretical risk to human health, and crop and livestock exports to the EU. Scientifically and morally, the action of the EU was reprehensible. Zambia has around 1.75 million of its population facing starvation, and suffers 20% HIV/AIDS infection rates. Its President, Levy Mwanawasa, stated that "we will rather starve then give something toxic". Zimbabwe's chaotic political situation, HIV/AIDS pandemic, and drought, means that it too faces a prodigious humanitarian crisis. Three countries accepted GM maize: Lesotho, Malawi, and Swaziland. The UN World Food Programme has urged needy countries to accept the imports.

Sensitivity over GM crops extends to their use as animal feeds. The major UK retailers attempt to source non-GM products but recognise that for such products as fats and oils, carbohydrates, micronutrients, and additives it is difficult to have full traceability. *Current and future GM crop market dynamics : the case of soybeans,* published by Brookes West (graham.brookes@btinternet.com), noted the rise in the demand for non-GM soybeans and warns of the possibility of price rises whilst the prices of GM soybeans and meal fall in line with its global increase in production and yield efficiency. The extra costs will either have to be transferred down the supply chain, or further pressures will be placed on the feed and livestock-production sectors. A thriving market is developing for authenticity testing, essentially driven by pressure groups.

A useful, albeit incomplete, forward look on biotechnology was produced by the Agriculture and Environmental Biotechnology Commission (AEBC) in April 2002, entitled *Looking Ahead. An AEBC Horizon Scan* (aebc.contact@dti.gsi.gov.uk). It was intended to be an internal awareness document,

strongly focused on the UK, and drew on a series of consultations. Although virtually all the points raised in the consultations were relatively well-rehearsed in numerous debates and articles, including this series of Annual Reports, over the past six years, there was a polarisation of views, interesting because no commercial production of GM crops is permitted in the UK. Mention was made of mergers and acquisitions in the crop seed, agrochemical, pharmaceutical, and small-company biotechnology sector, such that there are now very few multinational agrochemical and seed companies (*e.g.* Syngenta, Bayer/Aventis, Monsanto, DuPont/Pioneer, Dow, BASF, Advanta) – but there was no detailed appraisal of the sharp contraction of the UK R&D effort in these areas in both the public and private sectors, a trend likely to continue for the short to medium term. Likewise, there was no audit of the UK intellectual property and competitive position. Transboundary issues, such as product segregation, smuggling, gene flow *etc.* were considered in brief. Herbicide tolerance, pest resistance, fungal resistance, viral resistance, bacterial resistance, abiotic-stress resistance, increased yield, food-product quality, animal-feed quality, plants as factories, other non-food crops, smart plants, trees, fish, insects, other animals, bioremediation and phytoremediation were assessed fairly naïvely in terms of the aim of the work, possible benefits, possible risks, and "further issues". Noteworthy of comment is the way in which the AEBC volunteered itself to cover all aspects of biotechnology, including social, economic, legal, and political trends, and offer what it regards as authoritative reports. Meanwhile, as science budgets have been squeezed, an increasing proportion of R&D spend has been directed to policy issues relating to potential adverse effects of GM technology, reducing the research effort in cutting-edge innovation. Presently, the diversity of approach to GM crops throughout the world and the low level of harmonisation of regulatory processes, means that the debate will continue, unresolved, for a few years yet. Many of the arguments for and against GM food are at cross-purposes; absolutes (as in virtually all areas of human activity) are rare; emotions run high; political and economic viewpoints can rarely be reconciled; rational analyses of risks, benefits, and existing technologies tend to be ignored; intolerance is rife; trust undermined; and some confuse research with commercialisation. The reader is recommended to consult *Genetically Modified Food and the Consumer*, edited by A. Eaglesham, S. G. Pueppke, and R. W. F. Hardy, National Agricultural Biotechnology Council Report 13, 2001. In this, an account is given of a meeting held to discuss the safety, ethical, marketing, and environmental issues that influence the acceptance of agricultural and food biotechnology by consumers. The risks of not researching and developing biotechnology are greater than failing to develop or impeding its development without just reason. In the UK, the Prime Minister's Strategy Unit produced a Scoping Note, *The Costs and Benefits of Genetically Modified (GM) Crops*, following an announcement by the Secretary of State for the Environment, Food and Rural Affairs in May 2002 (http://www.strategy.gov.uk and GMCrops@cabinet-office.x.gsi.gov.uk). This study will run alongside a review of the scientific issues raised by GM crops and feed into a protracted debate on the potential impacts of growing GM crops in the UK. In 1998, the EU stopped approving new applications for imports of GM food, a moratorium that was only lifted in October 2002, and which was *de facto* illegal under EU law and WTO rules. In the absence of commercially grown crops in the UK, the results of the Farm-Scale Evaluation trials in which SCRI is involved, are eagerly awaited. Homologous allelic recombination or replacement technologies (HARTs) are under active consideration by plant molecular geneticists as a way to amend specifically by site-directed processes the sequence of a particular gene or controlling DNA so that the plant remains in all other ways in its original genetic condition, with the exception of the targeted introduced subtle change, and there would only be a minor allelic variation. When HARTs emerge, ideally apomixis by HARTS, they will spell the single greatest technical breakthrough since DNA transformation of plants was announced (see R. A. Jefferson, *Transcending Transgenics – Are There "Babies in the Bathwater," or Is That a Dorsal Fin?* In *The Future of Food. Biotechnology Markets and Policies in an International Setting*, edited by P. G. Pardey, International Food Policy Research Institute, 2001).

The Marketing Battle over Genetically Modified Foods by B. Wansink and J. Kim (American Behavioral Scientist, *44*, 1405-1417, 2001), describe current models of consumer behaviour to point out the ineffectiveness of both proponents and opponents of biotechnology in educating consumers. Their analysis of fallacious and accurate assumptions is relevant to the UK debate. In this vein, food labelling is being actively pursued in some MDCs as a socio-political tool to help 'ethical' or belief-related perceptions of 'desirable' agricultural production (*i.e.* food produced

'organically' and locally, with free-range-based animal welfare, as opposed to food produced with the involvement of GM technologies ionising radiation, or multinational companies) subsume fundamental descriptions (*e.g.* composition, additives, nutritional values, safety, phytosanitary controls, audit controls, value-for-money *etc.*). Some pressure groups hoped that legally enforced labelling on their terms will help prejudice food-production systems they abhor, rather than simply inform dispassionately and offer freedom of choice. Agricultural development and production in exporting LDCs will be modified by complex labelling requirements, potentially to the detriment of those countries. By and large, producers of conventional agricultural products and GM produce were relaxed about more detailed labelling so long as it was concise, fair, accurate, and balanced, and extended to other products (*e.g.* medicines). There was evidence, however, that the impact of some of the proposed labelling recommendations, emblems of a perceived lack of trust, would not be as effective as assumed.

The Environment

Environment in 2001 According to the National Aeronautics and Space Administration (NASA), based on terrestrial and oceanic data from January to October 2001, the year was on schedule to be the second warmest on record. Lower tropospheric temperatures, however, were close to the 1979-1998 mean, indicating that the warming trend was located at or close to the surface. By April 2001, equatorial temperatures returned to normal, indicating that La Niña (the below-normal ocean-surface temperatures in the central and eastern equatorial Pacific) which had begun in 1998 had petered out. La Niña was thought to have accounted for long-term drought in the south-eastern USA. Drought continued in the Middle East and south-central Asia, northern China, and North and South Korea. Storms affected the Northeast, Great Plains, the South and mid-Atlantic coast of the USA, Beliza, Honduras, Nicaragua, Cuba, Algeria, Taiwan, Philippines, China, and Japan. Monsoon floodwaters badly affected India.

Climate Change At the Sixth Conference of the Parties to the 1992 UN Convention on Climate Change held in The Hague in November 2000, there was sharp disagreement over carbon "sinks" and nuclear power. Whole-plant physiologists and soil scientists who are able to provide base-line data and determine carbon fluxes are surprisingly rare these days. Australia, Austria, Canada, Japan, New Zealand, Norway, Russia, Switzerland, Ukraine, and the USA wanted forests and agricultural land to be counted as carbon-dioxide-absorbing sinks, a stance opposed by the EU on the basis that this would obviate positive measures to meet Kyoto targets. In March 2001, President G. W. Bush of the USA stated on the grounds of cost that he would not accept mandatory controls on carbon-dioxide emissions. Later, in July 2001, the conference of parties met in Bonn leading to the acceptance by 178 countries to rules for meeting Kyoto targets. The USA did not accept the agreement even though there were concessions on the inclusion of carbon sinks. In November, details of the treaty were finalised: 40 MDCs would be required to reduce greenhouse-gas emissions by an average of 5% below 1990 levels by 2012. Even so, the Kyoto Protocol needed to be ratified by at least 55 countries before it could come into force. Words are usually preferred to actions in international politics.

In July, a massive report from the Intergovernmental Panel on Climate Change predicted that global temperatures might rise by 1.4 to 5.8ºC by 2100 on the assumption that levels of atmospheric carbon dioxide would reach 540-970 parts *per* million. Significantly, the combustion of fossil fuels and the emission of synthetic chemicals were deemed to have "contributed substantially to the observed warming over the last 50 years."

Pollution Marine and freshwater pollution events in 2001 came from (a) spills of lubricant, diesel, and bunker fuel oil; (b) pesticide and fertiliser run-offs from agricultural land and emissions from livestock farms and silage; (c) human sewage (contains diverse bioactive components); (d) contamination from mining and logging operations; and (e) domestic and industrial wastes. Toxins produced by naturally occurring "blooms" created difficulties for fisheries and shellfish industries. In June, a meeting in Spain of the parties to the Ospar Convention agreed on reductions on the discharge of oils into the northeast Atlantic, and raised to 29 the number of listed substances to be phased out from discharges onto the ocean by adding ethenyl ether, neodecanoic acid, and triphenyl phosphine to the list.

Around 500,000 tonnes of obsolete pesticides have been dumped in many LDCs and countries in economic transition. In responding to prompting from the FAO, the Global Crop Protection Federation (GCPF) awaited a scheme for safe dispersal of pesticides from the FAO that would be confined only to the products derived from the companies that con-

tributed financially to the scheme. Of greater hazard than pesticides was the unsafe storage of radioactive wastes from nuclear weapons, nuclear power stations, hospitals and laboratories, and industrial sources. The greatest such problems remained in the former Soviet Union. Since the 1950s, a remarkable improvement has taken place in agrochemical efficacy, specificity, and targeting. In several countries, there are official disposal schemes. Changing legislation in the EU aimed at reducing the number and type of pesticides permitted for agricultural and horticultural use, is leading to concerns about the building up of resistance in pests and diseases. Consumer, pressure-group, and retailer demands for lowered pesticide usage, coupled to environmental obligations to reduce pollution will inexorably lead to a greater focus on plant breeding to deliver pest and disease-resistant cultivars in conjunction with integrated crop production (ICP) strategies, crop mixtures, companion plants, and quality-audited production systems. Aspects of this approach were favoured in July by the agriculture ministry in The Netherlands, strengthened by an ICP certification plan, a tax on pesticides to begin in 2003, and a proposal to ban pesticide usage on non-ICP-certified farms. (See also Agriculture and Food Section)

In May 2001, an international treaty to reduce or preferably eliminate the production and application of aldrin, chlordane, dieldrin, endrin, heptachlor, mirex, toxaphene, and hexachlorobenzene, was opened for signature in Stockholm. It will enter into force once 50 countries had ratified it; apparently this will not be a problem given that representatives of 122 governments had finalised the treaty in Johannesburg in December 2000. Tropical countries would be allowed to continue to use DDT for malaria control, the most cost-effective method, until suitable substitutes become available. Technological advances mean that there is no longer any reason to use DDT in agriculture. Likewise, the slow phasing out of polychlorinated biphenyls would permit the use of equipment containing them until 2025.

MEA A $21-million multinational, multiorganisational quadrennial study of the condition of the global environment, the Millennium Ecosystem Assessment, was announced on World Environment Day, June 5, 2001, by Kofi Annan, the UN Secretary-General.

Fossil Fuels The combustion of fossil fuels continued to cause concern, most notably the use of coal. The environmental effects of mining coal, transporting it and its pollutant emissions are well known and documented, but perversely it is an industry which received subsidies (*e.g.* Germany, Spain), or is exempted from compliance with emissions regulations (*e.g.* USA). According to the International Energy Agency, there are 1.6 billion people worldwide who are unable to access sources of modern energy, and along with the rest of the world's population will create a need for new power plants; many of these plants are likely to burn coal despite the quality and effects of their carbon emissions unless firm international accords are brought into play. For LDCs, coal can be a relatively cheap source of energy, and many (*e.g.* China, India, South Africa) have substantial reserves. Wood and charcoal are still the only sources of heat for many in the LDCs, leading to the depletion of forests and scrubland, soil erosion and desertification. Poor people can often be condemned to travel vast distances to gather fuel and collect water. Figures from UNDP *World Energy Assessment 2000*, and Howard Herzog, Massachusetts Institute of Technology (see *The Economist* July 6 2002, pp 93-94) point to a global resource base of over 5000 GtC (billion tonnes of carbon equivalent) for coal, compared with 509 GtC for unconventional natural gas (*e.g.* coal-bed methane), 253 GtC for conventional natural gas, 407 GtC for unconventional oil sources (*e.g.* tar sands), and 241 GtC for conventional oil resources. Various technological solutions need to be developed and implemented in order to avoid or minimise the major but not the sole consequence of combusting (oxidising) the carbonaceous fossil fuels – the release of carbon dioxide which thought to be an important anthropogenic greenhouse gas. These range from "sinks" or "buffers" *e.g.* photosynthesising forests, captive processes during or immediately after the combustion pressure, or sequestration. Integrated gasifier combined cycle systems which separate carbon dioxide formation from the heat-generation process, and the "scrubbing" of carbon dioxide from exhaust gases could deliver the greenhouse gas in a way that could enable it to be disposed of in the seas and oceans, in depleted oil and gas reservoirs in porous rocks capped by impermeable rock, in coal seams, and in deep saline aquifers. The geological route may play a role in emissions-reduction credits trading. Of the non-photosynthesis-based sequestration options, oceans are estimated to have a global capacity in orders of magnitude of 1,000s GtC, deep saline formations 100s-1,000s GtC, depleted oil and gas reservoirs 100s GtC, and coal seams 10s-100s GtC. Photosynthesis is a remarkable sequestration route, especially into long-lived perennials and wood products.

Information The Aarhus Convention – the UN Economic Commission for Europe (UNECE) Convention on Access to Information, Public Participation in Decision Making and Access to Justice in Environmental Matters - was adopted in June 1998 (see http://www.unece.org/env/pp/documents/cep43e.pdf) by 37 UNECE members, including the 15 EU member states and the European Commission (EC) itself. In order to ensure that EC environmental legislation is consistent with the legislation, the EC proposed in July 2000 a revised Directive on Access to Environmental Information. During 2001-2002, member states reviewed the original 1990 EC Directive 90/313/EEC in the freedom of access to information on the environment and the national legislation that gives effect to the Directive.

Groups According to the American Association of Fundraising Counsel Trust for Philanthropy, donations to environmental groups in the USA alone were more than $6.4 billion in 2001; globally, the income of environmental organisations was at an all-time high. The focus of attention from these advocacy groups has been business, economic growth, financial markets, profits, governments, regulators, mainstream scientists and technologists, modern agriculture, the aeroplane, and the internal combustion engine. American multinationals, fossil-fuel producers, mining companies, forestry companies, and chemical companies are particular targets of ire. Campaigning has become an industry in its own right, pressuring democratic governments and companies alike. Undoubtedly, the emphasis on the environment has led to improvements in the quality of water and air in many MDCs, and the areas of national parks and reserves, and conservation activities generally have all increased. In a climate of intolerance and inflexibility, though, it may be difficult for companies to embrace innovation to deal with the environmental costs of their actions when the pressure groups require the 'mandate, regulate, and litigate' approach rather than foster market-based environmental reforms as well.

UK Perspectives

Environment Environmental protection in the UK is shaped by a combination of over 50 international conventions and protocols, over 300 European Directives, legislation and strategies of the UK Government, and the actions of charities and voluntary bodies. Various individuals, organisations (and companies also) are actively engaged in environmental protection. Regulation is the responsibility of the Environment Agency, the Scottish Environment Protection Agency, and the Environment and Heritage Service for Northern Ireland. At the EU level is the Sixth Environmental Action Programme, *Environment 2010: Our Future, Our Choice* which has the intent of improving the implementation of current legislation; integrating environmental concerns into other policies; working with the market; empowering private citizens and helping them modify behaviour; and taking account of the environment in land-use planning and management decisions.

Sustainable development is the main focus of the environmental agenda in the UK, considering social and economic development as well as environmental issues, in the worthy understanding that sustainable development meets the needs of the present generation without compromising the ability of future generations to meet their own needs. Starting with the first UK sustainable development strategy in 1994, and the first set of sustainable development indicators in 1996, the latest strategy *A Better Quality of Life* was published in May 1999. It has four objectives (social progress, environmental protection, prudent use of natural resources, maintenance of high and stable levels of economic growth and employment), 14 headline indicators, and 150 other indicators against which progress is measured. Separate indicators are being developed for Scotland. Related to governmental strategies is the commitment of local authorities to formulate sustainable development strategies for their own areas, driven by Local Agenda 21 which came out of the 1992 UN Conference on Environment and Development in Rio de Janeiro.

The Framework Convention in Climate Change, signed and ratified by 184 countries including the UK, governs the UK's response to climate change. It came into force in March 1994 and is intended to reduce the risks of global warming by limiting the emission of 'greenhouse' gases. Progress at meeting targets are assessed regularly at conferences, the most famous being the 1997 meeting in Kyoto, Japan, where a protocol (The Kyoto Protocol) to the

Convention was adopted. Six greenhouse gases are covered: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. MDCs agreed to cut emissions of greenhouse gases by 5.2% below 1990 levels by 2008-2012, but EU members agreed to an 8% reduction, and the UK specifically to a 12.5% reduction. Three ways (the Kyoto mechanisms) were devised to increase the flexibility and reduce the costs of meeting the targets, *viz.* the clean development mechanism; emissions trading; and joint implementation. Unfortunately but not surprisingly, the Sixth Conference of the Parties, held in The Hague, in November 2000, where it was hoped to clarify the methodology of using "sinks" such as vegetation and a compliance regime to monitor performance of countries, was suspended.

A programme setting out how the UK intends to meet its Kyoto target, and progress towards meeting a domestic aim of a 20% reduction in carbon-dioxide emissions by 2010, was published in November 2000. Measures already or about to be implemented are (a) a climate-change levy on sales of electricity, coal, natural gas, and liquefied petroleum gas to the business and public sectors; (b) agreements with energy-intensive users to meet reduction targets; (c) integrated pollution prevention and control; (d) reducing transport congestion and pollution; (e) energy-efficiency initiatives and standards of performance; better countryside management; cuts in fertiliser use; new targets for improving energy management of public buildings; and emissions trading. The Scottish climate-change programme was published in November 2001.

Air pollution is being addressed under other conventions, policies, strategies, and duties. The Convention on Long Range Transboundary Air Pollution, adopted in 1979, came into force in 1993 and involved protocols covering various pollutants including nitrogen and sulfur oxides. Within the UK, the Environmental Protection Act 1990 specified two regimes: integrated pollution control to regulate emissions to any environmental medium from certain types of industrial process; and local air-pollution control to regulate emissions from smaller processes to air. In fact, the recent European Integrated Pollution Prevention and Control Directive was largely based on the UK's Environmental Protection Action, but will cover more types of installation and site reinstatement.

The first National Air Quality Strategy published in 1997 was revised in January 2000 with air-quality objectives to be met by 2003-2008 for reducing the levels of eight main pollutants (benzene, 1-3 butadiene, carbon monoxide, lead, ozone, nitrogen dioxide, particulates, and sulfur dioxide). All district and unitary authorities have a duty to monitor air quality in their areas and to assess whether the air-quality objectives are being met. Specific air-quality targets to be met by 2010 in the UK included reductions in emissions based on 1990 levels of sulfur dioxide by 63%, nitrogen oxides by 41%, volatile organic compounds by 40%, and ammonia by 17%.

Under the auspices of the EU Water Framework Directive, the EC Bathing Water Directive, (which applies to 391 coastal and nine inland bathing waters in the UK), river-quality objectives set by the Environment Agency, and abstraction and discharge licences relating to the European Urban Waste Water Treatment Directive, mean that water-quality targets are set for drinking water sources, wastewater discharges, rivers, coastal waters, and bathing water. These include ensuring that 97% of bathing waters meet European directive standards consistently by 2005, provision of secondary treatment for discharges above 15,000 population equivalent by March 2002, and provision of secondary treatment by 2005 for all significant coastal discharges from settlements of above 2,000 population.

Policies and strategies to deal with commercial, industrial, and domestic wastes have evolved from the old "the solution to pollution is dilution" approach to the current principles of (i) a waste hierarchy of reduce, reuse, recycle, and dispose; (ii) the proximity principle of disposing of waste close to its site of generation; and (iii) national self-sufficiency in dealing with wastes. The EU Landfill Directive has been brought into the public eye through its stringent targets for reducing the amount of wastes sent to landfill sites, and particularly through its planned integrated products policy which aims to internalise the environmental costs of products throughout their life-cycle through market forces by emphasising "eco-design" and incentives to promote "greener" products. Producer responsibility directives for packaging waste and the end-of-life vehicle directive adds greater responsibilities and therefore costs on to producers, and consumers ultimately. Waste strategies operate for England and Wales, Scotland, and Northern Ireland. The main UK targets include (a) reduction of industrial and commercial wastes going to landfill by 85% of 1998 levels by 2005; (b) recovery of 40% of municipal waste by 2005, 45% by 2010, and 67%

by 2015; (c) recycle or compost 25% of household waste by 2005, 30% by 2010, and 33% by 2015; (d) reduce biodegradable waste sent to landfill by 75% of 1995 levels by 2010, 50% by 2013, and 35% by 2020; (e) increase the proportion of waste paper in UK newspaper feedstock to 65% by 2003 and 70% by 2006; (f) reduce the amount of waste going to final disposal by 20% in 2010 and 50% by 2050; and (g) proposed re-use and recovery of 85% of the mass of discarded vehicles and a minimum to 80% recycling by 2006, rising to 95% re-use and recovery and 85% recycling by 2050. Increasing costs of disposal worry farmers whose land is vulnerable to fly-tipping, but most of the public and business seem blissfully unaware of the implications of legislation on wastes.

Bioremediation of the atmosphere, land, and waters is patently a key technology in addressing the various tough and ambitious targets set by the EU and the UK government. Several of the targets require entirely new approaches unless there are substantial changes in lifestyle or even disenchantment of the electorate. Biotechnological advances in generating and propagating novel organisms to handle and exploit wastes, improving and maintaining planting schemes, the development of new manufacturing processes and recyclable materials, new biofuels and other renewable energy schemes will need to be introduced soon, and will require underpinning R&D. Although sporadic small-scale public-sector investments have been made in this area, fresh and concerted effort must be made in the near future. Private-sector investments have been minimal.

In addressing many of the political and social issues on the environment, biodiversity, and recreation and leisure, there has been growing appreciation of the roles of the National Parks; Areas of Outstanding Natural Beauty in England and Wales, and Northern Ireland; National Scenic Areas in Scotland; the National Forest; Sites of Special Scientific Interest; National Nature Reserves; Local Nature Reserves; Forest Nature Reserves; and Marine Nature Reserves. The ten National Parks of England and Wakes set up after the National Parks and Access to the Countryside Act 1949 received the Royal Assent, were created to conserve and protect scenic landscapes (visual amenity) from inappropriate development and to provide access to the land for public enjoyment. Designation of National Park status does not directly affect ownership of the land or remove the rights of the local community – indeed, only 2.3% of the land is owned by the National Park Authorities. A special statutory authority, the Broad Authority, was established in 1989 to develop, conserve, and manage the Norfolk and Suffolk Broads, and there is an intention to give the New Forest a status equivalent to a National Park. In August 2000, the National Parks (Scotland) Bill received Royal Assent, leading to the recent formation of the first Scottish National Park of Loch Lomond and the Trossachs, soon to be followed by the Cairngorms.

In England and Wales, the National Parks and Access to the Countryside Act 1949 made provision for deregulating Areas of Outstanding Natural Beauty (AONB) by the Countryside Commission – now the Countryside Agency in England, and the Countryside Council for Wales. The 41 AONBs emphasise the protection of flora, fauna, geological, and other landscape features but have less emphasis on the provision of open-air enjoyment for the public than the National Parks. There are nine AONBs in Northern Ireland. In Scotland, there are 40 National Scenic Areas which have a broadly equivalent status to AONBs.

As of March 2001, there were 4,115 Sites of Special Scientific Interest (SSSIs) in England, 1,449 in Scotland, and 1,008 in Wales, covering more than 2 million hectares. In Northern Ireland, there are 161 Areas of Special Scientific Interest (ASSIs) covering over 83,000 hectares. Both SSSIs and ASSIs have been identified by English Nature, Scottish Natural Heritage, the Countryside Council for Wales, or the Department of the Environment for Northern Ireland, as being of special interest because of the flora, fauna, geological, or physiographical features; some are managed as nature reserves. Owners or occupiers of the sites must gain written consent before they can undertake certain listed activities on the site, but may receive funds to protect the site, and may benefit from increased valuations of their sought-after properties. Related to the SSSIs and ASSIs, under the same forms of control, are the National Nature Reserves designated for the study and preservation of the flora, fauna, geology and physiographic features. As of March 2001, there were 208 National Nature Reserves in England, 72 in Scotland, 65 in Wales, and 46 in Northern Ireland, totalling 221,000 hectares. Local authorities have designated 665 Local Nature Reserves in England, 34 in Scotland, and 51 in Wales, totalling around 45,000 hectares, as well as 38 km of 'linear' trails. Forestry Enterprise, an executive agency of the Forestry Commission, manages 46 Forest Native Reserves in England, Scotland, and Wales, and

18 Caledonian Forest Reserves in Scotland to protect and expand 16,000 hectares of native oak and pine woods in the Highlands. There are 35 Forest Nature Reserved in Northern Ireland administered by the Forest Service.

Three statutory Marine Nature Reserves for the protection of marine flora and fauna, and geological and physiographical features on land covered by tidal waters or parts of the sea in or adjacent to the UK, have been set up in Lundy, Skomer, and Strangford Lough, with two other areas proposed – the Menai Strait, and Bardsey Island (visible from Aberystwyth on a good day) with part of the Llyn peninsula. In addition, there are non-statutory marine reserves established by conservation groups.

UK Flora Changes in the UK flora have been monitored and reported in the 910-page *New Atlas of the British and Irish Flora*, Oxford University Press, 2002. A decrease was noted in species associated with northern (Arctic and Boreal) vegetation zones, and an increase in Mediterranean-zone plants. This shift in vegetation composition has been blamed on habitat destruction and global warming, as the 1,396 native species that arrived by natural colonisation following the last Ice Age, and the small group of 149 archeophytes (ancient introductions before AD1500 – probably by early farmers), are being displaced by the more recent introductions (neophytes) after AD1500 – mainly horticultural and forestry species. Changes to the 'natural' flora of the UK in recent years reflected (a) a substantial increase in the areas down to plantation forestry; (b) fungal diseases of trees leading to premature death; (c) encroachment on lowland heathland; (d) restoration of fenlands; (e) reduction in peat extraction which ceased at Thorne Moors near Doncaster and Wedholme Flow in Cumbria following compensation to the owner by the UK government; and (f) suburban expansion.

Red Tape Bureaucratic impositions – red tape – afflict all UK organisations adversely affecting their international competitiveness and profitability, although the phenomenon is not confined to the UK. The British Chambers of Commerce estimated that since 1997 the total cost to business of compliance with regulatory measures had risen to £15.6 billion by May 2002, the most expensive being the Working Time Directive (£7.65 billion), the Data Protection Directive 95/46/EC (£3.1 billion), the EU Pollution Directive 98/69/EC (£1.6 billion), the National Minimum Wage (£674.5 million), IR 35 (£523.5 million), Disability Discrimination (£364 million), Stakeholder Pensions and Welfare Reform Bill (£314 million), Part-Time Workers Directive (£306 million), Working Families Tax Credit (£262.8 million), Student Loan Repayment (£255.8 million), Young People-time off for studying/training (£273 million). In 2001, 4,642 sets of regulations were introduced, yet to be tested in case law. Proposed legislation on maternity and paternity benefits, dismissal procedures, the rights of temporary workers, and health and environmental controls will add to the considerable burden on employers not only to balance their accounts but to act as unpaid tax collectors, providers of statistics for government departments, providers of social and welfare services, and - particularly in food and agriculture - key players in expensive quality-assurance systems. Concerns were expressed specifically about meeting the administration costs of addressing information requests from staff and customers expressing their rights under the Data Protection Act. Employers and company profitability are now especially vulnerable to legal challenge. The OECD, however, observed that in recent times the UK has had a regulatory environment that is among the most supportive of market openness and global competition in the world, with entrepreneurs operating in a better business environment than in most of the other 30 member countries. Particular praise was given to competition policy, trading arrangements in the electricity sector, and reform of the telecommunications sector. Recent positive developments such as reductions of tax on profits, taper relief on the sale of businesses, and R&D tax credits are helpful to small- and medium-sized companies, especially in biotechnology. Entrepreneurial behaviour, though, is closely linked to the generation and exploitation of intellectual property, and it is readily suppressed by an oppressive and turbulent regulatory and taxation environment.

R&D Scoreboard In the *2002 R&D Scoreboard*, the twelfth consecutive annual report in the series produced by the Department of Trade and Industry (DTI), it was clear that the UK still lags behind its international competitors in several areas of R&D support. The report is based on an analysis of the R&D investment data in the audited annual reports and accounts of the top 600 UK and top 600 international R&D-investing companies, with classification based by FTSE sectors. R&D-active UK companies in pharmaceuticals & biotechnology account for 37% of total R&D, and aerospace and defence for 10%, both investing above international levels. The UK is

also strong in food processing and oil & gas (9% in total compared with 2% internationally) but only has 4.5% of R&D in electronic & electrical compared with 10.4% internationally. IT hardware (25%), automotive (16.5%), and pharmaceuticals & biotechnology (16.3%) dominate international R&D. An important measure is R&D intensity as defined by R&D spend as a percentage of sales. Within the international group of companies, the Americas (principally the USA) have an R&D intensity of 5.1%, the rest of the world (mainly Japan) 4.1%, and Europe 3.6%. Although within Europe, the UK has the lowest R&D intensity (2.2%), it has increased from the particularly low level of 1.8% in 1998. Further analysis shows that UK company R&D intensity is above international levels in pharmaceuticals & biotechnology (14.6% *versus* 13.0%), aerospace and defence (6.5% *versus* 4.3%), and health (6.5% *versus* 4.9%), but in the electronic & electrical, software & IT services, chemicals, and engineering, the UK figures are lower than its international competitors. Moreover, as many universities and research institutes ruefully realise, UK subsidiaries of overseas companies have a higher average R&D intensity than UK-listed companies. At an international level, the five sectors comprising electronic & electrical, health, IT hardware, pharmaceuticals & biotechnology, software & IT services have the highest R&D intensity values and account for over 60% of all R&D. The US dominated in four sectors, and Japan in one (electronic & electrical).

For many years, it has been clear that R&D is a key to successful growth; companies with above-average R&D spend tend to show above-average sales-growth, productivity, and market value or shareholder return. Companies mainly grow by acquisition or by organic means through R&D or other investments. The acquisition route is frequently much inferior to the organic route in terms of total shareholder return, although it has been the preferred route in recent times, and could account in part for the recent poor performance of many companies that have used the merger and acquisition route. Even so, competitive advantage fundamentally requires a suite of attributes: management and worker skills, capital investments, market development, originality, adaptability, and commitment. The *Scoreboard* report recognises that its analysis is not and cannot be comprehensive. It does not include those companies that undertake R&D but do not declare the amount invested in their accounts, nor does it include UK companies investing less than £260,000 *per annum* in R&D. Importantly, it excludes publicly funded R&D but it would be useful to try to relate this component of R&D expenditure to the various FTSE sectors, and to assess over a suitably long period, *e.g.* 30 years or more, the societal impacts of that R&D. It is the aspiration of government and scientists that the various incentives for R&D investment in addition to improvements in the science base and business environment should accelerate the process of success through innovation. The UK needs more small- and middle-sized companies in the high-R&D sectors, and more of them with high R&D intensities: it is from this category that the new major international companies will emerge. From the work of D. B. Audretsch and R. Thurik in 2001 ((i) *Linking Entrepreneurship to Growth*, OECD STI Working Papers 2001/2.DSTI/DOC (2001)2. OECD Paris. (ii) *What's New about the New Economy? Sources of Growth in the Managed and Entrepreneurial Economies*, Institute for Development Strategies, Indiana University, Centre for Advanced Small Business Economics and Tinbergen Institute at Erasmus University Rotterdam, EIM Business and Policy Research, Zoetermeer), it is clear that small-firm economies tend to have higher growth than large-firm economies, as the industrial economy gives way to the knowledge economy, one characterised by (a) investment in innovation, (b) gaining from creativity rather than investment, (c) being consumer- rather than product-oriented, (d) having short product life-cycles, (e) constantly adapting to change *i.e.* turbulent, and (f) enjoyment of both jobs and high wages. N. Crafts and M. O'Mahoney, in *A Perspective on UK Productivity Performance (Fiscal Studies*, 22, 271-306, 2001), made the point that compared with Europe, the UK and Scotland invest less in physical capital (plant, buildings, and machinery), and in human capital (skill levels). Compared with the USA, the UK and Scotland invest less in innovation and communication technology, and are less entrepreneurial. They also point out that business R&D expenditure as a percentage of output over the period 1990-1998 was 1.98% in the USA, 1.77% in Germany, 1.45% in France, 1.35% in the UK, and only 0.62% in Scotland. Another measure to consider is exploitation of R&D. Over the period 1996 to February 2002, the numbers of US utility patents *per* million population were 976 for Taiwan, 400 for France, 376 for the Republic of Korea, 287 for the UK, 208 for the Irish Republic, and 74 for Scotland. This figure for Scotland is out of kilter with the research output and citation impact of its scientists, and the fact that R&D

expenditure by higher education as a percentage of GDP over the last three years was 0.6% in Scotland, 0.5% in Finland, 0.4% in Denmark and the UK, 0.3% in the Irish Republic, New Zealand, and Wales. Spin-out companies have been viewed as a major route for exploitation of IP arising from the public sector. According to the Bank of England *Finance for Small Firms – A Ninth Report* (Domestic Finance Division, London, 2002), venture capitalists and UK universities alike regarded the top issue as accessing suitably qualified management. Fast-growth companies tend to have better qualified managers than slow-growth businesses. As market valuations decline, however, there is increasing danger of mergers and acquisitions by companies from overseas competitors, or a shifting of decision-making staff to other countries, or even a firesale of potentially valuable intellectual property.

UK Agriculture

Overview An authoritative and clearly presented overview of the UK agricultural industry is provided by the keynote publication *Agriculture in the United Kingdom 2001* produced by the Department for Environment, Food and Rural Affairs; Scottish Executive Environment and Rural Affairs Department; Department of Agriculture and Rural Development (Northern Ireland); and National Assembly for Wales Agriculture Department. This publication was the fourteenth in an annual series, and relates also to other publications, including *Agricultural Census Statistics in the UK,* the *Agricultural Atlas*, the *June Census Analyses*, *Historical Agricultural Data*, and *Farm Incomes in the United Kingdom 2000/01.* Particularly useful websites include www.defra.gov.uk, www.wales.gov.uk, www.scotland.gov.uk, www.dardni.gov.uk, www.food.gov.uk (Food Standards Agency), www.potato.org.uk (British Potato Council), www.hgca.com (Home Grown Cereals Authority), www.statistics.gov.uk (Office for National Statistics) and www.europa.eu.int (European Union – Eurostat).

FMD The most severe outbreak of foot and mouth disease (FMD) since 1967-1968 took place during the period February 20, 2001 to January 14, 2002, directly affecting Dumfries and Galloway, Cumbria, Northumberland, North Yorkshire, Durham, Lancashire, Powys, Gloucestershire, and Devon, but dramatically affecting the entirety of the UK rural economy. Official figures note that 2,030 FMD cases were confirmed, 6.1 million animals were slaughtered, 4.1 million for disease-control purposes, and 2 million for various welfare reasons; most, 4.9 million, were sheep, and 526,000 were slaughtered under the Light Lamb Scheme. Some sources claim that the official figures excluded many young animals and the real figure was around 9-10 million. Between June 2000 and June 2001, the total cattle population declined by 4.8%, the dairy herd by 3.4%, the beef breeding herd by 7.3%, sheep and lambs by 13%, the sheep breeding flock by 12%, the number of pigs by 9.8%, and the pig breeding herd by 2.0%, figure influenced by the incidence of FMD, movement restrictions, the outbreak of Classical Swine Fever in pigs in 2000, and the ongoing downward trend in the market. Debate persisted as to the legality and cost of the official pre-emptive slaughter activity. A total of £1.2 billion was paid in compensation to farmers for value of stock lost in the outbreak, with considerable other disposal and disruption costs, estimated by some commentators to be in the order of £5-6 billion. Exports of livestock and livestock products were banned, and thereby the reputation of the UK livestock industry was severely dented.

Economic Contribution Provisional data in the calendar year 2001 edition indicated that the contribution of agriculture to the total UK economy gross value added (GVA) as a percentage of total GVA at current prices, declined yet again from 0.8% in 2000 to just 0.7%, contrasting with a figure of 1.5% in 1996. At current prices, the GVA in 2001 equated to £6,418 million, compared with a downwardly revised figure of £6,535 million in 2000. Using a new basis for calculating the workforce in agriculture, that now for the first time includes spouses of farmers, partners, and directors, about 2.2% of the total workforce was employed in agriculture (550,000); the relentless decline in rural employment continued apace. As in previous years, there was no media attention on this issue contrasting with less diffuse redundancies announced in manufacturing, mining, and service industries. As before, the data do not take into account a large tranche of the UK workforce involved directly with agriculture, ranging from parts of the public sector (staff in government departments, agencies and institutes; Research Councils and their institutes; higher-education and further-education bodies; and groups related to the EU); to several parts of the private sector; food-processing, storage, distribution, and retail sectors; the industrial feedstock industry; restaurants, hotels, and the tourist trade. Contrasting with agriculture, the food and drink manufacturing, wholesale, retail, and food-service sector accounts for

circa £57 billion GVA, or 6.9% of GDP, and is responsible for around 3 million jobs. Although the food and drink manufacturing industry is the second largest of any manufacturing sector in the UK in terms of output, it does not receive the same level of publicly-funded R&D support as agriculture. The Total Income From Farming (TIFF) measure in 2001 was estimated to be £1.7 billion, some 11% in real terms higher than in 2000, and comprised business profits plus income to farmers, partners, and directors, and those with an entrepreneurial interest in the business. At £7,861, TIFF *per* annual work unit of entrepreneurial labour was 13% higher in real terms, compared with 2000, but TIFF itself was forecast to be 72% below its peak in 1995. Average subsidies *per* annual work unit amounted to £11,293 in real terms, and were unequally distributed according to the sector of agriculture. Total-factor productivity decreased by 6.1% in 2001, reflecting the impacts of FMD and the effects on the arable sector in 2000 of the wettest Autumn for at least 230 years. The percentage of total household final consumption expenditure (formerly 'consumer's expenditure' until the European System of Accounts was adopted in 1998) on household food was provisionally 9.7% compared with 5.9% for alcoholic drinks.

The component countries of the UK varied in their contribution to agriculture according to the local economic, political, and social roles of the industry. Thus, the Gross Value Added at basic prices in 2001 was £4,757 million in England, £824 million in Scotland, £312 million in Wales, and £526 million in Northern Ireland. The TIFF estimates were £1,206 million in England, £273 million in Scotland, just £47 million in Wales, and £190million in Northern Ireland; only the figure in England was lower than in 2000. Estimates of the share of agriculture of total regional gross value added at basic prices, continued recent trends in that it was lowest in England (0.6%), followed by Wales (0.9%), Scotland (1.1%), and then Northern Ireland (2.9%) where agriculture had grown in relative importance since the previous year (2.6%). As before, a slightly different pattern persisted for the share of total regional employment by agriculture; the official data include employees in direct agricultural and horticultural employment, the relevant self-employed workforce, and those engaged in work-related government training schemes, but because the industry includes a relatively high proportion of temporary and part-time workers, any comparison on the basis of full-time equivalents with other sectors of the economy would yield significantly lower percentages. For 2001, 1.9% of total employment was officially attributable to agriculture, with the lowest level in England (1.5%), followed by Scotland (2.9%), Wales (4.7%), and Northern Ireland (7.6%).

Land Areas In June 2001, the total area of UK agricultural land plus common rough grazing was estimated at 18,549,000 hectares, of which 4,454,000 hectares were down to crops, and 43,000 hectares were bare fallow. These figures compare with an average of 18,862,000 hectares devoted to agriculture, and 4,984,000 hectares down to crops in the period 1990-1992. More detailed analysis of the cropping data reveals that the area devoted to cereals declined by 10% from 3,348,000 hectares in 2000 to 3,014,000 hectares in 2001. This was mainly due to the decline in the wheat area from 2,086,000 hectares in 2000 to 1,635,000 hectares in 2001, although there was an increase in the barley area from 1,128,000 hectares to 1,245,000 hectares. Only small changes were noted in the areas devoted to oats (109,000 hectares in 2000; 112,000 hectares in 2001), rye and mixed corn (10,000 hectares in 2000; 7,000 hectares in 2001), and triticale (16,000 hectares in 2000, 14,000 in 2001). The potato area decreased slightly from 166,000 hectares in 2000 to 165,000 hectares in 2001. Other arable crops, excluding potatoes, increased in area to the levels of the early 1990s, from 979,000 hectares in 2000 to 1,103,000 hectares in 2001. This was mainly as a result of an increase in the area down to oilseed rape (332,000 hectares to 404,000 hectares), and to peas for harvesting dry and field beans (208,000 hectares to 276,000 hectares). There was a sharp decline in the area of linseed (71,000 hectares down to 31,000 hectares), and hops fell from 2,000 hectares in 2000 to just 1,000 hectares in 2001. Sugarbeet not for stockfeeding rose slightly from 173,000 hectares to 177,000 hectares. Although there was a slight increase in the area of horticultural land, from 172,000 hectares in 2000, to 173,000 hectares in 2001, this was still down markedly from the average of 203,000 hectares cultivated in the period 1990-1992.

The areas of vegetables grown in the open (120,000 hectares), orchard fruit including non-commercial orchards (28,000 hectares), soft fruit including wine grapes (9,000 hectares), ornamentals including hardy nursery stock, bulbs, and flowers (14,000 hectares), and glasshouse crops (2,000 hectares), were closely similar to those in 2000.

Production In terms of production, the decreased area of land given over to cereals accounted for the decline in the volume of harvested production (23,990,000 tonnes in 2000 to a provisional 18,990,000 tonnes in 2001). The value of production fell from £2,338 million to £2,019 million. Exports to the EU and the rest of the world amounted to 2,470,000 tonnes, and imports were 2,719,000 tonnes; domestic usage was 20,816,000 tonnes. Wheat production fell from 16,700,000 tonnes in 2000 to 11,570,000 tonnes in 2001, and yield declined from 8.01 tonnes *per* hectare to 7.08 tonnes *per* hectare, similar to the average yield in the period 1990-1992. The value of UK wheat production was at a new low since the 1980s of £1,222 million. Of the 13,256,000 tonnes of wheat used domestically, 5,627,000 tonnes were used for flour milling, 6,480,000 tonnes for animal feed, 330,000 tonnes for seed, and 819,000 tonnes for other uses and waste. Barley, one of SCRI's mandate crops, recorded an increase in production from 6,490,000 tonnes in 2000, to 6,7000,000 tonnes in 2001, although yield declined from 5.75 tonnes *per* hectare to 5.49 tonnes *per* hectare. The value of production was £726 million. Domestic consumption was 5,583,000 tonnes, of which 1,939,000 tonnes were used in the brewing and distilling industries, 3,429,000 tonnes were used as animal feed, 169,000 tonnes for seed, and 46,000 tonnes for other uses and waste. The major beneficiary from the UK malting barley is the Treasury which receives on current excise duty and value-added taxation rates more than 200 times the profit realised by the producers, ignoring indirect taxation on producers. Oat production declined to 615,000 tonnes in 2001 from 640,000 tonnes in 2000, still greater than the average of 518,000 tonnes in the period 1990-1992. Yields were 5.60 tonnes per hectare, and the value of production was £64 million. UK domestic consumption was 527,000 tonnes, with 282,000 tonnes used for milling, 227,000 tonnes for animal feed, 16,000 tonnes for seed, and 3,000 tonnes for other uses and waste.

The production of potatoes, one of SCRI's major mandate crops, was down by 1.9%, from 6,652,000 tonnes in 2000, to 6,528,000 tonnes in 2001. Reflecting the declining market for earlies, and delayed planting due to wet conditions, the area devoted to earlies declined from 12,200 hectares in 2000 to just 7,5000 hectares in 2001, whereas the maincrop area increased from 153,800 hectares to 158,400 hectares. With yields of 23.2 tonnes *per* hectare for earlies and 40.1 tonnes *per* hectare for maincrop potatoes, the volume of harvested potato production was 6,528,000 tonnes, with 175,000 tonnes for earlies, and 6,354,000 tonnes for maincrop cultivars. The total value of production on farm was estimated at £600 million in 2001, compared with £454 million in 2000. A total of 7,643,000 tonnes were used in UK markets in 2001, down from 8,155,000 tonnes in 2000, with 6,429,000 tonnes used for human consumption, 381,000 tonnes for seed tubers, 833,000 tonnes as chats, waste, and retained stockfeed.

Of the other arable crops, oilseed rape production at 1,159,000 tonnes was closely similar to 2000, and had a value of £167 million. Yield was 2.57 tonnes *per* hectare. Interestingly, that portion of the UK crop containing unauthorised genetically modified (GM) plants was destroyed and compensation payments were made. Linseed production declined to 39,000 tonnes, contrasting sharply with the 302,000 tonnes recorded in 1999. Although the area of land in linseed had declined from 74,000 hectares in 2000 to 31,000 hectares in 2001, average yield had increased from only 0.58 tonnes *per* hectare to 1.24 tonnes *per* hectare; in the period 1990-1992, yield had average 1.73 tonnes *per* hectare. Sugar beet production based on "adjusted tonnes" at standard 16% sugar content stood at 8,180,000 tonnes, with a value of production of £255 million. Sugar content averaged 17.15%. Sugar production in the UK on a '000 tonne refined basis fell to 1,200,000 tonnes, and imports amounted to 1,310,000 tonnes.

The combined value of peas for harvesting dry and assumed to be used to stockfeed (approximately 80% of pea production) and field beans used mainly for stockfeed rose from £113 million in 2000 to £141 million in 2001; subsidies amounted to £63 million in 2001. With a yield of 3.54 *per* hectare, pea production reached 280,000 tonnes; field bean production was 590,000 tonnes with a yield of 3.50 tonnes *per* hectare. Vegetable protein production will become an important issue as around 70% of the protein used in the EU is imported.

Horticulture remained an industry dominated by financially stretched, small-scale producers without ready access to subsidies and lacking both capital and influence in a market place dominated by a few supermarkets. Vegetables were cultivated on 145,100 hectares, only 1,100 hectares of which were protected. Nevertheless, the value of production was £970 mil-

lion, of which £659 million were for vegetables grown in the open, and £311 million for vegetables grown under protection. The principal vegetable crops were cabbages, carrots, cauliflowers, lettuces, mushrooms, peas, and tomatoes. Fruit production in the form of commercial orchards only, and soft fruit excluding wine grapes, took place on 33,400 hectares, with a total value of production of £243 million, inclusive of glasshouse-produced fruit, orchard fruit accounting for £97 million (mainly desert and culinary apples, and pears) and soft fruit £133 million (mainly strawberries and raspberries). Ornamental production on just 20,000 hectares was valued at £708 million, accounted for by £395 million for hardy ornamental nursery stock, £282 million for protected crops, and £31 million for flower bulbs, including forced flower bulbs, in the open.

Livestock Feed Purchased livestock feedingstuffs, valued at £2.297 billion, rose from 19,698,000 tonnes in 2000, to 19,855,000 tonnes in 2001. Compound feedingstuffs for cattle, calves, pigs, poultry, and other livestock rose in value by 9.3% in 2001 to £1,404 million.

Seeds Total purchased seeds totalling 1,030,000 tonnes and valued at £292 million represented a decline from the average of 1,162,000 tonnes valued at £318 million in the period 1990-1992. Agriculture, horticulture and plantation forestry are dependent economically on a flow of improved cultivars, as end-user demands change, and pests and diseases overcome genetic resistance systems and pesticide efficacy. Throughout the EU, the plant-breeding industry was under severe financial pressures, not aided by regulations and the threat of even more regulations to monitor GM crop seeds. In the UK, the virtual elimination of public-sector plant-breeding R&D, and consequently the training and education of plant breeders, and development of commercially relevant germplasm resources, bode ill for the future of the UK's competitive position and the ability to capitalise on the range of new technologies to improve the efficiency of plant breeding, selection, and propagation.

TIFF Total Income From Farming (TIFF) is an oft-cited figure but should be used with caution. It refers to business profits plus income to those with a direct entrepreneurial interest in the agricultural industry (*e.g.* farmers, growers, partners, directors, spouses, and most other family workers), but it is sensitive to relatively small changes in the values of outputs and inputs, compounded by the provisional nature of the 2001 data, and the fact that as a result of the perfectly rational decision by the Office for National Statistics that livestock destroyed for FMD and associated welfare purposes should be treated as "exceptional losses" under capital transfers and not as part of income. As in many areas of central statistical analyses, TIFF is also sensitive to changes in statistical methodology and services of the data. It is derived by deducting interest, rent, and paid labour costs from Net Value Added (NVA) at factor cost, an appropriate measure of value added by the agriculture industry because it accounts for NVA at basic prices plus other subsidies (less taxes) on production. According to *Agriculture in the United Kingdom 2001*, TIFF was estimated to have risen by 13% (11% in real terms) to £1,710 million compared with its level in 2000. In real terms, TIFF was stated to be 72% below its peak in 1995, after more than doubling in the period between 1990 to 1995. The revised figure for 2000 was £1,513 million, contrasting with £3,016 million in 1997. The NVA at factor cost in 2001 was £4,433 million compared with £4,275 million in 2000, and £5,823 million in 1997. According to the aggregate balance sheets in terms of assets and liabilities for UK agriculture, at current prices the net worth in 2001 was £103,357 million, compared with £99,972 million in 2000, and £49,444 million in 1997, reflecting in large measure the leap in the valuations of land and buildings, but yet fully to show the impact of FMD. Perhaps the private satisfaction of owning land and farming it as a garden or other type of recreation should be regarded as an output element of agriculture.

In the short to medium term, the downward pressure on the prices of agricultural products is likely to continue. Technological advances in agriculture and food processing and storage have facilitated new purchasing and marketing strategies, especially those capitalised on by the large, market-dominant supermarket/discount retailers, which have successfully adjusted to consumer demands. In Germany, the major retailers have driven down prices of food and non-food products, a trend likely to spread throughout Europe, aided by trade liberalisation, adoption of systems that utilise the efficiencies from increasing the scale of operation, and learning from the USA. Innovation in the form of R&D could be regarded as a potential victim of this trend towards price deflation, as much as the small-scale producer acting alone, or inefficient and unimaginative retailer. A switch in agriculturally related R&D priorities in both the public and private sectors is likely, as new market developments are introduced.

Productivity Productivity of the UK agricultural industry can be assessed in various ways: volume of output, labour productivity, profitability, import substitution *etc*. Total factor productivity in terms of the volume of output leaving the industry *per* unit of all inputs, including capital and paid labour (a significant portion of agricultural labour is unpaid), has increased by 35% since 1973. This has arisen by increased output without corresponding increases in capital and labour inputs. During the 1990s, however, gross output less transactions within the agricultural industry remained relatively static, but inputs decreased slightly. In 2001, output decreased and inputs were more or less static. The trend in productivity growth since 1973 relates in large measure to a doubling in labour productivity as measured by the volume of NVA *per* unit of paid and entrepreneurial labour. Even so, in 2001, the NVA *per* Annual Work Unit (equivalent of an average full-time person engaged in agriculture) of all labour, using volume indices 1995=100, was 102.5, compared with 124.2 in 2000. Around 40% of the agricultural workforce now comprises low-paid part-time workers. Total factor productivity as given by the final output *per* unit of all inputs, including labour and fixed capital, using 1995=100, fell from a revised figure of 109.2 in 2000 to a provisional 102.6 in 2001. Fortunately for the taxpayer, the minimum wage legislation does not apply to the self-employed that make up the bulk of agriculture and horticulture.

Across the Member States of the EU, there was again great variation in the percentage changes in income derived from agricultural activity as measured by Eurostat's Indicator A (see Eurostat-Statistics: *Statistics in focus*. December 2001), which is based on NVA *per* whole-time person equivalent. Provisionally, rises were noted in Denmark (12.5%), Portugal (9.5%), Austria (8.5%), Republic of Ireland (7.3%), Belgium (6.2%), Germany (5.7%), The Netherlands (4.3%), UK (4.3%), Finland (3.0%), Sweden (2.8%), Spain (2.7%), Greece (1.4%), and France (0.8%). Declines were recorded for Italy (-0.8%) and Luxembourg (-2.4%). Across the 15 Member States incomes rose by an average of 2.7% concomitant with a continuation in a reducing volume of labour. Parenthetically, in 2000, the UK suffered an alarming decline of –10.8%.

Subsidies Support from the public purse for agriculture takes many forms. When the UK joined the European Economic Community in January 1973, the Common Agricultural Policy (CAP) came into force, with the laudable aims of guaranteeing food security, increasing agricultural productivity, safeguarding the livelihoods of farmers, and stabilising markets that historically had been prone to wide fluctuation. In 1973, the UK had the most dynamic agricultural industry of the Member States, as it entered a system of greater market regulation in peacetime than it had experienced before. To counteract commodity surpluses and escalating costs of the CAP, both of which attracted adverse publicity, a series of reforms to the CAP were introduced, leading to direct-aid payments, set-aside, environmental and social measures, encouragement of organic farming and diversification grants, with lessened emphasis on price and market price support mechanisms. At present, there are three main types of public-sector agricultural support: (a) intervention purchases and import tariffs; (b) direct payments for production; and (c) direct payments for rural development. The direct payments are made under three main headings: (i) direct subsidies and levies, which in 2001 were provisionally £2.457 billion less levies, some 1.9% more than in 2000, and increasingly the subsidies were less related to the amount produced; (ii) arable-area payments, which in 2001 amounted provisionally to around £1billion, including agrimonetary compensation; (iii) direct support to livestock producers, which in 2001 amounted provisionally to around £1billion, including agrimonetary compensation. Agrimonetary compensation evolved from the original "green rates" arrangements originally introduced to protect farmers from the vagaries of currency exchange-rate turmoils, through to special arrangements to take account generally of the introduction of the euro in January 1999, and specifically to allow for the relative strength of sterling against the euro. For many farmers, though, one of the most contentious issues is the topic of modulation, essentially a recycling or virement of direct CAP payments under the various commodity regimes. Thus, in 2001, modulation was introduced at a flat rate of 2.5% to help fund the Rural Development Programme, which on an accruals basis effectively reduced arable and livestock subsidies in the year by £44 million. Proposals to limit payments to farmers were another contentious matter – Scotland has the largest average farm size (131 hectares) in the EU, compared with an average of 72 hectares in the UK as a whole, and an average of 27 hectares in the EU. Other forms of support for agriculture include export subsidies, including food aid; payments made under structural objectives, especially relevant to Objective 1 areas; and various kinds of tax relief.

Subsidies to help UK organic growers were announced in July 2002, with a €140 million package of maintenance payments under the EU's Rural Development Programme spread over five years, supplementing compensation payments for losses sustained while converting from conventional farming. Around 70% of organic food sold in UK supermarkets is imported; sales of organic food in 2000-2001 reached £802 million, and *circa* £950 million in 2001-2002. Top fruit (apples, cherries, pears, and plums) farmers will benefit most, with subsidies of up to £600 *per* hectare, compared with £30 *per* hectare for arable farmers. There are no subsidies for conventionally grown fruit, vegetables, or flowers in the UK. *Organic farming – Guide to Community Rules* published by the EU Directorate-General for Agriculture outlines briefly the history of organic farming and explains the development of the community legislation that supports it (see also http://europa.eu.int/comm/agriculture/qual/organic/index_en.htm).

The CAP-related subsidy categories supporting UK agriculture (Table 2) are not the only sources of support. Additional costs came from operating market regulation, animal health, education, research, advice, food standards, and relevant public-sector staffing and associated facilities; some of such costs, of course, do not directly benefit producers but are designed to benefit consumers and trade interests. As a result of the FMD episode and establishing the Livestock Welfare Disposal Scheme, the total UK expenditure in 2001-2002 was forecast to increase substantially from the previous year by £2.2 billion to £5.3 billion. Spending under the CAP regime was forecast to increase from £2.7 billion in 2000-2001 to £2.9 billion in 2001-2002, divided into seven main headings: Arable Area Payment Scheme (36%); Beef and Veal (non-BSE measures) (27%); Beef and Veal (BSE Measures) (13%); Sheepmeat (8%); Milk (6%); sugar (4%); and other activities including processed goods (6%). A Rural Payments Agency, an Executive Agency of the Department for Environment, Food & Rural Affairs, was established in October 2001 as a single accredited EU paying agency with responsibility for CAP schemes in England and for certain UK-based schemes, although the Scottish Executive, the National Assembly for Wales, and the Department of Agriculture and Development for Northern Ireland retain administrative responsibilities for schemes within their respective bailiwicks. Expenditure on conservation grants, Exchequer funding of accompanying measures, assistance for agriculture in special areas, and in particular FMD compensation and related disposal costs, amounted to around £2.4 billion in 2001-2002, compared with £324 million in 2000-2001.

Environmental Impact Further developments took place in 2001 in considering the environmental impact of agriculture and how it relates to the environmental accounts compiled by the Office for National Statistics. Many international bodies are beginning to offer guidance on environmental accounting frameworks, and it is becoming an area of active academic study, not least as the multipartite concept of sustainability continues to gain credibility. In *Agriculture in the United Kingdom 2001*, positive and negative impacts of farming were considered briefly, and recognition was given to the subjective nature of valuing the environment. According to the report by O. Hartridge and D. Pearce, *Is UK Agriculture Sustainable? Environmentally Adjusted Economic Accounts for UK Agriculture*, July 2001), the provision of environmental services by agriculture as practiced currently, is outweighed by damage caused by the release of greenhouse gases and water pollution. It was based on some contentious and incomplete assumptions, scrutiny of agriculture should be seen in the context of mass urban-related habitat destruction, squalid urban public and private places, and urban-derived wastes and activities blighting the countryside. Using the DEFRA's *Towards Sustainable Agriculture: a pilot set of indicators* (see www.defra.gov.uk), the environmental accounts for UK agriculture are in three related sections as follows. (i) The state of the agricultural environment as adjudged by bird populations on the basis of their wide habitat distribution and proximity to the top of the food chain *i.e.* the bird population index is used as a biodiversity indicator for sustainable agriculture. Although 105 native species have remained fairly constant over the period 1970-2000, there was a marked decline in farmland bird populations between 1977 and 1993, stabilising thereafter. DEFRA has a Public Service Agreement target to reverse the long-term decline in farmland birds by 2020, but the reasons for the decline are manifold, and are not simply due to land-management practices. (ii) The levels of damaging emissions, *e.g.* fertiliser and pesticide contamination of water, gaseous pollution from animals, manure and slurry, and emissions from energy expenditure. Most of the emissions are diffuse, difficult to quantify and their impacts unclear. Integrated Farm Management (IFM) whole-farm policies offer the most immediately attractive route to minimise and ameliorate adverse environmental

Arable payments:
- wheat
- barley
- other cereals (mixed corn, oats, rye, triticale)
- oilseed rape
- linseed
- peas and beans
- other crops
- other crop subsidies (hops and herbage seed support, hemp and flax aid, oilseed rape and linseed support, British Potato Council compensation payments)

Livestock subsidies:
- beef special premium
- suckler cow premium scheme
- sheep annual premium scheme
- extensification payment scheme
- dairy agrimonetary compensation

Set-aside

Other animal disease compensation

Less-favoured areas support schemes

Agri-environment schemes:
- Environmentally Sensitive Areas
- Countrywide Stewardship
- Nitrate-Sensitive Organic Conversion Areas
- Habitat
- Moorland
- Woodland Schemes
- English Heritage Sites of Special Scientific Interest (SSSI)
- Tir Cymen (Wales)
- Tir Gofal (Wales)
- Countryside Council for Wales (SSSI)
- Scottish Natural Heritage

Table 3 CAP-related Subsidy Categories for UK Agriculture

impacts by focusing on soil management, crop nutrition, crop protection, pollution control and waste management, energy efficiency, animal husbandry, and landscape and wildlife features. It attempts to integrate economic viability with environmental sustainability. The best non-ideological exponent of the system is Linking Environment and Farming (LEAF) that has over 13,000 members and operates with a self-assessment audit. DEFRA has issued its Codes of Good Practice for the Protection of Soil, Air and Water, and the Scottish Executive has issued the Prevention of Environmental Pollution for Agricultural Activities. (iii) The use of finite (non-renewable) and sustainable (renewable) resources in agriculture can be assessed at several levels. Consumption of finite resources (petroleum, coal and gas in energy generation; metals and plastics in equipment manufacture; certain chemicals; excessive use of natural resources such as water and soil. It was estimated that in 2000, the direct and indirect energy consumption of UK agriculture was 191.6 PetaJoules (less than 1% of total UK energy consumption), compared with 240.3 PetaJoules in 1985. Agricultural biomass was estimated to account for 15% of renewable energy in the UK. By having a two-pronged strategy of small-scale on-farm combustion for heat production and electricity generation for sale under the forthcoming Non-fossil Fuel and Renewables Obligations programme, it is expected that agricultural biofuels will contribute to the generation of 10% of UK electricity from renewable resources by 2010.

With the three objectives of improving and extending wildlife habitats; conserving historic, geological and landscape features; and restoring traditional aspects of the countryside, support through agri-environment schemes is set to increase substantially. In June 2001, 623,202 hectares of land in the UK were registered as being farmed organically, aided by Organic Conversion schemes.

Historical Perspectives: Agriculture in Britain 1700-1900

By 1700, many foods and crops were exchanged between Europe, Asia, and the Americas. In Britain, the potato, tea, coffee, chocolate, tobacco had become commonplace, and sugar was a cheap commodity. From 1700 to 1800, there were fundamental societal changes and turmoil, including the Union of England and Scotland on May 1 1707 and adoption of the Union Jack; the incorporation of the South Sea Company (1711); the Treaty of Utrecht (1713); the "Fifteen" Jacobite rising in Scotland (1715-1716); the war with Spain (War of Jenkin's Ear; 1739-1748); War of the Austrian Succession (1740-1748); the Second Jacobite Rebellion (1745-1746); adoption of the Gregorian calendar (1752; "Give us back our eleven days" – the days between September 2 and September 14 were omitted); land and naval war between Britain and France (1756-1763); the Treaty of Paris (1763); the resignation of Lord North for failing to subdue the American colonies (1782); and the War of American Independence (1775-1783). At the beginning of 1801, the legislative union of Great Britain and Ireland was enacted, under the name of the United Kingdom.

The Eighteenth Century is thought by many historians to represent artistically the shift from the Classical to the Romantic ages, but it was the initiator of the Industrial Revolution and the Agricultural Revolution. Robert Burns died in 1796, by which

time there had been a war with Revolutionary France for three years. Science and technology had already made great strides, *e.g.* John Tuberville Needham (1713-1781) in *Observations upon the Generation, Composition, and Decomposition of Animal and Vegetable Substances*, published in 1748, reported that boiled, sealed flasks of broth teemed with "little animals", but Lazzaro Spallanzani (1729-1799) devised properly controlled experiment to test such factors as the amount of heat needed to kill contaminating microorganisms. In 1749, George Leclerc, the Compte de Buffon (1707-1788) published the 54-volume *Histoire naturelle*, focusing on the main elements of evolutionary biology up to the beginning of the 20th century – geographical distribution, development, isolation, transmutation, correlation, and variation of organisms. In the tenth edition of *Systema naturae*, published in 1758, Carl Linnaeus (1707-1778) catalogued all the then-known flora and fauna, including humans, consistently using a binomial nomenclature, thereby laying the basis of modern taxonomy. Agriculture had been advanced by the publication in 1732 of Jethro Tull's (1674-1741) *New Horse Hoeing Husbandry* describing his inventions and introductions, such as the seed drill (1701), the horse-hoe, and soil pulverisation. Robert Bakewell (1725-1795) introduced selective breeding of livestock. Charles Townshend (1674-1738) introduced crops such as turnips and clover for winter fodder. These early pioneers, whose efforts were publicised by Arthur Young (1741-1820), produced the Agricultural Revolution that led to fundamental changes globally in the production of foodstuffs and animal materials such as wool and hides. By 1801, Franz Achard (1753-1821) built the first sugar-beet factory in Silesia, enabling the sugar beet industry to develop in France and Germany. In 1834, Cyrus H. McCormick (1809-1884) patented his reaper. Plough technology was developed by Jethro Wood (1774-1834) with the cast-iron plough in 1819; John Lane in 1833 with the steel-bladed ploughshare; John Deere (1804-1886) introduced the steel plough in 1837; the chilled plough of 1855 by James Oliver (1823-1908) was improved in 1857 by the Marsh brothers; cable ploughing was introduced in 1850 to be followed by the steam plough by John Fowler in 1858. The revolving disc harrow was introduced in 1847, the binder in 1850, two-horse straddle-row cultivator in 1856, combine harvester in 1860, combine seed drill in 1867, and the sheaf-binding harvester in 1878. Pasteurisation as a preservation technique for beer, wine, and milk was introduced in 1861 after the pioneering work of Louis Pasteur (1822-1895). Chemical fertilisers came into widespread use in the 1880s following the pioneering research at Rothamsted by J. B. Lawes. Mechanical freezing, long-distance rail travel, internal-combustion-engined tractors were introduced in the latter half of the 19th century. Between 1850 and 1900, about 200 million hectares of grazing land in the USA were converted into grain fields; similar conversions to arable land took place in Australia, Russia, and several countries in South America.

In the first part of the 19th century in the UK, the ending of the Napoleonic wars was associated with economic depression, and as a form of remedial action, the Corn Law of 1815 was introduced to protect agricultural landlords from imported grain until home-grown corn reached the "famine price" of 80 shillings a quarter. Bread prices rose and there was widespread malcontentment. In the 1820s, William Huskisson, the then President of the Board of Trade, breached the protectionist mercantile system by reducing duties in several imports (*e.g.* coffee, sugar, cottons, woollens, silk, iron *etc.*). In 1828, the Corn Law was modified to permit grain to be imported at any time and fixing duties on a sliding scale. Parliamentary reform characterised the period 1830-1846, introducing important social developments (abolition of slavery in the colonies, the Factory Act, growth of trade-unionism, new Poor Law *etc.*). In 1845-1846, there was considerable agitation against the Corn Law, fostered by Richard Cobden and John Bright, political leaders of the Manchester School, building on the Manchester Anti-Corn Law Association (1838) and Anti-Corn Law League (1839). The ruin of the Irish potato crop and the threat of famine were instrumental in gaining the support of Robert Peel, leading in turn to the Repeal of the Corn Laws on June 6 1846. By June 29 1846, the government led by Peel was overthrown by a parliamentary revolt led by Benjamin Disraeli. In 1879, there was a severe agricultural depression arising from the worst harvest of the century, a period associated with a general economic downturn, several strikes, the unpopular Afghan and Zulu wars, and problems with Ireland. The remainder of the 19th century, like the rest of the century, was marked by growing internationalisation of trade, and scientific and technological achievement.

UK agriculture was transformed with enclosure (inclosure) of 'waste' and common land. During 1702 to 1802, 577 Acts were passed for enclosing over 8 mil-

lion acres of such land. *The First Report from the Select Committee of The Honourable The House of Commons Appointed to take into Consideration the Means of promoting the Cultivation and Improvement of the Waste, Uninclosed, and Unproductive Lands of the Kingdom*, 1 January 1796 (price one shilling and replete with interesting spellings and the long s(f)!) resolved that "the cultivation and improvement of the waste lands and commons of the Kingdom is one of the most important objects to which the attention of Parliament can possible be directed, and that the granting of a bounty to encourage the cultivation of potatoes, in lands at present lying waste, uncultivated or unproductive, would not only be the means of augmenting, in a considerable degree, that valuable article of food, but might also be the means of promoting the improvement of extensive tracts of land, at present of little value". The Select Committee also opined that "certain legal liabilities that stand in the way of division and enclosure of waste lands should be removed". Reference was made to the idea of lands in common was "derived from that barbarous state of society, when men were strangers to any higher occupation than those of hunters or shepherds, or had only just tasted the advantages to be reaped from the cultivation of the earth". "Those who live in the neighbourhood of great wastes are still an idle and lawless set of people", "that such commons are the frequent resort of thieves and other depredators on the public", "and are on that account but particularly near the capital, a public nuisance". The Bishop of Landaff stated "That whilst there is an acre of such waste improveable land in Great Britain, it may be hoped that when the Legislature shall turn its attention to the subject, no inhabitant of this island will be driven, by distress, to seek a subsistence in Africa or America". The report estimated that there were 7,888,777 acres of uncultivated land in England and 14,218,224 acres in Scotland giving a total of 22,107,001 acres of waste land, compared with 39,027,156 cultivated acres in England, and 12,151,471 acres in Scotland. The uncultivated area was regarded as a great source of future national wealth.

"The waste lands above enumerated are not only uncultivated themselves, but they have a tendency to make the farmers in the neighbourhood neglect the improvement of the lands they enjoy in severalty".

"If any person entertains an idea, that a General Inclosing Bill is an impractical measure, his doubts will probably be removed, when he is informed that such an act was passed about a century ago in Scotland, and has been found to answer the purpose thereby intended". "Act concerning the dividing of commonties, passed in the Parliament of Scotland, 17th July 1695".

"In regards to the climate of such wastes, it is evidently worse in consequence of the want of cultivation. – At the same time, from the insular situation of Great Britain, the climate is infinitely milder and better than in any part of the continent of the same latitude. It is stated in one of the Reports, on the most respectable authority (George Dempster Esq), that very fine barley and oats ripen in due season, on the summit of a hill in Forfarshire, elevated 700 feet above the level of the sea; and that in Invernesshire, at an elevation of 900 feet above the same level, wheat of a good quality has been grown. – Hence it may be inferred, that grain, and other articles of a similar nature, may be raised to such a height upon the sides and summits of all the hills in the island; and, in regard to grass, it is well known, that luxuriant crops of hay are obtained at the lead hills of Lanarkshire, elevated 1,500 feet above the sea. The climate of this country, therefore, can hardly be urged as an objection to the improvement of the greater part of our wastes, either for grain or grass; as to trees, it is not to be questioned, that the larch grows in Italy on higher mountains than any we have in this island."

"Lastly, at least a million acres of the Waste Lands in the kingdom may certainly be brought to an astonishing height of produce by watering or irrigation. – This great means of improvement, though long established in some parts of the kingdom, yet in others has been unaccountably neglected. But when once that art is extended as it deserves, the advantages thence to be derived cannot easily be calculated, - for by it land is not only rendered perpetually fertile without manure, but the luxuriant crops which it raises, produces manure for enriching other fields; and the manure obtained from the produce, it another source of national wealth, that otherwise could not be looked for."

"Nor ought the wealth to be derived from the improvement of our Wastes to be alone taken into consideration. The increase of population, and above all, of that description of persons who are justly acknowledged to be the most valuable subjects that any government can boast of, merits to be particularly mentioned. His mind must indeed be callous, who feels himself uninterested in measures, by which not only the barren Waste is made to smile, but of which

the object is, to fill the desart with a hardy laborious, and respectable race of inhabitants, the real strength of a country; being the fruitful nursery, not only of our husbandmen, but also of the fleets, the armies, and the artists of the nation. The additional number of inhabitants, who might thus receive occupation and subsistence, cannot easily be ascertained; but if the present population of Great Britain amounts to about ten millions, these Wastes and Commons, properly improved, might be the means of adding, at least, from two to three millions; - a number, it may be proper to observe, equal to that possessed by the United States of America, when they first erected the standard of independence against the Mother Country. The evils were then felt from the creation of such an extent of population at a distance: but from such an increase of people at home, instead of similar consequences being to be apprehended, additional strength and prosperity of every description may be looked for with certainty".

"There is another point of view in which this subject ought also to be considered. – The improvement of Wastes not only adds to the wealth and population of a state, but also renders it more defensible. An inclosed country is, perhaps, the strongest of any. Every hedge and ditch becomes a rampart, through which an enemy cannot easily penetrate, and which there is little difficulty in defending. Were this kingdom completely inclosed, and no opportunity afforded of fighting any pitched battle (the only thing to be dreaded in the event of an invasion) we should have little reason to apprehend the landing of any body of men, however numerous, or however well disciplined. They might do some mischief on the coast, but could never penetrate into the interior of an inclosed country. The best defence the capital can have, is not to suffer a spot of unenclosed ground to remain between it and the coasts in its neighbourhood."

"Before concluding this Address, it is necessary to take notice of one important circumstance. For some years past, this kingdom has been under the necessity of importing grain from other countries; and the importation seeming to increase, rather than otherwise, it was seriously apprehended that the agriculture of this island could not furnish grain sufficient for the use of its inhabitants. – Many reasons may be assigned for the scarcity of grain; the seasons, since 1754, have certainly been in general unfavourable. We have seldom had two successive good seasons, but often two successive bad ones. To this natural cause may be added the increased population, consumption, and the luxury of the people, and the greater attention that of late has been paid to the improvement of stock, in consequence of which considerable tracts of arable land have been converted into pasture. This, instead of being a public loss, was undoubtedly a national benefit. Land that for ages had been kept in tillage, and produced but scanty crops of grain, required rest, and was usefully appropriated for pasture."

"Appendix D.
On the culture of POTATOES in Waste and Boggy Lands; from the Publications of the Board of Agriculture, and other Authorities."
"Old pastures have always been considered extremely favourable to the culture of potatoes, and even upon bogs partially or wholly drained, and upon such rough soils as are difficult to plough, this method has been successfully adopted; - pare and burn the surface: add lime to the ashes: strike the lands into straight beds, six feet wide, with intervals of two feet, and two and a half. Lay the sets twelve inches square on the beds, and cover them two or three inches deep, with spades from the intervals: when the plants appear, cover them again in the same manner, one and half or two inches more. Keep them clean by one hand-hoeing, and successive weeding. They may be taken up with the plough; by splitting the beds, and filling the former intervals; converting the open furrows, left in the center of the former beds, into drains, deep enough to leave the land dry in winter."
"In Dumbartonshire, the potatoe culture for improving waste and mossy soils, universally acknowledged to be of great advantage. Cutting down brush-wood, and removing great stones, is the whole preparation, previous to planting."
"In West Lothian, it is observed, that the upland parts of the country produce larger crops, than the more cultivated and low situations."
"In East Lothian, in the high district, the crops more productive than in the low part of the country. Sixty bolls, barley measure, is not reckoned a great crop; but in the low district, rarely more than forty or fifty."
"Sir W. Stirling, in Perthshire, has often raised forty bolls of potatoes on an acre of light moor, not worth 1s. – Rent at 5s. only: here are two hundred rents."
"In Roxburghshire, Baron Rutherford has found them the best means of bringing Waste Lands into culture."
"In Dumbartonshire, Sir James Colquhoun improved a peat moss, by planting potatoes in the lazy bed ways; sowed after them, meadow soft grass, with the oats, which is excellently adapted to mossy soils, as it spreads quickly. This was mown every year; the bog,

being ten or twelve feet deep, could not be pastured."
"In the highlands of Scotland, the fairest and largest potatoes are produced upon the spongy mosses, planted in lazy beds."
"They find in Perthshire, that mosses, when drained, are a favourable soil for potatoes."
POTATOES on WOODLANDS
"Mr. Abdy, of Essex, an honorary member of the Board, grubbed a wood, dunged it with twenty wagon-loads an acre, and planted potatoes: produce 563 bushels *per* acre; expence £.16. 13s. 6d.
Observation. – This single experiment may be of use to those who grub up woods, as it may probably be found that no other crop is better adapted to be first had resource to on such occasions. – It merits a trial to discover whether dung is necessary in such cases."
Improvement of Waste, by TURNIPS and POTATOES
"The following practice seems to be well entitled to particular attention, as an excellent mode of improving Waste Lands. First burn the surface of the coarse grounds, such as the outskirts of bogs, and lands overrun with furze, heath, fern, &c. in the months either of March of April, or even May, and spread the ashes about the beginning of July. Then plough and harrow the lands, and sow it with turnips, the crop from which will probably pay the rent and expences. In the Spring following plough and harrow the land, and without any farther manure plant the potatoes with a small plough. The crop from new ground treated in this way is very great: Sometimes a second crop of potatoes is taken, but in general the sooner new land can be laid down in pasture, the better, until it has acquired strength sufficient to yield crops of grain in regular rotations. According to the nature of the soil, it may be laid down with grass-seeds, either with barley, if the land is light, or with oats, if it is strong or heavy."

At the end of the 18th century, food security and agricultural technology were patently high-priority issues in government. In the next report in this series, I shall comment on the period 1900 to the present.

Concluding Comments

Research in the life and environmental sciences is progressing at a phenomenal rate, producing unprecedented numbers of discoveries, inventions, concepts, products, and new processes that are having substantial societal and scientific impacts. The life science industry in the USA alone raised $44 billion between mid-1999 and mid-2001. A widening gulf is opening up between those elite organisations and companies that have attained a critical mass of talented scientists and state-of-the-art physical resources, and lesser well-resourced or inappropriately managed organisations and companies striving unsuccessfully to be world class. Innovation, as some of the major pharmaceutical companies now realise, is a precious asset that requires careful custodianship and sensitive management that allows intellects to blossom. Micromanagement, excessive short-term target setting, constant reviews, and persistent financial instability provide the wrong environment.

Over the next five years, agriculture is likely to remain under massive price pressures in order to meet the demands of urban populations and politicians for cheap and wholesome food, all-year-round, regardless of the weather. Food prices globally have progressively declined in real terms. Irrespective of the generic nature of the science, engineering, and technology used in the life and environmental sciences, agricultural innovation is likely to be one of the casualties of these pressures, as profitability and investment decline. Agricultural production is essentially a private-sector activity – it has been badly affected in the past by unnecessary regulation, intervention by heavy layers of bureaucracy, taxation, subsidy, and an underlying willingness of certain states to become almost a monopoly supplier – collectivisation, after all, has led to starvation. A stagnation or suppression of agricultural R&D – R&D well supported in the past by both the public and private sectors - is a potential disaster as governments have become complacent on the back of technology-dependent agricultural successes, forgetting the vagaries of the weather and the adaptability of pests and diseases, and population pressures in various parts of the world. In *Agriculture and rural extension worldwide. Options for institutional reform in the developing countries,* FAO, Rome, 2001, agricultural extension systems in various countries are now described as failing, moribund, in disarray, or barely functioning. Access to water, water-use efficiency, and nutrient-use efficiency by crops, and cultivar performance are huge issues. Numerous studies have shown that agricultural improvement reduces poverty and inequality. In Africa, agriculture employs around 66% of the labour force, and accounts for 37% of GNP and around 50% of exports (*World Development Report 2000,* World Bank, Washington DC). N. Nagarajan in *The Millennium Round: An economic appraisal* (European Commission Economic Papers, European Commission, Brussels) estimated that developing country gains from a 50% cut in mainly agricultural tariffs, by both MDCs and LDCs, would be in the

order of $150 billion, about three times the aid given to LDCs. These gains would help improve LDC agriculture. The CGIAR Centers are now under financial pressure. Even international genebanks and germplasm collections are suffering from declining funding – according to FAO, there are about 6 million samples of plants held in around 1,300 repositories, many of which in the LDCs may be lost, despite the worldwide commitment to safeguard biodiversity. I urge policyholders in the UK and elsewhere to consult *Global Food Projections to 2020. Emerging Trends and Alternative Futures* by M. W. Rosegrant, M. S. Paisner, S. Meijer, and J. Witcover, International Food Policy Research Institute, August 2001, and related documents from that CGIAR Center. As P. Pinstrup-Andersen points out, there is one inescapable conclusion: "even rather small changes in agricultural and development policies and investments, made in both developed and developing countries, can have wide-ranging effects on the number of poor and undernourished people around the world. The policy choices we make now will determine to a considerable degree what kind of lives the next generation will lead".

Another particular pressure in the UK is the policy environment surrounding agriculture and the countryside, with the involvement of a wide range of stakeholders, some holding irreconcilable opinions. Agriculture in the UK remains in the doldrums and faces further harsh times. It tends to be judged on farm-gate prices rather than its underpinning role in supporting other sectors of the economy; few realise that there are more people employed in rural manufacturing than in urban manufacturing (A. Michael MP; November 9 2002), or that the profitability of the food processing industries, the catering and resturant, and retailing is dependent on low-cost primary produce. Industries directly related to agriculture, such as plant breeding and agricultural chemicals are under stress. Many companies are disinvesting from the UK, and their associated R&D activities terminated. There is talk of a 'post-agricultural' countryside such that farming is but one of several participants and often regarded merely as a recipient of rural social therapy (*i.e.* public funding) to maintain 'environmental goods'. New thinking is required. Farming is eminently capable of producing new types of crop and livestock; new ways of helping to provide the lungs, kidneys, visual amenity, and recreational base for the urban masses; as well as producing the usual food and non-food items. Most important, agriculture can be, should be, and must be, a successful business. A UK agricultural roadmap should be synthesised. Allied to the present decline in UK agriculture is a decline in plant science (botany). From a position of international pre-eminence in numerous universities, institutes, and companies, botany has diminished rapidly in national importance, such that there is a loss of scholarship in certain key areas of the subject. It is in the scientific, diplomatic, and economic interest of the UK that the situation is rectified. Fortunately, the generic nature of the research conducted in certain institutions such as SCRI, and its applicability to a range of environmental, industrial feedstock, regulatory, and health-related industries and activities, mean that there remains a thriving core of basic, strategic, and, to a lesser extent, applied research in the UK.