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UNITED NATIONS
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CONTRIBUTION OF BIOTECHNOLOGY TO SUSTAINABLE DEVELOPMENT WITHIN THE FRAMEWORK OF THE UNITED NATIONS SYSTEM*

Prepared by

M. S. Swaminathan**

* The views expressed in this paper are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO. This document has not been edited.

** Centre for Research on Sustainable Agricultural and Rural Development, Madras, India.

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Preface

This paper has been prepared in response to a decision taken at a meeting of the United Nations ACC Task Force on Science and Technology for Development, held in New York from 6 to 8 February 1991. At that meeting it was agreed that the Task Force should concentrate over the next year on the area of the contribution of biotechnology to sustainable development and that a paper would be prepared to cover the national, regional and international (NGOs and UN) system/levels, with particular reference to socio-economic and legal implications, ethics, safety, the impact on employment, the international division of labour, etc. The paper was to be both analytical and forward-looking, with specific recommendations.

The Task Force agreed that UNIDO should take the lead in preparing the paper, with inputs from concerned organizations and agencies. The audience for this publication was to be the policy-making organs within the UN System that address biotechnology-related issues.

The present paper, which awaits consideration by the Task Force, has been written in a manner that is of interest to a wide audience. It is hoped that the recommendations contained in this paper will be acted upon by the international community.

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INTRODUCTION

Sustainable development demands the integration of the principles of ecological soundness and of equity with those of economic efficiency in the development of both technology and public policy. The broad group of technologies associated with modern biotechnology offer new opportunities for promoting a better quality of life for all, while living within the carrying capacity of supporting ecosystems, provided proper research priorities and strategies and public policies are followed.

The scientific principles and tools underpinning biotechnology are largely the outcome of research done in universities and public-funded institutions. On the other hand, the conversion of scientific discoveries into economically viable technologies is being done largely in the private sector in industrialized nations. The hard core of modern biotechnology is genetic engineering or recombinant DNA methodology, which enables the creation of novel genetic combinations. Such novel combinations need access to a wide range of genetic material, thereby resulting in a feed-back relationship between biotechnology and biodiversity.

These features of biotechnology have resulted in international debates and dialogues between industrialised and developing countries on matters relating to intellectual property rights and patenting procedures for living organisms on the one hand, and reward and recognition to the informal innovation systems of rural women and men, responsible for the preservation of a wide range of intra-specific genetic variability, on the other. The recent adoption of a revised UPOV convention for the protection of new varieties and the patenting of plant related biotechnological inventions, the statement of the Green Industry Biotechnology Platform and the acceptance of the concept of Farmers' Rights in FAO meetings are significant events in the ongoing debate on biotechnology and IPR. The establishment of an International Centre for Genetic Engineering and Biotechnology (ICGEB) by UNIDO is an important milestone in the history of biotechnology development for developing countries.

Biotechnological innovations offer scope for making substantial impacts on crop and animal husbandry, fisheries, forestry, biomass-based energy, bioremediation, health, industry, pollution control and a wide range of human activities having a bearing on sustainable development. No wonder many members of the UN family, as well as the World Bank and Regional Development Banks like the Asian, African and Inter-American Development Banks are playing a pivotal role in the development of biotechnological innovations and their widespread dissemination in developing countries. In addition, international scientific bodies like the International Council of Scientific Unions (ICSU) regional associations like the Commission of the European Communities and private industry are actively involved in various aspects of biotechnology research and development.

The human population is likely to double in about 35 years. More than 10 billion people will have to fed, clothed and provided with jobs under conditions of shrinking land and water resources for agriculture, expanding biotic and abiotic stresses, increasing genetic erosion and rising cost of fossil fuel energy reserves. Compounding these social and economic problems is the possibility of alterations in climate, rise in sea levels and greater incidence of ultraviolet-B radiation, caused by both unsustainable life styles and the undesirable consequences of some of the current industrial and agricultural technologies.

It is in the above context that the Preparatory Committee for the United Nations Conference on Environment and Development (UNCED) concluded at its Third Session held in Geneva from 12 August to 4 September 1991, that the environmentally sound and safe application of biotechnology is essential for health care and food security, pollution control, higher efficiency of industrial development processes and biodegradation of industrial wastes. The Committee therefore urged the acceleration of current efforts on the development and application of biotechnologies, particularly in developing countries.

How can such a goal be achieved? Obviously this will call for institutional mechanisms which can ensure that public good and private profit are not mutually antagonistic. The UN principle of "one country one vote" helps to keep all points of view in decision making. The UN principles are the ones which will promote harmony and understanding under conditions of diversity in needs, perceptions, socio-economic conditions, technological capability and biological wealth. How can the power o_ modern biotechnologies be used for promoting economic development without damage to the ecological health of our planet and for ensuring that the welfare of the poor is enriched and not eroded by technological progress?

During the last two decades, the institutional structure represented by the Consultative Group on International Agricultural Research (CGIAR), cosponsored by FAO, UNDP and IBRD, has proved to be an effective mechanism for reaching the resource poor farmers as well as for inspiring donor confidence. As a consequence, the annual budget of CGIAR comprising <u>voluntary contributions</u> by bilateral and multilateral donors and philanthropic foundations rose from about US$ 10 million in 1971 to about US$ 350 million in 1991.

Considering the far-reaching implications of biotechnology for human welfare and planet protection, it would be appropriate if a global coalition is formed through a <u>Consultative Group for Biotechnology</u> (CG-Biotech), which can bring together appropriate members of the UN system, bilateral and multilateral donors, foundations, private and public sector industries and governmental and non-governmental organisations. The CG-Biotech could help to mobilize the necessary financial, technical and institutional resources for ensuring that the benefits of "green" or environmentally benign biotechnologies reach the unreached.

The participants of the International Conference on "An agenda of science for environment and development into the 21st century" (ASCEND 21) sponsored by ICSU and held at Vienna from 25-29 November 1991, concluded that unprecedented crises are likely within the lifetime of half of the world's population, arising from such changes as:

- world population doubling to 10 billion in only 35 years;
- migration and urbanization, assuming dramatic proportions, with notable consequences on coastal zones;
- continuing rise of energy consumption exerting increasing pressures on the global ecosystem;
- climate change, sea-level rise and associated impacts on the biosphere;
- irreversible loss of a substantial part of the total number of living species;
- continued reduction and deterioration (including chemical population) of quality of the natural resource base including the exhaustion, degradation, salinization and loss of a major proportion of the world's soils;
- growing and widespread water scarcity.

Biotechnology can be a powerful ally in the development of avoidance and adaptation mechanisms which can prevent or mitigate the adverse impact of such crises.

Hence, no further time should be lost in the development of a suitable institutional framework, which can foster the growth of a global coalition committed to removing the technological component of the wall dividing prosperity and poverty. Innovative and dynamic institutional structures are essential for dealing with the human implications of a dynamic science. Suggestions are therefore given to convert the idea of a CG-Biotech into reality.

CHAPTER I

Sustainable Development and Biotechnology

1.1 Definition of terms

Sustainable development can be defined in several ways. The World Commission on Environment and Development (WCED) defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This definition, in operational terms, creates problems in distinguishing sustainable development from sustainable growth. IUCN, UNEP and WWF in their strategy for sustainable living titled "Caring for the Earth" published in October 1991, have therefore preferred the following definition:

> "Sustainable development is improving the quality of human life while living within the carrying capacity of supporting ecosystems".

A sustainable economy is the product of sustainable development. It maintains its natural resource base. It can continue to develop by adapting and through improvements in knowledge, organisation, technical efficiency, and wisdom. A "Sustainable Society" lives by the following nine principles:

a. Respect and care for the community of life
b. Improve the quality of human life
c. Conserve the Earth's vitality and diversity
d. Minimise the depletion of non-renewable resources
e. Keep within the Earth's carrying capacity
f. Change personal attitudes and practices
g. Enable communities to care for their own environments
h. Provide a national framework for integrating development and conservation
i. Forge a global alliance

The document "Caring for the Earth" also provides indicators of sustainability and strategies for achieving sustainability. Among the indicators, the Human Development Index (HDI) of UNDP (1990), which includes the following three components, is regarded as an important one:

a. Longevity
b. Knowledge and
c. Income

An ecologically sustainable society is one which

a. Conserves ecological life support systems
b. Conserves biodiversity
c. Ensures that uses of renewable resources are sustainable
d. Minimizes the depletion of non-renewable resources, and
e. Keeps within the carrying capacity of supporting ecosystems.

Successful strategies for sustainable development have four components in common:

a. Consultation and consensus building
b. Information assembly and analysis
c. Policy formulation
d. Action planning and implementation

The inter-governmental negotiations currently in progress in connection with the 1992 UN Conference on Environment and Development (UNCED) relate in several aspects of the call of WCED "to transform this report into a UN Programme of Action on Sustainable Development". Conventions on climate, biological diversity and forests are under negotiation under the auspices of WMO, UNEP and FAO respectively. The following goal is also listed among the priority objectives of UNCED:

> "Eradication of poverty and ensuring access by the poor to sustainable livelihoods and the requirements for human development"

What are the implications of biotechnology to these critical issues being grappled today in international fora? The literature on this subject is vast and quite opposing views are often expressed. Albert Sasson's book "Biotechnologies and Development" published by UNESCO in 1988 is a comprehensive and credible source of information on developments in biotechnology.

Henk Hobbelink's book titled "Biotechnology and the Future of World Agriculture" published in 1991 articulates very well the concerns of developing countries with reference to the potential adverse and positive impacts of biotechnology on global and national food security. The book "Agricultural Biotechnology: Opportunities for International Development" edited by Gabrielle J. Persley and published by C.A.B. International in 1990 gives a good overview of the role of international institutions in the development of biotechnology. The book "Social Consequences of Genetic Engineering" edited by David Weatherall and Julian Shellley (1989) is a good source of information on the interaction between science and society in the area of Biotechnology. Similarly, the book "New Technologies and the Future of Food and Nutrition" edited by Gerald Gaull and Ray Goldberg (1991) provides an excellent summary of the work done by private industry and of the problems arising from public perceptions on the safety of food arising from genetic engineering research. The book "Biotechnology in Agriculture: Reaching the Unreached" edited by M.S. Swaminathan and published by MacMillan India in 1991 is the most recent and comprehensive treatment on methods of imparting a pro-poor bias in the development and dissemination of biotechnological innovations.

The term biotechnology is currently being used to connote a wide variety of biological manipulations such as cell and tissue culture, embryo transplantation, transfer of DNA material across sexual barriers,vaccine production, bio-remediation, microbiological enrichment of cellulosic material, fermentation and various forms of biomass utilization. There are immediate opportunities for the multiplication of superior clones of fruit and forest tree species, as well as plantation crops like cardamom and oil palm through tissue culture methods. Enchancing biomass production and its conversion into energy are important applications.

The hard core of biotechnology is recombinant DNA technology resulting in transgenic micro-organisms, plants and animals. The first transgenic plants expressing engineered foreign genes were produced in tobacco in 1983 by the use of Agrobacterium tumefaciens vectors. Since then, transgenic material has been produced in a wide range of plants, animals and micro-organisms. The Animal and Plant Health Inspection Service of the U.S. Department of Agriculture issued nearly 100 permits for testing genetically engineered material in the field between November 1987 and September 1990. The plants with new characters now under testing include maize, cotton, soybeans, potato, tomato, tobacco, alfalfa, cucumber, cantaloupe, squash, rice, walnut and poplar. We can expect even more rapid progress in the nineties as a result of the work of research networks like that supported in rice by the Rockefeller Foundation as well as due to the growing interest in the private sector for investing in biotechnology.

1.2 Biotechnology and Food Security

Since food is the first among the hierarchical needs of human beings, it may be appropriate to deal with food related issues first.

There has been considerable debate in recent years on the potential impact of new biotechnologies on agriculture. According to Ellen Messer and Peter Heywood ("Trying Technology: neither sure nor soon", Food Policy 15, pp. 336-345, 1990), the impact of biotechnology in overcoming hunger may have to await the next millennium. Since this view is not widely shared a few issues relating to research and extension in the field of biotechnology are dealt with at some length.

The significance of biotechnology for a better biofuture of the Third World can be illustrated by taking the example of Asian agriculture. Asia has over 50 per cent of the global population, over 70 per cent of the world's farming families, but only 25 per cent of the world's arable land. At the beginning of the 21st century, the per capita land availability will be 0.1 ha. in China and 0.14 ha. in India. The average Asian population growth rate is 1.86 per cent.

The only pathway open to countries like China and India for feeding their growing human populations is continuous improvement in yield. This involves research which can further raise the yield ceiling. China has gone into the large scale exploitation of hybrids in rice for this purpose. The tools of biotechnology can help in raising the productivity of major crops through an increase in total dry matter production, which can then be partitioned in a way favourable to the economic part. Improved irrigation water management and the incorporation of genes for drought-tolerance in major crop plants are urgent necessities.

According to the Senior Advisory Group on Biotechnology (SAGB), a senior industrial forum for debating policy issues affecting biotechnology in the European Community, crop improvements under active development around the world using modern biotechnologies include disease and pest resistance, higher nutritional value and improved taste, longer storage life, tolerance of heat or cold, tolerance of salty soil, tolerance of wetness and aridity and reduction of post-harvest losses.

In animal husbandry also, the needs of developing nations, particularly in South and Southeast Asia, differ from those of the industrialised countries. Most of the productive animals in India, for example, are stall-fed. In India, this enables government to provide farm animals to landless labour families for increasing their household income. Such resource-poor animal-rearing families have to be assisted in running the enterprise as efficiently and economically as possible, by providing services in the areas of genetic improvement, health care, nutrition and marketing. Nutrition has to come from high-yielding fodder legumes and grasses grown in crop rotations and from enriched cellulosic material.

A market research report entitled "Biological Products for Aquaculture - A Worldwide Market Study on Vaccines, Therapeutics, Diagnostics, Hormones and Genetic Manipulations" published in 1990 by the Technology Management Group. New Haven, USA, suggests that as aquaculture farms increase their production per unit space, effective disease and stress control will assume greater importance. The markets for vaccines, diagnostics, hormones and new feeds will increase. It is anticipated that by the year 2000, 25 per cent of world-wide seafood consumption is likely to be produced by aquaculture. Vaccines are seen as a growth area, since vaccines are still needed for many major diseases. In Scandinavia and parts of the USA, nearly all trout and salmon, produced by aqauaculture, were vaccinated in 1989 as compared to 5 per cent in 1984.

Many companies are developing aquaculture therapeutics to meet the growing demand. It is estimated that over 50 per cent of the total global production of fish, shellfish and molluscs is lost to disease. Breeding programmes and genetic engineering have led to the production of new "boneless" breeds of trout that have a better feed conversion rate, and salmon which possess an antifreeze gene to enable them to survive in colder waters. Further research in fish breeding is expected to focus on growth acceleration, sex identification and determination, flesh quality, disease resistance, sea water adaptation, and the ability to utilize specific dietary components. Thus, biotechnological research is opening new windows of opportunity both in terrestrial and aquatic farming systems.

1.3 Industry

As regards industry, industrial processes based on modern biotechnology often consume less raw material, water and energy than traditional methods. They consume renewable organic raw materials rather than non-renewable resources. Typically, they do not rely on the use of hazardous compounds, and employ low temperatures and pressures. They produce biodegradable industrial waste, usually in smaller volumes compared with traditional methods. Micro-organisms able to decompose noxious and toxic substances in water, air, soil and solid waste provide safe and highly effective treatment of household and industrial waste. It is claimed that specially selected or adapted micro-organisms today can decompose more than fifty pollutants typically found in hazardous waste sites, rendering them harmless and that biological methods of waste treatment and clean-up are often cheaper and more effective than physical and chemical alternatives. The clean-up of oil-contaminated soils using micro-organisms has proven particularly successful.

The following table, material for which has been taken from a SAGB document, illustrates certain products produced by modern biotechnology and their environmental pay-off.

Product	Environmental pay-off
Diagnostic agents: Modification of a natural micro-organism to produce glucose-6-phosphate dehydrogenase has improved production efficiency of this biochemical used for blood diagnosis.	One cubic metre of fermentation capacity now replaces 600 cubic metres of capacity, giving dramatic reductions in the consumption of raw materials, water and energy, and far smaller volumes of waste.
Antibiotics: An enzyme isolated from a modified micro-organism now makes the enzymatic conversion of penicillin G more efficient than chemical synthesis.	Elimination of most chemical outputs and chemical solvents; consumption of half the energy for the same output.
Detergents: Enzymes derived from modified micro-organisms are now used in more than 75 per cent of all "enzyme" detergents (already most of the world detergent market).	Energy savings of 30 per cent or more from lower temperatures; improved cleaning performance at lower temperatures, with preservation of colours and fabrics due to milder conditions.

Leather production:
Enzymes derived from modified micro-organisms are increasingly used for the removal of hair from animal hides and to treat chrome shavings in tannery waste streams.

Use of less lime and sodium sulphide to dissolve hair; elimination of large quantities of organic solvents in the production process; reduced biological demand for oxygen in waste water; re-use of chrome salts instead of dumping of chrome shavings.

Paper production:
Enzymes derived from modified micro-organisms now facilitate the separation of lignin from cellulose.

Reduction in the use of chlorine bleach in paper and pulp production by up to 35 per cent.

Plastics and polymers:
Modified micro-organisms now make practical the production of these materials from organic matter - e.g. bioplastic is already used in certain packaging applications.

Use of renewable raw materials; biodegradable product waste; no net addition of CO_2 when decomposed or incinerated.

According to a study of the UN Centre on Transnational Corporations, the use of recombinant DNA techniques has proved to be substantially more cost-effective in producing antibiotics than the conventional fermentation techniques. Alpha interferon could be produced in large quantities under US$ 1,000 per pound by recombinant DNA technology, whereas the conventional technology of purifying from human white blood cells would cost an astronomical US$ 20 billion per pound. According to J.L. Glick, the use of recombinant DNA technology would yield a unit cost of US$ 6.14 per pound with a concentration of 6 per cent antibiotics with fermentation beer, while the traditional method resulted in a unit cost of US$ 13.32 per pound with a concentration of 1.2 per cent antibiotics. This sizeable cost reduction was made possible by the increased efficiency of the genetically engineered organism. In addition, a substantial cost saving was observed in the use of raw materials; savings of 50 per cent capital expenditure for equipment, building and storage, and utility bills for processes were achieved.

An immobilised cell system can be developed by genetically engineering a microbial strain. The use of an immobilised cell system rather than the conventional batch fermentation could bring about a considerable unit cost reduction in many cases. For example, for a two million pound plant producing a typical amino acid, the difference in the unit cost is quite substantial, US$ 4.15 per pound for batch fermentation and US$ 2.85 per pound for the immobilised cell system. In particular, the prices of two amino acids, methionine and lysine, which are sold in bulk as animal additives, dropped drastically from around US$ 8 and US$

24 per pound prior to 1960 to around US$ 1 and US$ 2 respectively, 20-30 years later. At the same time, annual sales world-wide increased 70-fold for methionine from 1954 to 1980 and 450-fold for lysine from 1958 to 1980.

It is generally agreed that biotechnology holds its most immediate promise in the pharmaceutical industry. Recombinant DNA technology is expected to generate the large-scale manufacture of many drugs and vaccines at lower costs than conventional technology. The list of drugs to be produced by gene splicing techniques include human insulin, human growth hormone, human interferons, Hepatitis-B vaccine and penicillin G-acylase.

In the chemical industry, the application of biotechnology is becoming increasingly important. Since the beginning of this century, the chemical industry has been heavily dependent upon petroleum as a raw material. But because of the rising cost and dwindling sources of petroleum, the chemical industry is turning more and more to the biotechnological possibilities of converting biomass and carbohydrates into chemicals. Thus, biotechnology plays a dual function of providing both the raw materials and a production process for the chemical industry.

In particular, most chemical processes are catalytic reactions requiring high temperatures and pressures. By contrast, biological synthesis utilizes nature's catalysts, or enzymes, which operate at much lower temperatures and pressures and require only moderate acidity. Traditionally, enzymes are extracted from plant or animal tissues. Today, however, microbial production of enzymes is proving to be far superior to the old methods. Yields are greater and more economical because of shorter fermentation time required, and growth media are inexpensive and the screening procedures for purity and efficiency simpler. Some of the market predictions are indicated in Tables 4, 5, 6 and 7.

The recent Gulf War and the Exxon oil tanker's spill in Alaska have underlined the importance of stepping up research on micobial remediation of such pollution. Bioremediation can also be used to desufurize high-sulphur oil or reduce the viscosity of heavy oil. Bioremediation uses microorganisms to get rid of toxic chemicals. In cleaning up oil spills, mainly on land, it involves the stimulation of naturally occuring oil eating microbes with specifically formulated liquid fertilisers containing nitrogen and phosphorous. It is therefore vitally important for oil exporting and importing countries to develop capabilities in research and development and application of the technology. UNIDO has therefore initiated a Bioremediation and Oil Recovery (BIOROR) programme.

1.4 Biotechnology and Third World concerns

A reference needs to be made to a few of the major concerns of Third World scientists and political leaders relating to current global trends in the objectives and organisation of biotechnological research. First, the farm sector is a major export-earning enterprise for Third World countries. Therefore, there is genuine concern about the potential adverse impact of genetic engineering research directed at finding substitutes for natural products. Some examples are: high fructose corn sweetener as a substitute for sugarcane sugar and substitutes for vanilla, cocoa and diosgenin extracted from **Dioscorea** species.

A second major concern relates to the safety aspects of genetic engineering research. Will tests be done in the Third World which are not permitted in the industrialized countries? Will "super weeds" arise from research aimed at the development of pesticide and herbicide resistant crop varieties? Will the ecological groundrules underpinning the field testing of transgenic material be the same everywhere?

Third, the nutritive quality and food safety issues relating to genetically engineered strains and growth promoting agents like bovine growth hormones need careful study, using criteria more relevant to conditions where under-nutrition and malnutrition are widespread. Will crop varieties with multiple resistance to pests contain toxins which will ultimately affect the health of the human beings or animals consuming their economic parts? What kinds of safety evaluation procedures are needed for food ingredients produced by microorganisms, single chemicals and simple chemical procedures and whole foods and other complex mixtures?

Fourthly, will the biotechnology revolution help resource-poor farmers increase productivity largely with the help of farm-grown inputs? How can we design mutually reinforcing packages of technology, services and public policies which can ensure that all rural people - rich or poor, land owners or landless labour families - can derive economic and social benefit from new biotechnologies? Is it possible to design a pro-small farmer and pro-poor biotechnology programme?

Fifthly, what will be the impact of the extension of intellectual property rights to individual genes and genotypes on the availability of such improved material to developing countries and resource-poor farm families? Also, will intellectual property rights be exclusively reserved for rewarding formal innovation, although the informal innovation system has played and is playing a key role in the identification and conservation of plant and animal genetic resources? What are the rights of the farm families who have conserved and selected genetic diversity in contrast to the rights of the breeders who have used them to produce novel genetic combinations? How can the concept of genetic diversity as a common human heritage be promoted, if only a few can derive economic benefit from such diversity?

Sixthly, will priorities in biotechnology research be solely market-driven or will they also take into consideration the larger interests and the long-term well-being of humankind, whether rich or poor? In other words, will **orphans remain orphans** in the choice of research priorities and investment decisions?

For example, rice is the staple of nearly half the human population most of whom live in Asia. Yet, the application of biotechnological know-how to solve some of the important problems in rice production would not have received the financial and scientific support they needed but for the decision of the Rockefeller Foundation to make a major long term investment in this area. Human diseases like leprosy also illustrate this point.

Finally, basic research underpinning the techniques of biotechnology has largely been carried out in universities and public-funded laboratories. However, the work on the conversion of scientific information into economically viable technologies has largely been undertaken in the private sector. This had led to the question whether the fruits of such research will be available only to those who can afford to pay adequately for them. For example, in agriculture, some experts have stated that while the "green revolution" technologies arising from research funded by philanthropic foundations like Rockefeller and Ford Foundations and by governments of developing and industrialized countries were available to all farmers who could derive benefit from them, the "gene revolution" technologies associated with biotechnological research may not likewise be available, since they owe their origin by and large to investments made by private companies and may be protected by patent rights. Where should the line be drawn between private profit and public good, particularly in a world characterized by glaring economic inequities?

The results of genetic engineering research in medicine, such as the production of insulin, interferon and different kinds of vaccines, are being disseminated by the pharmaceutical industry. Likewise, applications in animal health care and production can be expected to be spread by private industry. Similar may be the case of enzymes like renin used for making cheese. In the case of crop improvement, there is an on-going debate about methods of integrating the principles of equity with those of economic profitability. The basic dilemma arises from the fact that while developing nations often represent centres of biological diversity and have rich endowments of biological wealth, the capacity to convert biological diversity into biological productivity through science and technology resides predominantly in industrialized countries, where such conversion work is increasingly in the hands of private industry.

The above concerns can be met only by a proactive analysis of the potential beneficial and adverse impacts of biotechnological research, not only from the economic angle but also from the ecological, equity and ethical perspectives. Social scientists and ecologists should be involved in project design teams right from the beginning and should not just come at the end to make a post-mortem analysis. For biotechnology to lead to a better future for human-kind, we need a systems approach, keeping in mind Albert Einstein's exhortation that human well-being should be the ultimate objective of all scientific endeavour.

1.5 Socio-economic impact

There is considerable literature on the socio-economic aspects of biotechnology particularly in developing countries. As stressed at the outset, it is possible to impart a pro-poor bias to technology development and dissemination at the national and international level. For example, the green revolution technology in agriculture was scale neutral with regard to relevance to farmers cultivating different size of holdings. However they were not resource neutral since inputs are needed for output. Biotechnology affords an opportunity for integrating scale and resource neutrality in technology development. This unique opportunity should be fully capitalised by ICGEB in collaboration with IARCs (see Table 7 for a list of IARCs under the CGIAR network). The UN report on the overall socio-economic perspective of the world economy for the year 2000 shows a widening gap in income and production performance. The ratio in the per capita income in countries like China and India in relation to countries in Europe was 1:2 towards the end of the last century. It has now reached the level of nearly 1:70. The socio-economic perspective reveals that such a trend may continue unless special efforts are taken to impart a pro-poor bias in technology sharing, training and trade. For example,agricultural biomass is the most important feedstock available to poor countries. In rural areas, biomass refineries can help to get value added products from such biomass. The European Community has promoted programmes in the area of LEBEN (Large European Bio Energy Network) and biorefineries. Such programmes are even more urgently needed in developing countries. The impact analysis of new technology innovations should include equity both in terms of gender and economic status.

The Economic Commission for Latin America and Caribbean has undertaken a detailed study on how social equity can be combined with the spread of new technologies.

Biotechnology can make a useful contribution for integrating brain and brawn in rural professions. For example, Kerala State in India is developing the district of Ernakulam as a Biotechnology District, for taking advantage of its rich educated human resource, particularly educated women, who often tend to be employed in unskilled jobs (see Swaminathan, 1991). The programme will include extensive tissue culture propagation of forest tree species, banana, cardamom and ornamental and medical plants, genetic improvement of cattle and poultry and the establishment of biomass refineries. The cause of educated unemployment is often not the lack of employment opportunities per se, but the paucity of employable skills in educated youth. The prevailing mismatch between the skills needed for the sustainable conversion of natural endowments into economic wealth could be ended through a carefully planned learning revolution. Centres of training in biotechnology, based on the method of learning by doing can play an important role in ending this mismatch.

1.6 Poverty, employment and biotechnology

The two decades between the United Nations Conference on the Human Environment held at Stockholm in 1972 and the United Nations Conference on Environment and Development (UNCED) scheduled to be held at Rio de Janeiro in June 1992 has been a period of sustained, often path-breaking activity in the fields of development research and action. It has also been a period of unprecedented environmental sensitivity and of conscientious, often pioneering, research and action in respect of different aspects of the environment and its protection. Many lessons are to be drawn from the experience of these two decades; of them, an unshakable one surely is this: the goals of social and economic development are not conflicting goals; they must not be counterposed to one another, but must be integrated, in our thinking and practice, in a single process of sustainable development. The title "Environment and Development" for the Rio d Janeiro Conference conveys this message powerfully.

It is now clear to social science theory that the process of development is more than merely the growth of incomes. If the term development is to refer, as it must, to enhancing the opportunities for individuals to develop their full potential as human beings, then the goals of development are unattainable if the environment in which human beings live is polluted, degraded and destroyed.

Prime Minister Indira Gandhi and Barbara Ward articulated at the Stockholm Conference in 1972 the links between poverty and environmental quality. Since then, much has been spoken and written on this topic. While there is much to be learned from that discussion, there is no avoiding the fact that the creation of societies whose basis is the untrammelled exploitation of natural resources without regard for the social cost of such exploitation has vastly increased humankind's capacity to destroy the environment. No pre-industrial society or community can destroy vast forests as logging companies can. In addition, anthropogenic pressures on natural resources have also increased considerably, particularly in developing countries.

The crisis of the environment is one that affects not only the poor; it can, however, be said that the poor are the worst victims of the crisis. For those who still pursue traditional livelihoods and for whom the development process has not provided alternative forms of life and work, environmental degradation often entails the loss of occupations, of sources of fuel, and fodder and of access to hitherto common property resources. Working people, street dwellers, and other sections of the poor are the worst victims of industrial pollution and disaster; they are the worst affected by the pollution of water sources and by unhealthy living and work environments. Hence there is need to re-orient development strategies in a manner that the quality of human life is improved while living within the carrying capacity of supporting ecosystems.

In recent years, in different parts of the developing world, various schemes have been put into practice for the creation of employment - wage employment and self-employment - and other forms of income support among the urban and rural poor. There have been disaster-relief projects, some of them ad hoc, as well as sustained employment and other income-support schemes. The World Food Programme has supported many "Food for Work" and similar programmes designed to link productive work with household food security.

It is now recognised that schemes that guarantee manual employment for people who are unemployed can play an important role in providing disaster relief as well as providing regular sustenance through enhanced incomes for the poor. Such schemeshave a crucial role to play in development policy. The International Commission on Peace and Food chaired by Dr. M.S. Swaminathan has has therefore proposed a global initiative for an employment entitlements scheme that uses the labour and creativity of the poor to protect, sustain and enhance the quality of the environment. The International Commission on Peace and Food has recently proposed such a scheme for consideration at UNCED.

Such an international programme to ensure employment entitlements for sustainable development will require global vision and international commitment and cooperation. It will also - perhaps more importantly - have to be finely tuned to local circumstances, resources and opportunities. Such a scheme of employment entitlements for sustainable development can, by way of illustration, be designed to

- arrest and reverse the damage to land and water resources and to forests;
- conserve and develop bio-diversity and balanced ecosystems;
- maintain watersheds and hydraulic cycles;
- prevent soil erosion and degradation;
- reduce the silt loads of tanks and rivers, and moderate floods and;
- recycle garbage and sewage for energy generation and composting;
- promote environmental hygiene;
- develop safe drinking water resources.

The need cannot be too strongly emphasised for detailed assessments of local resources, needs and opportunities. These must be made by concerned communities of participating people, and shelves of projects must be designed on the basis of such assessments.

Such a scheme to create employment entitlements for sustainable development also envisages the intensification of scientific research and extension activities in relevant areas. The areas include:

- soil erosion and degradation;
- restoring degraded lands;
- water conservation and management;

- monitoring climatic change and standardising avoidance and adaptation mechanisms;
- improved seed and feed production for aquaculture
- ocean capability and productivity studies;
- evaluating the impact of different levels of ultraviolet-B radiation on crop and farm animal productivity and on the vulnerability of ocean phytoplankton organisms; and
- standardising methods of saving endangered species and ecosystems.

To sum up, it would be appropriate to shift food security considerations solely from the global and national angles to the level of individual households and to link the livelihood security of rural and urban communities with the ecological security of nations. What role can biotechnology play in such a poverty elimination agenda? It is obvious that biotechnology can play an important role, through tissue culture and micro-propagation techniques, animal health care, propagation of elite forest tree species, aquaculture, and establishment of biomass refineries. The opportunities afforded by Recombinant-DNA techniques and microbiological transformation have much relevance to the development of new genetic strains of crops and microorganisms and to the establishment of biomass refineries designed to promote the preparation of value-added products from every part of the plant and animal biomass.

1.7 Biodiversity and biofuture

Our biological future depends on our ability to conserve and utilize the rich genetic diversity occurring in living organisms on our planet. The extent of ignorance on the number of species existing on earth came out clearly at a Conference on the Ecological Foundations of Sustainable Agriculture organized by the C.A.B. International at London in July 1990. Some experts felt that more than 50 million species may be occurring, particularly when we take into account invertebrates and microorganisms while less than two million have been described so far. This underlines the importance of training more biosystematists, particularly in relation to invertebrates and micro-organisms.

Unfortunately, there is much controversy on methods of saving and sharing the global biological wealth. Discussions on this topic are in progress in various international fora such as FAO and UNEP. The Keystone International Dialogue Series on Plant Genetic Resources has tried to throw light on methods of resolving opposing viewpoints. Terms such as "Farmers' Rights" and "Breeders' Rights" are freely used to indicate the importance of according recognition to the informal innovation system in conjunction with the rights already accorded to plant breeders in the 20 developed nations which have so far adhered to the rules of the International Union for the Protection of New Varieties of Plants (UPOV). The ongoing discussions at the General Agreement on Tariffs and Trade (GATT) on Trade-related Intellectual Property Rights (TRIPs) are also important in the context of North-South relationships in germplasm conservation and exchange. Fourteen developing nations have proposed to the

Negotiating group on TRIPs at the Uruguay Round of Multilateral Trade negotiations that plant or animal varieties or essentially biological processes for the production of plants or animals should not be subjected to patent protection.

Farmers and breeders are allies in the common task of advancing biological productivity. Therefore, their rights should be presented not as mutually antagonistic rights but as mutually reinforcing ones. Such a goal can be achieved if UPOV ultimately evolves into an International Union for the Protection of Breeders' and Farmers' Rights, with its membership including all countries - industrialized and developing.

The UPOV convention has now been revised. The concept of "dependence" which would ensure that a variety "essentially derived from another variety protected by Plant Breeders' Rights (PBR) cannot be used commercially without the permission of the breeder of the protected variety has been introduced". It should not be difficult to develop a methodology under the dependence clause which enables recognition and reward for informal innovation. The financial reward in this case will have to go to a special fund which can help to finance conservation and plant breeding activities in the country from which the key genetic material came. The participants of the Keystone Dialogue at their meeting held in Oslo in June 1991 have proposed a Global Initiative for the security and sustainable use of plant genetic resources. This North-South consensus programme will go a long way in resolving prevailing conflicts (Keystone Dialogue on PGR, 1991).

1.8 Potential adverse impact of biotechnology

There is growing volume of literature on the adverse impact of biotechnology on environment and health in addition to its potential adverse effects on equity related issues. The report of the Biotechnology Working Group based on reports of public interest organisations in the USA has cataloged some of the potential problems in its report titled, "Biotechnologies Bitter Harvest".

The declaration of INUYAMA on human gene mapping and genetic screening and gene therapy brings out some of the ethical issues involved in genetic engineering research.

1.9 Bio-safety

There is considerable public apprehension on safety aspects particularly with reference to the release of organisms into the environment. The wholesomeness aspects also cause concern in the public mind as was evident in the case of bovine growth hormones. Efforts on the development of pest resistant strains creates apprehension in public mind on the possibilities of toxins doing harm to human health. On the other hand, there is considerable data on naturally occurring pesticides and their impact particularly in chronic doses on the health of the consumer. These are two issues which will have to be considered both nationally and internationally. Almost all countries which have active biotechnology programmes have mechanisms for safety regulations. The guidelines adopted by each country concerning safety have undergone changes during the last 20 years.

Nevertheless, there are still on going debates which would be evident from the following few illustrative examples of potentials and fears.

Researchers at the University of Minnesota, USA, have come up with the idea of producing genetically-engineered pigs specially designed for use as organ donors for human transplants. At present, there is a shortage of human donors for organ transplants and difficulties in finding compatible matches mean that many suitable patients do not receive transplants.

As farm animals are already bred in large numbers for food, the moral questions associated with using them as organ donors might not be a problem. The most suitable animal, because of its size and availability, would be the pig.

On the other hand, the US Department of Agriculture was being challenged by the Environmental Defence Fund (EDF) and several other groups to reject an application for a field test of a genetically engineered tobacco mosaic virus (TMV). The application from Biosource Genetics Corp. concerns trichosanthin, an active component of the Chinese medicinal plant Trichosanthes kirilowii. This drug has been shown to have abortifacient properties, inhibits tumour growth and the immune response, and has recently been shown to act selectively against human immuno-deficiency virus-infected cells. The equivalent gene for trichosanthin has been isolated from cucumber and inserted into a TMV vector with the aim of producing the drug in plants. Human haemoglobin and rice amylase were also to be tested. The test uses Biosource's Geneware technique which inserts genes into the cell cytoplasm rather than in the nucleus.

The EDF is a pressure group which has previously criticized some biotechnology field tests. It fears that the trichosanthin gene could be transferred accidentally into tomato plants (which are susceptible to TMV) and that this might result in exposure of humans to toxic levels of the drug.

Biosource Genetics Corp disagrees that there is any cause for concern, and claims that the EDF does not understand the biology of TMV adequately.

The US President's Council on Competitiveness argues that 'unnecessary burdens' must be removed to allow the USA to stay ahead in biotechnology, according to its 'Report on National Biotechnology Policy'. The administration should oppose any efforts to create new or modify existing regulatory structures for biotechnology through legislation, it says. The report argues that the risks of bioengineered organisms should not be exaggerated, stating "products developed through biotechnology do not per se pose risks to human health and the environment".

The principle of risk-based rather than 'process based' assessment is championed. The Biotechnology Working Group intends to find ways of promoting inter-agency coordination and to address problems with state and local laws (which it says include NIMBY (not in my back yard legislation)). It highlights the current uncertainty over whether a tomato genetically engineered for pest resistance would be evaluated by the US Department of Agriculture, Environmental Protection Agency or the Food and Drug Administration.

UNIDO has prepared a voluntary code of conduct for the release of organisms into the environment for being considered by the Informal UNIDO/UNEP/WHO/FAO Working Group on Biosafety. FAO has also been developing a code of conduct. National Governments have their own code of conduct. Some countries like Germany have serious reservations while others like Japan do not seem to share their view. For example, the Environmental White Paper called "The 1991 Quality of Environment in Japan" which represents the official view of the Japanese government, affirms that there have not been any particular environmental problems through the development and utilisation of biotechnology including recombinant DNA technology. This report was drafted by the Environment Agency, approved by the Japanese Cabinet and reported to the Diet as the unified view of the Japanese government. The voluntary code of conduct prepared by UNIDO under the auspices of the UNIDO/UNEP/FAO Working Group basically attempts to lay down the minimum commonly accepted principles in regard to the subject. It draws on existing directives and regulations and does not intend to develop new concepts. It stipulates general principles, the obligations of governments and the obligations of the proposer and the researcher. It has been framed in such a way that more specific guidelines could be built up on it for specific products or applications. Cooperation of the ICGEB, the OECD and several experts was also enlisted for the preparation of the code. The Preparatory Committee of the Member States of the ICGEB considered the draft of the code and expressed the view that it provided a good basis for international cooperation and also contained the essential elements which could be adopted in national bio-safety regulations.

1.10 Proprietary and patent rights

The sphere of plant genetic resources collection, conservation, and use cannot be discussed without considering the issues of intellectual property rights, plant germplasm ownership, and the control of plant germplasm accessions in gene banks. These issues have been the focus of substantial debate and publication in numerous international fora for nearly two decades.

Due to the very nature of the biotechnological entities, the issues of patenting in this field are still a matter of intense debate and many developing countries have yet to decide which direction to follow. Court decisions have shown that there still are different interpretations on the scope and enforcement of patent protection in the field of biotechnology.

One basic issue is whether the patent system for inventions is suitable of protecting proprietary rights related to living material. The United States Supreme Court affirmed the patentability of micro-organisms in 1980. In other developed countries there has been a trend in this direction, although the matter is still under debate at the national level as well as in multilateral negotiations, eg. the Uruguay Round in GATT.

Other forms of protection, applicable to plants and plant biotechnological innovation exists: the industrial patent and the plant breeders' right (PBR). This is a right granted by Government to plant breeders to exclude others temporarily from producing and selling propagating material of a protected plant variety. As mentioned earlier, possible developments in PBR laws are also regarded as a way of granting increased protection in genetic material and processes as sought by developed countries while allowing a less restrictive environment for the utilizer, as compared to the one derived from the current patent laws.

The practices and trends in technology transfer in the field of biotechnology have followed a pattern, which is intrinsically related to the genesis of biotechnology development, the market value of biotechnology entities, the costs of R&D activities, the intellectual property protection and the strategic options of technology owners.

While there seems to exist a significant amount of technology transfer activities among firms and institutions of developed countries, it also seems to be a fact that, for licences in developing countries, the access to technology under favourable terms seems to be very difficult.

The licensing in biotechnology has taken various forms. Originally, biotech start-up firms would license their inventions to large corporations because they lacked capabilities to undertake successful market operations and needed financial resources to continue their R&D activities.

This situation changed as some biotech start-up firms followed the road of inventing,developing and marketing the products themselves. On the other hand, large pharmaceutical companies decided to upgrade their in-house expertise by recruiting outside specialists or taking over smaller start-up firms.

Important sources of technology are also the universities which can have their own technology licensing programmes or otherwise conduct research under the sponsorship of governments or large corporations.

There has also been a tendency among specialised firms to form strategic alliances with other enterprises that have certain assets to offer in exchange, e.g. technological capabilities, financial resources or market access.

Licensing fees in biotechnology are usually higher than in many other industrial sectors. Royalty rates can range from 5-10 per cent for therapeutic products (monoclonal antibodies, cloned factors etc.) or even higher 12-15 per cent for approved or approved recombinant pharmaceutical. These are all issues which finally have to be debated and decided by WIPO.

The Keystone International dialogue Series on Plant Genetic Resources, at its Session held in Oslo in June 1991 under the chairmanship of Dr. M.S. Swaminathan concluded as follows with reference to plant breeders' and intellectual property rights.

Concerns have been expressed that the application of intellectual property rights to the successes from biotechnology research in developed countries could have negative consequences for developing countries. The Keystone Dialogue group discussed the question what will be the net impact in economic terms of extending IPR to biological materials and of privatizing resources that were previously freely available.

a. **Evolving international IPR activities**

Legislative activities at the international level will have a significant influence on the availability of intellectual property rights in developing countries. These activities include the ongoing General Agreement on Tariffs and Trade (GATT) negotiations, the recently concluded revision of the International Union for the Protection of New Varieties (UPOV) Convention, and the patenting of plant-related biotechnological inventions.

In the absence of the GATT negotiations, the revision of UPOV and plant biotechnology patents might assume less significance for the developing countries and the survival of their plant genetic resources. However, as part of the Trade-Related Intellectual Property Issues (TRIPs) negotiations of the current Uruguay round of GATT, developed countries are pressing the developing countries to implement stronger intellectual property rights for a much broader range of materials.

If the GATT negotiations result in the strengthening of IPR within developing countries, this, in turn, might result in both the adoption of plant variety protection systems and the patenting of plants, animals, and the genetic materials that are contained in them. The Dialogue group expressed strong concern about the imposition of IPR for plant genetic materials through the GATT or bilateral trade negotiations. Every country has the right to decide whether and to what extent they adopt IPR for PGR. No country should be pressed to do so. To date, the issue has received little attention and discussion by the GATT negotiators. The Dialogue group strongly recommended that the implications of IPR for PGR be given adequate discussion and evaluation by the negotiators, with input from national experts and other entities involved with PGR such as FAO, UNEP, UNESCO, UNIDO, World Intellectual Property Organization (WIPO), UPOV, and several NGOs, before any GATT action is taken.

Intellectual property right (IPR) systems have been instituted by many countries to varying degrees in order to stimulate innovation throughout all sectors of society and especially to promote investment by and secure rewards for the private sector. They are meant to provide an incentive to create innovation and to disclose its details.

There is little doubt that IPR systems under certain economic conditions are capable of encouraging innovations which may contribute to improvements in productivity. However, it is not possible to predict how those productivity gains might be distributed. If IPR systems are extended to plant genetic resources, depending on the precise nature of subject matter that qualifies for intellectual property protection and the scope of protection ultimately granted, some parties will be limited in their access to the protected germplasm. Developing countries have been the principal sources for PGR, but the poor farmers in those countries are most likely to be at a disadvantage without construction of proper safeguards.

The Keystone Dialogue group reviewed these issues and the status of certain international activities in these areas. This review has proven especially complex for several reasons. There are significant differences in structure and complexity among the agricultural systems in developed and developing countries, the definition of protected subject matter as it applies to biological material is still evolving and far from fixed even in developed countries, and specific legal provisions in the area of intellectual property rights for biological content are currently under consideration.

b. **Physical Property and Intellectual Property**

In the context of a discussion on PGR ownership, the Keystone Group felt that it is important to distinguish between property in the physical plant genetic resource (e.g., seed) and intellectual property. A seed is a tangible asset or resource which can be sold. Intellectual property is an intangible asset, such as a patent or Plant Breeders' Right (PBR), recognized by society which grants certain rights for its exclusive exploitation. There are significant differences in the strategies used to control and manage each and in the nature of their impact on access to the plant genetic resources.

Based on past events and current policy, most countries have serious concerns about guaranteed access to plant germplasm collections, especially those that originate in their country and are stored in another. It has been formally recognized by the FAO Undertaking on Plant Genetic Resources that the world's plant genetic resources are part of a global heritage which should be accessible to anyone who has need of it for plant breeding and scientific purposes.

The Keystone Dialogue group recommended that every effort should be made to minimise all restrictions on the access to germplasm, from any quarter. Nevertheless, it is recognized that breeders' lines can remain outside the full exchange relationship in order to allow breeders to complete their work and make a formal varietal release. In the same way, there exist other genetic resources, improved or unimproved, for which there may be a reason for temporary constraint to exchange. In such cases, the world community must yield to the judgement of the holder of the germplasm.

At the November 1989 FAO Conference, all member countries endorsed an agreed interpretation of the Undertaking that recognizes both Plant Breeders' Rights and Farmers' Rights. Plant Breeders' Rights are a formal system for rewarding developers of plant varieties. The principle of Farmers' Rights recognizes the fact that farmers and rural communities have contributed greatly to the creation, conservation, exchange, and knowledge of genetic and species utilization of genetic diversity. This interpretation aims at reconciling the view of the "technology-rich" and the "gene-rich" countries in order to ensure the availability of PGR within an equitable system.

The concept of Farmers' Rights emphasizes the importance of the contribution of farmers and rural communities to "...the creation, conservation, exchange, and knowledge of genetic and species utilisation of genetic diversity; that this contribution is ongoing and not simply something of the past; and that this diversity is extremely valuable".

Currently, no formal recognition and reward system exists to encourage and enhance the continued role of farmers and rural communities in the conservation and use of plant genetic resources. This concern should be considered within the context of the Dialogue group's recommendation regarding a Global Initiative for the Security and Sustainable Use of Plant Genetic Resources, which includes the establishment of a PGR Trust Fund.

The topic of ownership and use of genetic resources is currently under discusion at the inter-governmental level as a part of a global biodiversity convention being negotiated under the auspices of UNEP.

c. **Biotechnological Exploitation of PGR** The call for equitable compensation for the use by biotechnologists and other scientists of plant-derived genes is likely to increase as improved plant varieties and other products developed by the new technologies reach the marketplace within the next few years.

Although compensation usually is discussed in financial terms, there are other ways that developing countries may obtain a reciprocal benefit for their contribution. Access to genetically engineered germplasm for local breeding, or to gene constructs for transfer into indigenous crops, are two mechanisms of compensation. An example can be cited in the case of rice.

1.11 Some directions of biotechnology research

The International Service for National Agricultural Research (ISNAR) convened a consultation in May, 1991, which helped to identify directions for biotechnology research during the nineties. The following are some of the conclusions arrived at this meeting.

Biotechnology can be represented as a gradient of technologies, starting at a relatively simple level with tissue culture and rising sharply through recombinant DNA to the genetic engineering of plants, animals and microorganisms (fig.1). Plant breeders have based their work on biotechnology since they adopted the principles of genetics, first outlined by Mendel in 1866. New techniques, based on recombinant DNA technology, monoclonal antibodies, and novel methods of cell and tissue culture, which are arousing such widespread interest today, should be labeled "modern biotechnology".

There is no debate over whether developing countries should start moving up the gradient: the more richly endowed national systems are already well on the way. Even the smallest and poorest should be thinking about a "survival kit" based on modern techniques. For instance, a country where root crops are a staple food could profitably invest in a tissue-culture laboratory. At a capital cost of about US$ 10,000 this would permit the importation in tissue culture of virus-free clones developed in research stations abroad, and their rapid multiplication if they prove adaptable to local conditions and acceptable to producers and consumers.

Further up the gradient, the issue for decision is how far a national system should develop its own in-country capacity in modern biotechnology, and how far it should rely on access to outside institutions. This will to some extent be a political matter. If the main concern is for export crops, countries may well be influenced by the atmosphere of high international competition for markets, and go for the maximum in-country capacity they can afford. They will, however, have to bear in mind that the costs of the new techniques are falling continuously as new methods and new machines are devised; they will need to take precautions against locking themselves into a highly expensive approach that may become obsolete within a very few years.

The development of biotechnology will increase the load on traditional plant breeding programme. since only practical breeders can effectively test the new varieties that may emerge from the laboratories. Indeed, the existence of a traditional plant breeding programme is a pre-requisite for a successful move up the gradient of biotechnology in the area of crop production.

Current technology can modify a single gene on a chromosome. Major break-throughs will require more complex transfers. For instance, transferring the ability to fix atmospheric nitrogen to cereals (and thus limiting the need for nitrogenous fertiliser) involves at least six genes. **Longer-term progress will depend on further advances in basic science, notably in such areas as the mapping of genomes.** Among possible research objectives, priority might be given to efforts to increase the total biomass of a given crop, and at the same time to improve the partitioning between food and nonfood components.

Patents are now granted in some countries belonging to the Organisation for Economic Cooperation and Development (OECD), notably the USA, for genetically manipulated plants, animals microorganisms, and related biotechnology processes. In the OECD countries as a whole, about half of the work on modern biotechnology is being done in the private sector. The question of access to new technology on the part of developing nations is thus a highly important one. National legislation on intellectual property rights will become necessary for access to patented technology held abroad, as well as for protecting the commercial value of discoveries made at home. In negotiating access, a developing country will need to be well informed or well advised. It should also have a clear idea of who, initially and ultimately, is going to pay for commercially acquired technology. International and regional mechanism will have to be developed for providing such know-how.

Concerns about biosafety are high on the international agenda. No country will wish to enter the field of recombinant DNA without having in place adequate mechanisms for ensuring the safe release of genetically modified organisms. Considerable experience is accumulating in risk assessment, and it can be drawn upon by new national systems.

There is also concern to ensure that the end results of modern biotechnology are socially benign. The Green Revolution was accused because of a failure to distinguish between the roles of science and of public policy of indifference to the fate of small farmers. It will be necessary to undertake proactive social research from the earliest phases to avoid the same charges being leveled again. Bringing biotechnology to bear on "orphan commodities" that are important to small farmers as either food or cash crop is one way in which benefits could reach those most in need of them, although this will require major institutional changes in how science supports such developments.

Opinions are divided on whether modern biotechnology should be the subject of a specialized institution or slotted into existing research organisation. Clearly, it is a set of new tools for research, rather than a new discipline. In most instances, integration of the new techniques into the existing NARS and university research programme will have the most beneficial, long-term effects on the development of science within a country. At the same time, it involves policies (on property rights, biosafety, etc.) that fall outside agriculture. For this reason, there is a powerful case for creating a national committee or commission to bring together the various sectors concerned in order to develop a national policy on the application of biotechnology to agriculture. Large countries like India have addressed this issue by creating a separate Department of Biotechnology in Government.

How far will the new techniques be translated, over the next twenty years, into actual yield increases in farmers' field? This is a question to which only the most tentative answer can be given.

Progress will obviously depend, in the first place, on the ability of scientists to produce results. Practical impacts in such areas as diagnostic tools and vaccines can already be seen, and this is likely to strengthen over the shorter term. More far-reaching progress in gene enhancement could arrive within a decade and could have a major impact on the production figures between ten and twenty years hence. It seems likely that new technology will, for certain commodities, reduce the length of the "product cycle" in agriculture, just as it has in industry. More rapid methods of testing, reproducing, and diffusing new varieties, new vaccines, or new types of inputs should permit their widespread use much more quickly than we have hitherto seen. Extension to farmers should be no problem if the new product offers a truly significant increase in profitability. Progress could thus be rapid, once new technologies have been developed and their cost, risk and return structure demonstrated to users.

One needs to recall, however, that we are dealing with two variables: the rate of progress in basic science and the rate at which discoveries can be translated into widely usable technologies. Peering into the future beyond the next five years yields speculations, not predictions. Caution must be the watch word.

The annex contains a case study of rice illustrating attempts made to impart a pro-poor bias in biotechnology research and application.

1.12 Pro-poor biotechnology research and IPR

The Rockefeller Foundation programme on rice biotechnology, was cited earlier as an example of a pro-poor biotechnology programme. Hence, it may be useful to indicate the policy guidelines regulating this programme.

The goal of the Rockefeller Foundation's International Programme on Rice Biotechnology is to apply advanced biological technologies to rice production in developing countries for the benefit of low income rice producers and consumers. The research supported is expected to contribute, through a series of cooperative projects and transfers of technology, to the production of improved seed and other materials used by farmers.

Mechanisms are in place, coordinated by the International Rice Research Institute (IRRI) and the Centro Internacional de Agricultura Tropical (CIAT), which facilitate the free exchange and distribution of rice breeding lines. Improved varieties ultimately reach the developing-world farmer either through public sector distribution or through commercial varieties. In general, the developing world farmer should have access to varieties at the lowest possible price and should pay no royalties, or at most nominal royalties. If there is exclusivity at this level, it should be only to facilitate effective distribution.

It is expected that Rockefeller Foundation rice biotechnology grantees will share materials and technology resulting from Foundation-supported research with cooperating researchers at zero royalty for use in developing countries. Grantees should not enter into agreements that conflict with this obligation. If such agreements are already in place, the Foundation should be so informed. This policy covers intermediate steps such as research results, transformation procedures and rights under material transfer agreements as well as final products and rights under patents or other forms of intellectual property.

At the same time, it is recognized that grantees may wish to pursue intellectual property rights on their discoveries and their improved materials in order to obtain economic return in developed countries for the support of further research and to maintain a strong bargaining position in the event of any intellectual property disputes.

Collaboration and the free exchange of research materials are hallmarks of the rice biotechnology network and contribute much to its success. In many cases materials are shared and technologies transferred prior to publication. Such principles need consideration when research programmes designed to promote household nutrition security among the poor are designed and funded by national, bilateral and multilateral agencies.

The CG-Biotech proposed in the last section of this paper should develop similar procedures in the case of all biological organisms of interest to global food and ecological security. Such mechanisms will help to harmonise the need for incentives for private investment and initiative in biotechnology research and for promoting public good.

ANNEX

Imparting a pro-poor bias in biotechnology research and application: Case study of rice

If it is agreed that development which is not equitable will not be sustainable in the long run, it is important that attention is given to the integration of the principles of equity with those of economics and ecology in the design of new technologies. It is now widely recognized that the realization of the pro-poor potential of biotechnology depends on the priorities of research. Rice biotechnology illustrates how a pro-poor bias can be imparted in investment decisions.

In 1984, the International Rice Research Institute (IRRI) organised a conference on Biotechnology and International Agricultural Research. Stimulated by the results of that conference and by the fact that a crop like rice, where the output is largely utilized for consumption by those producing the crop, is unlikely to attract attention from commercial biotechnology companies, the Rockefeller Foundation funded an International Programme on Rice Biotechnology.

Toennissen and Khush (1991) have recently summarized the major accomplishments of this project. Since the results obtained in rice within a span of five years are indicative of the power of both the tools of biotechnology and of methods of organization of research, it may be useful to quote the conclusions of Toennissen and Khush (1991).

Rice breeders face a major challenge of producing rice varieties for diverse environments in which the crop is grown. These varieties must have increased yield potential, superior grain quality, resistance to diseases and insects, and tolerance for abiotic stresses. Plant breeders have always used the best available technology to achieve such breeding objectives but perhaps no other innovation has facilitated plant breeding work as much as the recent breakthroughs in biotechnology.

Plant breeding involves two phases:

* The evolutionary phase where variable populations are produced. The time-tested methods used to create variability are hybridization and, to a lesser extent, the induction of mutations.

* The evaluation phase where desirable genotypes are selected from the variable populations. Various methods, such as bulk population breeding, pedigree selection, recurrent selection and single-seed descent, are used to identify desired genotypes. The yield performance of selected genotypes are then evaluated in replicated trials.

The tools of biotechnology will not replace - and are not intended to replace - any of the time-tested methods of crop improvement. Rather, biotechnology techniques either increase the efficiency of various methods of plant breeding, or allow breeders to accomplish objectives that cannot be achieved through conventional plant breeding. For example, wide hybridization through embryo rescue or somatic hybridization, somaclonal variation, and genetic engineering are useful in the evolutionary phase. The selection efficiency with doubled haploid lines produced through anther culture of F-hybrid is higher due to absence of dominance variance. RFLP markers, when used to tag genes of economic importance, can aid the selection process and increase its efficiency. The marker-based selection holds particularly high promise for quantitative traits and those that are difficult to evaluate with presently available techniques. Nucleic acid probes and monoclonal antibodies are proving of great value in selection for disease resistance.

Perhaps the most important contribution of biotechnology will be in adding alien genes to the gene pools of the crop species through genetic engineering. The elegant techniques for gene identification, gene cloning, and transformation allow introduction of genes from any living organism to another where it imparts a useful function. Such gene transfers are beyond the capability of conventional breeding methods. The following are some areas of immediate impact:

a. **Wide Crosses**

Rice biotechnology is already contributing to the production of improved varieties. Wide-cross hybridization, including use of embryo rescue techniques, has allowed the transfer of useful genes from wild Oryza species to elite cultivars. Many more potentially useful genes remain available in the wild species and new tools from biotechnology will speed their utilization. RFLP maps and species-specific DNA probes will enable rice breeders to more effectively follow the introgression of alien chromatin from wild species to elite lines. Using in situ hybridization of these probes and scanning electron microscopy, it is even possible to visualize the alien chromatin on the rice chromosomes.

As protoplast regeneration protocols become more efficient and available for a broader range of rice cultivars, protoplast fusion followed by regeneration should become another technique for wide crossing. It can be anticipated that numerous genes from wild relatives will be used to transfer useful new traits in rice in the coming years.

b. **Anther Culture**

Anther culture allows the production of homozygous plants in two generations and can reduce the time required to produce new rice varieties. The gametic genotype, including recessive genes, is expressed and early generation selection becomes feasible due to the additive effect of the doubled haploid lines and the elimination of dominance variance. Anther culture of rice has been proven effective and several varieties have been released in China using this method. It is likely that this technique will be more broadly utilized, particularly in locations where only one generation per year is feasible for conventional breeding. Anther culture should also enable greater utilization of minor genes for resistance, the cumulative effect of which may provide more durable resistance than that provided by major genes. Further theoretical and empirical research aimed at improving the anther culture response of indica rice is under way and should help advance application of this valuable breeding tool.

c. **Maps, Markers and Gene Tagging**

Rice is particularly well suited for DNA-based genetic mapping. It is a true diploid with a small genome having ample polymorphism and it is highly recombinogenic. There are major RFLP mapping programme under way at public sector institutions in at least four countries, and gene tagging studies are being done in numerous locations worldwide. The maps and markers are shared and made freely available to any scientist. The International Rice Research Institute is facilitating collaboration, coordination, synthesis of results, and integration of the RFLP map with the classical map. Both IRRI and the International Centre for Genetic Engineering and Biotechnology (ICGEB) in New Delhi are making progress toward the development of non-radioactive probes that would enable routine use of RFLP markers in rice breeding programmes

By combining the independently developed RFLP maps of rice, a densely saturated map should soon be available. In tagging experiments this will allow identification of markers that are closely linked to the genes responsible for any trait that can be scored. For complex traits (such as drought tolerance) the markers can then be used not only to follow inheritance of major genes, but also as an analytical tool for dissecting the trait and identifying its major physiological and biochemical components.

The RFLP map soon will be sufficiently dense to allow chromosome mapping and map-based cloning of rice genes. Thus, it should soon be possible to clone rice genes with a known phenotype but an unknown function.

The maize Activator (Ac) element was recently transferred to the genome of rice plants and shown to transpose. Assuming transposition continues to occur in progeny plants, transposon tagging will also be available for cloning rice genes of unknown function. These methods will enable important genes, such as those controlling pest resistance, to be cloned and their function studied at the molecular level. A wealth of knowledge concerning biochemical and physiological mechanisms should result and strategies for useful modification of these genes should emerge.

d. **Genetic Engingeering**

Several laboratories have established the capacity to produce transgenic rice plants via protoplast uptake of DNA followed by plant regeneration. For some japonica cultivars, transformation efficiencies have improved significantly and numerous transgenic plants can be produced. Transfer of transformation protocols from one laboratory to another is also occurring. A variety of interesting rice gene constructs are being tested for research purposes and to evaluate their potential usefulness.

Steady progress is being made towards developing protoplast-based transformation protocols for indica rice but efficiencies remain low. There are unpublished reports of genotypes-independent transformation of Indica and Japonica rice using particle bombardment and of transgenic rice plants produced via Agrobacterium vectors. Within a few years one or more of these transformation techniques should be sufficiently routine to enable rice biotechnology laboratories to establish a transformation capability for any rice cultivar.

Homologous recombination was recently reported in plant cells following Agrobacterium mediated transformation suggesting that allelic replacement of plant genes may soon be possible. Using particle bombardment, Svab et al. (1990) achieved stable transformation of the chloroplast genome. This opens the possibility of using chloroplasts as sites of alien gene expression and vehicles for alien gene delivery. While these results were in tobacco, further refinements will surely enable them to be repeated for other species, including rice.

Methods for the manipulation and transfer of large DNA fragments are being developed and will provide another set of valuable tools for plant genetic engineering. This includes experiments aimed at transforming plant protoplasts with large DNA fragments (200-500kb) cloned in yeast artificial chromosomes (YACs). If successful, it should then be possible to transform rice with YACs that carry DNA fragments shown by RFLP mapping to contain useful genes.

Scientists are beginning to experiment with concepts for producing artificial plant chromosomes. While still at an early stage of exploration this is a realistic research objective with significant potential for further strengthening plant genetic engineering.

e. Useful Genes

Thus, new tools are becoming available for identifying and cloning rice genes. In addition, a major international research programme has been launched designed to obtain the complete genetic sequence of the flowering plant Arabodopsis and to identify and clone many of its genes. The combination of RFLP mapping and transposon tagging in maize is also leading to the identification and cloning of many genes. These genes, or modifications of them, may confer useful traits if transferred to rice and in most cases they can be used as heterologous probes for isolating the analogous gene from rice. The coding and regulatory sequences of these genes will provide a substantial and valuable source of raw materials for rice genetic engineers.

Over the next 10 years numerous genes worthy of testing in rice should become available.

From the foregoing survey of Toennissen and Khush (1991) it will be obvious that the prospects for the future of rice biotechnology are extremely promising. The scientific understanding that underlies the technology continues to advance rapidly, allowing constraints to be overcome and the technology to be strengthened. In Japan for example, a Rice Genome Advisory Committee was constituted in 1990 for promoting the mapping and sequencing of the rice genome.

Rice Genome Cooperative of Japan: The progress made in improving the yield potential of rice during the last two decades is shown in figure 2. Research institutions in rice-growing countries are now at the forefront of applying new technologies and they have the scientific capacity to further advance it. Before the end of the century, rice producers and consumers should begin to reap the benefits. Thus, this international collaborative project provides evidence of the usefulness of organised cooperation among basic and applied scientists and of the power of a multi-pronged strategy for achieving the desired goals speedily and surely.

CHAPTER II

Biotechnology and sustainable development: Contributions of the UN system and other international organizations

United Nations entities and programmes

Many organizations of the UN have programmes/activities relating to the application of biotechnology in agriculture, industry and medicine. There are also several inter-governmental and non-governmental organizations at global, regional and national levels concerned with biotechnology to a greater or lesser extent. The scientific and technological aspects as well as the social impact of new technologies are receiving attention. The work is so extensive that it will be difficult to do justice to the wide spectrum of activities currently in progress in a brief paper. Nevertheless, it is important to refer to a few highlights, however inadequate the summary may be. The source of information in most cases is the summary of their work sent by the respective organizations to UNIDO.

2.1 Office of the Director-General for Development and International Economic Co-operation

It has been suggested that action be directed to the following:

(a) Harmonization and codification, so that a wider use could be made of what has been agreed upon; and

(c) The impact on socio-economic issues, with particular emphasis on employment and transfer of technology - including funding for such transfer.

The UN system, it was concluded, and in particular UNIDO, could play a greater role in this area through dissemination of information and awareness on the most important issues in the field of biotechnology.

2.2 Centre for Science and Technology for Development (CSTD)

The work of the Centre for Science and Technology for Development (CSTD) on biotechnology is undertaken within the framework of the Advanced Technology Assessment System (ATAS). It began its work in the early 1980's with the publication of the first ATAS Bulletin, which carried out an assessment of tissue culture and development. Biotechnology has also figured as a part of an analysis of new and emerging science and technology (NEST), and then in a workshop on the commercialization of biotechnology in developing countries, held in Rio de Janeiro, Brazil, in 1988.

In 1990, the Centre began what it plans to be a series of regional and national level workshops on biotechnology for development. The first of these took place in Dakar, Senegal, on biotechnology for food production in dry areas. A second workshop was organized in Hanoi, Viet Nam, in December 1991, to assess biotechnology for food production and food processing in Southeast Asia, with particular emphasis on the needs of Viet Nam.

The CSTD considers the following to be both important and possible regarding action to be taken by the United Nations system in the field of biotechnology:

(a) The organization of national "dialogues". (The CSTD is now organizing such country dialogues through its Programme of Endogenous Capacity Building;

(b) Technology assessment;

(c) Promotion of linkages;

(d) Provision of the latest information on the organization and production of biotechnologies world-wide;

(e) Assistance to developing countries by using its good offices to devise biosafety guidelines appropriate to developing countries and to develop equitable arrangements in respect to issues of accessibility of biotechnology;

(f) Co-ordination of work in biotechnology in order to provide the developing countries with a consistent and cohesive set of measures to be undertaken to use biotechnology as a tool for development.

The CSTD considers that the ATAS has an important role to play in the above activities.

2.3 United Nations Conference on Trade and Development (UNCTAD)

UNCTAD prepared a report for the Committee on Transfer of Technology entitled "Trade and development aspects and implications of new and emerging technologies: The case of biotechnology" (document TD/B/C.6/154, dated 11 march 1991). This report draws on research from a larger study on agricultural biotechnology, presently being carried out jointly by UNCTAD and UNIDO. Some relevant aspects are summarized below.

The actual, as compared with the potential generation and diffusion of biotechnology and its applications, depends on the complex interaction of an array of not only technical, but also economic and institutional factors. The growing relative importance of private as compared to publicly-funded agricultural R&D, are some of the present trends. Moreover, in so far as they do not participate in the emerging networks of manufacturers, research laboratories and public institutions engaged in the development of biotechnological innovations in industrialized countries, the developing countries are missing out in the generation and sharing of knowledge relevant to their needs and in the negotiation of licenses under favourable terms that takes place among the participants. The "privatization" of the knowledge produced by biotechnological research contrasts with the openness and incitement to widespread dissemination of the results of largly publicly-funded Green Revolution research that contributed so much to agricultural productivity in many developing countries.

The drive to extend the scope of intellectual property rights protection of biotechnology through reform of industrial patent and/or plant breeder's rights legislation could accentuate these tendencies, particularly if it were left to a proscription of the existing rights of breeders to use protected plant varieties for the creation and commercialization of new varieties.

Unlike chemical or mechanical engineering, advances in agriculture are not readily transplanted from one locale to another without considerable investment in adaptation. However, except for a handful of major tropical exports, the private sector in developed market-economy countries has little commercial incentive to invest in the adaptation and transfer of biotechnology innovations to agriculture in developing countries. Hence, the ability of most developing countries to realize the potential offered by biotechnology for their agricultural production and exports will depend in part on the size and quality of their investment in adaptive R&D.

A major challenge facing developing country governments and the international community will be how to devise channels and mechanisms for the transfer of useful biotechnologies from private enterprises in developed market economies to developing countries and for the meaningful involvement of these countries in the research networks in biotechnology involving enterprises that are being formed in the developed market-economy countries. Special attention will need to be given to the promotion of research for a range of crops important to developing countries, but not grown in developed countries - including a number of widely consumed cereals, pulses and food crops as well as some export crops - in which the private sector in developed market-economy countries has no commercial interest.

There is a need to study more carefully how different types of reform of protection of intellectual property rights would achieve the aim of stimulating invention and promoting technology transfer and co-operation in the area of biotechnology, particularly in developing countries, before agreement is reached on the adoption of uniform international standards of protection of living material. A related issue meriting study is the corresponding protection of the traditional crop breeding by farmers in developing countries that has never been remunerated as such and which could serve as a means of conserving plant genetic resources.

2.4 United Nations Centre on Transnational Corporations (UNCTC)

The views of the UNCTC on the contribution of biotechnology to sustainable development and the role of transnational corporations in this process are amply set forth in a technical paper on "Transnational corporations in biotechnology". Some of the findings in this respect have been referrred to earlier in this report.

2.5 United Nations Environment Programme (UNEP)

UNEP was set up on the basis of recommendations of the UN Conference on Human Environment held at Stockholm in 1972. UNEP has played a catalytic role on all aspects of environmentally sound development. It is currently coordinating efforts in the development of a global convention on biological diversity. UNEP's "Environmental Perspective to the Year 2000 and Beyond", published in 1988, lays considerable stress on the role of biotechnology in the renewable energy sector. UNEP is also a member of the UNIDO/UNEP/WHO/FAO Working Group on Biosafety.

2.6 United Nations Development Programme (UNDP)

Recognizing the importance of biotechnology for development UNDP/UNFSSTD prepared, primarily for those concerned with UNDP assistance, a Programme Advisory Note entitled "Plant Biotechnology, including Tissue Culture and Cell Culture". Apart from assistance to countries, UNDP's regional and global programmes also give attention to biotechnology either directly or through assistance related to the fields of agriculture, health and industry. UNDP also supports several international networks operated by CGIAR institutions. Another institution supported by UNDP of relevance to sustainable development is the International Centre for Insect Physiology and Ecology in Nairobi, Kenya.

2.7 United Nations University (UNU)

The UNU has active programmes on various aspects of biotechnology research, including a programme in South America. In addition, the UNU's Research and Training Centre at Helsinki, Finland, the World Institute for Development Economics Research (WIDER) has been studying methods of imparting a pro-poor bias in technology development and dissemination. The UNU has also been sponsoring seminars and discussions on a wide range of topics relating to emerging trends in biotechnology.

Specialized agencies and other organizations in the UN System

2.8 Food and Agriculture Organization (FAO)

Biotechnology is just beginning to contribute to sustainable agricultural and rural development through aiding (i) development of pest and disease resistant clones/varieties/ breeds; (ii) freeing otherwise desirable planting materials of pathogens and enabling their rapid multiplication; (iii) use of monoclonal antibodies for precise and efficient diagnostics and for safe and specific treatment/control, viz. use of tailored vaccines in animal production (it is hoped that current advances in rinderpest vaccine production may offer a more convenient thermostable delivery system which will be extremely handy for use in remote areas in developing countries); (iv) use of efficient nitrogen-fixing mechanisms; (v) development of crop varieties efficient in mineral utilisation and tolerant to marginal areas; and (vi) use of genetically engineered microbes for degradation of wastes and breakdown of toxic residues.

Biotechnological applications will further promote sustainability through, among others, diversification of agriculture, forestry and fisheries production systems, supplementing genetic resources and developing life forms to fit in hitherto unthought of agro-ecological patterns, reducing environmental and economic risks.

The above applications are still extremely limited and the potentials have barely been exploited. The applications are being held in check by need for still more research to identify more useful genes and their effective expression in the transgenics, and to ensure that benefits do not entail harmful effects and pose biosafety problems.

At the national level, FAO is assisting several relatively well positioned developing countries to assess the requirements and to prepare the way through institutional and human resources development for undertaking research with special emphasis on the integration of biotechnology. In some instances assistance has focused on biotechnology for crop improvement, in others for production of vaccines and use of diagnostics (with involvement of the Joint FAO/IAEA Division) in livestock health and reproduction programmes.

Regional cooperation networks have been promoted under FAO guidance, viz., the Asian Network for Biotechnology in Animal Production and Health. A similar network for Latin America and the Caribbean and an Asian Network on Plant Biotechnologies are in the offing. A network for the Computer Assisted Analysis of Nucleic Acids and Protein Sequences (CAANAPS) in Latin America and the Caribbean covering seven countries and to be linked with similar European networks, has been initiated. A separate network on preparation and distribution of diagnostic probes/monoclonal antibodies for rapid diagnosis of livestock and poultry diseases in the same region is being established. Initiatives are planned for other region also.

Several expert consultations organised by FAO to prepare the ground for cooperative networks in animal production and health have recommended approaches and steps for FAO in this field. A quarterly bulletin, "Animal Biotechnology", contains information extracted from AGRIS, and initiatives to extend coverage in depth to other fields and in additional forms, are under consideration. Regional expert consultations were held in the Asia-Pacific Region in 1990 and 1991 to establish a cooperative network on plant biotechnology.

At the global level, most of the questions are being treated through the International Undertaking and the Commission on Plant Genetic Resources, for the collection, conservation and utilisation of germplasm. Elements, for a Code of Conduct on Biotechnology as it affects conservation and use of plant genetic resources, were prepared and submitted to FAO governing bodies. Collaboration with other UN Agencies is underway, as well as with NGO's, e.g. the UNIDO/WHO/UNEP/FAO Informal Working Group and OECD, the World Bank, IUCN, WWF and the European Community, on bio-safety.

As regards biosafety, although several studies have concluded that careful design of transgenic organisms, alongwith proper planning and regulatory oversight, will ensure that GMOs will pose little or no risk, risks are evident if pathogenicity is involved and calls for caution. The Fourth Session of the FAO Commission on Plant Genetic Resources, held in April 1991, resolved that FAO, in collaboration with other concerned organizations, should develop a Code which included and promoted basic biosafety standards for the contained use and deliberate release of GMOs, and for their importation and exportation. The Code will include elements to ward off the negative effects of GMOs on genetic diversity. FAO is also cooperating with UNIDO,UNEP and WHO in preparing codes for research, use, release, containment and monitoring of GMOs. The FAO/WHO Codex Alimentarius Commission is examining the implications of biotechnology influenced food products entering international trade.

FAO seeks, within its means and resources, to realize fully the positive impacts of biotechnologies and minimize, if not completely eliminate, the negative effects. In this resolve, FAO's strategy is to concentrate on activities such as provision of a forum of review of the trend, monitoring of developments and issuing early warning that clarify the issues and response options,to develop appropriate guidelines and codes to facilitate environmentally sound and equitable harnessing of modern biotechnologies, and to strengthen overall biotechnological capabilities of developing countries. In this respect, FAO also seeks to channelize its biotechnological support to developing countries for improvement of "orphan" crops, commodities and farming systems and promote pro-poor features of biotechnology. The congenial agro-ecological settings and availability of relatively cheaper labour in developing countries should be conducive to large-scale production of new high value crops, especially medicinal and aromatic crops, enabling such countries to maintain comparative advantage in these commodities. Use of biotechnology for development of biofertilisers, biological management of pests, detection of pathogens and their biocontrol, etc. which are scale neutral and labour-intensive will particularly be suitable for the majority of resource-poor farmers. Such areas of research will hence receive priority attention in FAO-sponsored programmes.

2.9 International Atomic Energy Agency (IAEA)

IAEA has been active in research activities in biological systems since its inception. IAEA has been working with UNEP, UNIDO, and WHO to assess the health and environmental risks from energy and their complex industrial systems. FAO and IAEA joint division has undertaken a wide variety of research and training activities in radiation biology and biotechnology. FAO and IAEA have been emphasising a shift in focus on agricultural research and development on the lines indicated in Table 6.

2.10 International Labour Organisation (ILO)

ILO has been concerned with an analysis of the implications of biotechnology on employment. ILO has also been promoting non-governmental organizations in spreading new technologies in rural areas. Dr. Iftikhar Ahmed of ILO has recently prepared a comprehensive book on **"Biotechnology: Hope or Threat"**. He has compiled information on the potential impact of genetic engineering on employment opportunities (Table 5).

An ILO study on the targetting of endogenous capability in Latin America is now in progress and looks at the potential impact of biotechnology, substitutions and public-private sector roles. These issues are linked to the impact on various categories of producers, consumers and the labour market.

Biotechnology, including gene technology, is considered to offer immense potential to society by contributing to improvements in health, agriculture and industrial production. There is, however, growing concern regarding safety and health problems associated with biotechnology; the concern is further intensified by the expected rapid growth of these activities. Biotechnology is increasingly used for producing a variety of medicinal and agricultural products, to alter, for example, the resistance of agricultural products to physical and biological damage. A study is therefore being prepared by the ILO on the impact of modern biotechnology, including gene technology, on workers' health and the environment. The study will identify potential risks related to the introduction of these new technologies and will serve as a basis for future work on preventive measures.

2.11 United Nations Scientific, Educational and Cultural Organization (UNESCO)

UNESCO is actively involved in promoting several areas of biotechnology research and application. The general approach of UNESCO to this problem is that there is an urgent need for the transformation of the existing science and technology systems of developing countries to respond to the challenges and opportunities offered by new technologies in general and biotechnology in particular.

UNESCO took the lead in the establishment of a network of

Microbial Resource Centres (MIRCENs - see Table 4) directed to the needs of developing countries. MIRCENs serve the microbial community in the collection, preservation, identification and distribution of microbial germplasm. They are also engaged in the dissemination of information relevant to the cultures and their uses, and in the development of research and training activities that are directed towards regional needs. UNESCO has seeded some efforts, through its global MIRCEN network and other arrangements, in promoting sub-regional and international co-operation, training and transfer and exchange of expertise in the biotechnologies field.

The goals of the programme are:

(a) to provide a global infrastructure that incorporates national, academic and/or research institutes geared to the management, distribution and utilization of the microbial gene pool in the context of international cooperation;

(b) to reinforce the conservation of micro-organisms, with emphasis on the Rhizobium gene pool in developing countries with an agrarian base;

(c) to promote sustainable economic and environmental applications of microbial technologies;

(d) to foster development of new inexpensive technologies native to specific regions;

(e) to serve as a foci for the training of manpower and the diffusion of microbial knowledge.

Recently, within the framework of joint UNESCO/UNDP collaboration, the Biotechnological Information Exchange System (BITES) was established and comprises MIRCEN network partners that are linked to current relevant information systems. The focal point of BITES is the UNESCO International Centre for Chemical Studies in Ljubljana, Yugoslavia.

UNESCO has also instituted short-term fellowships in biotechnology.

Further, UNESCO is drawing attention to an important problem that arises from the development of new technologies. The internal dynamics of scientific development as well as the external dynamics of industries and other private actors in basic technological research, have created new controls over research systems and the choice of research priorities. This may lead to the situation where the interests of small agriculturists might be neglected when growing, for example, such crops as sorghum, a vital crop for many developing countries, since this crop is not an item of international trade and hence does not bring big profits to agricultural companies.

UNESCO has also instituted short-term fellowships in biotechnology. Integration of traditional and frontier areas of technology is being given high priority. UNESCO has suggested that concerns relating to bacteriological warfare should also be addressed, possibly through a high-level seminar, since the recombinant DNA technology provides scope for the synthesis of powerful biological warfare agents.

2.12 United Nations Industrial Development Organization (UNIDO)

Recognizing the potential of biotechnology for development and that the first order of its impact would be on industry, UNIDO initiated work 10 years ago on methods of identifying the effective transfer of benefits of biotechnology research to developing countries. This ultimately resulted in the establishment of the International Centre for Genetic Engineering and Biotechnology (ICGEB). The ICGEB has now 45 Member States and affiliated centres in 15 of these States. The research and development programme of ICGEB is dedicated to the application of genetic engineering and biotechnology to problems of relevance to developing nations of the world. The 1990 Activity Report of ICGEB gives an excellent summary of the work being done under its two components located at Trieste and New Delhi. The major thrust of ICGEB and its component units are as follows:

Agribiology - with an emphasis on crop improvement
Human health - with an emphasis on vaccine production
Biomass conversion - lignocellulose degradation.

The ICGEB component laboratories are crucial to the success of the mission of the Centre in providing a world-class scientific milieu in which scientists can learn and apply new techniques and transfer them to their native countries. Through a process of consultation involving the Preparatory Committee, the Panel of Scientific Advisors (PSA) and scientists from the Member States, the above research topics were selected as being most in keeping with the declared aims of ICGEB.

(i) **Research at the Trieste component**

Under the development plan for the Trieste component, the full complement of research and support staff will by 1993 be divided into five research groups, each led by a senior scientist and composed of three to six junior scientists, plus a number of trainee fellows and technicians. These groups will address research topics in:

Virology, molecular and cell biology;
Immunology;
Pharmacology;
Protein structure and engineering;
Microbiology.

The group members will be drawn from a wide range of disciplines relevant to genetic engineering and bio-technology giving the Centre a multi-disciplinary character. The groups will interact and collaborate on the various facets of the research areas described above.

At Trieste, interaction with the local scientific community has already been established. Access to a very powerful source of X-rays from a synchrotron, to be operational by 1992, will enable ICGEB scientists at Trieste to pursue state-of-the-art research in protein structure and engineering.

(ii) **Research at the New Delhi component**

The research staff at the New Delhi component of ICGEB when at full strength (1993) will be divided into groups similar in structure to those at the Trieste component, each headed by a senior scientist and comprising a number of junior scientists, trainee fellows and support staff. These groups will be active in:

Plant biology;
Human diseases;
Structural biology.

The ICGEB has today become an extremely important institution with a global outreach through link centres. Its PSA comprises world leaders in biotechnology.

A number of technical cooperation projects in biotechnology have been implemented or are under implementation by UNIDO. An important example is the Regional Network for Biotechnology in Latin America and the Caribbean. UNIDO, with the financial assistance from the United Nations Fund for Science and Technology and UNDP, initiated in 1981 a preparatory phase of biotechnology activities in Latin America resulting in a regional programme and network.

Phase I of this programme funded by UNDP, was implemented jointly by UNIDO and UNESCO, with UNESCO covering the basic development of biotechnologies and products and UNIDO carrying out the technology development and industrial application of biotechnology. The programme's aim was to establish a framework for joint development policies in biotechnology, geared to solving regional priority problems through new products, processes and services. The programme's 13 country members formed a Regional Council as its top decision-making body. The Council selected nine biotechnology products of high regional priority, fostered training through training courses, workshops and fellowship programmes and identified 14 pipeline priority products and five priority areas not covered by the Programme. Phase II activities are under consideration by UNDP at present.

To complement the activities, the network has also been affiliated to the ICGEB. UNIDO also implemented technical assistance programmes in the region at national and regional levels.

Other activities undertaken through UNIDO's operational activities in applied biotechnology related to:

- biogas technology (industrial scale);
- ethanol production by fermentation from sugar, etc.;
- chemicals made by biotechnology processes such as amino acids, citric acid, enzymes, etc.;
- composting;
- assistance provided in biochemical engineering development;
- membrane technology;
- microbial pesticides;
- microbial leaching;
- plant tissue culture;
- waste water treatment, etc.

UNIDO's promotional programme in the field of biotechnology contains the following elements:

Programme element	**Examples**
(a) Identification of national and regional R&D priorities, monitoring of technological trends, sensitization of policy makers, scientists and technologists and the development of databases and bio-informatics networks.	Studies and policies and programmes in selected developing countries and on global trends in biotechnology etc. Development of a bio-informatics activity including a workshop in the USSR.
(b) National biotechnology policy formulation.	Biotechnology programmes in several African countries and advisory services under STAS.
(c) Research cooperation between institutions of industrialised and developing countries.	Programmes for research cooperation for vaccines, bioremediation of oil and enhanced oil recovery, lactic acid fermentation.
(d) Transfer of technology through investment promotion and technological cooperation at the enterprise level.	Expert group meeting on commercialization of biotechnology. Expert group meeting on the application of biotechnology to food processing in Africa.
(e) Monitoring regulatory issues, such as patenting and biosafety; formulation of safety guidelines for biotechnology research and manufacture for developing countries.	Development of a voluntary international code of conduct on the release of genetically modified organisms into the environment.

(f) National institution capability building through strengthening of R&D and production infrastructure and/or the International Centre for Genetic Engineering and Biotechnology (ICGEB).

ICGEB; institutional capability building in developing countries; increasing cooperation with affiliated centres.

Thus, UNIDO is striving to serve the growth and spread of biotechnological capability in developing countries and in harnessing the tools of biotechnology for promoting sustainable development. Also, as mentioned earlier, UNIDO has initiated a bioremediation project to combat oil pollution and an oil recovery programme (BIOROR) to assist countries in enhanced oil production.

2.13 World Bank

The World Bank has extensive programmes, particularly in developing countries, on various aspects of agricultural and industrial biotechnology and techno-infrastructure development. In recent years, considerable emphasis has been placed on integrating the concept of ecological sustainability with those of economic efficiency. In fact, the former President of the World Bank, Mr. Barber Conable said at a meeting at the World Resources Institute three years ago that if the World Bank was part of the ecological problems in the past, it would like to become a leader in the eco-development movement of today. The World Bank has also been increasingly supporting biotechnology research in developing countries and has appointed a Special Advisor to promote biotechnology research and applications.

2.14 World Health Organization (WHO)

The WHO has identified a number of specific areas for investigation to promote health care:

- Analysis of the structure and function of genomes of infection agents to better understand the process of infection and the mechanisms of pathogenisis and immunity;

- Preparation of monoclonal antibodies to identify constituents of infectious agents and the role of these constituents in pathogenisis;

- Identification and analysis of those antigens which elicit protective immune reactions, preparations of such antigens using recombinant DNA technologies or chemical synthesis and exploration of their use as vaccines;

- Development of reliable, comparable and easy to use procedures for the diagnosis of communicable diseases using monoclonal antibodies and defined and purified antigens;

- The development of specific anti-viral or anti-microbial compounds;

- Production of therapeutically active polypeptides, e.g. hormones and enzymes, of high purity;

- Identification of disease-specific hereditary traits providing a sound basis for genetic advice and for the development of genetic approaches to health promotion;

- Control and/or modulation of gene expression in diseases due to malfunction during differentiation;

- Genetic modification of biological control agents important in vector control;

- Identification of the oncogenes which are responsible for neoplastic transformation of cells, especially those that ae involved in human cancer common in the developing world, sch as primary hepatomas; development of DNA probes for the detection of activated oncogenes and of monoclonal antibodies against the corresponding proteins. Identification of specific tumour markers and development of reliable immunological assays.

Of these, it has been considered that three new techniques had the potential for early application. They were new approaches to vaccine development, improved techniques for diagnosis and the early detection of hereditary disorders.

There are four programmes in WHO, which have as a significant or main component the development of new or improved vaccines. They are the Special Programme for Research and Training in Tropical Diseases (TDR); the Diarrhoeal Diseases Control Programme (CDD); the Special Programme of Research, Development and Research Training in Human Reproduction (HRP); and the Vaccine Development Programme.

WHO has made considerable efforts to examine the potential of new diagnostic techniques, particularly those based on monoclonal antibodies, for use at the primary health care level. The potential of nucleic probes for rapid, sensitive diagnosis of infectious diseases is also to be noted.

Nucleic acid probes had already been used in the early detection of hereditary disorders, such as thalassaemia. If adopted universally and practised continuously, this approach might result in the eventual eradication of this and similar diseases. These techniques and technologies have been described in many articles both in scientific journals and WHO documents.

2.15 World Intellectual Property Organization (WIPO)

The work of WIPO is of great relevance to the question of gene and genotype patenting. It has convened three meetings of a committee of experts on biotechnological inventions and industrial property, and one of a committee of experts on the interface between plant protection and plant breeders' rights. The decisions taken by WIPO will be of particular relevance to South-North issues in biological diversity and biotechnology.

2.16 World Meteorological Organization (WMO)

WMO has been actively involved in programmes relating to climate change. The World Climate Programme has become an important source of reliable information on weather conditions. WMO has also established a global atmospheric watch (GAW) system to provide reliable assessment of atmospheric composition including carbon dioxide, ozone and other green house gasses. This knowledge is important for imparting stability and sustainability to production systems. WMO also trains personnel for national meteorological and hydrological services.

The second World Climate Conference organised by WMO in association with other UN agencies in October-November 1990 provided an updated and authentic picture of emerging trends in climate. Such information is relevant to biotechnology research since anticipatory programmes can be taken up for breeding strains of crops and farm animals capable of adaptation to changes in temperature, precipitation and ultraviolet-B radiation.

Information dissemination by the UN system

UN agencies are actively engaged in dissemination of information in the area of biotechnology particularly of relevance to developing countries. Some of the important activities in this area are the following:

The Advanced Technology Alert System, UNCSTD
The PANOS dossier published in 1990 by PANOS, prepared by Robert Walgate, now with WHO;
The training role of the Consultative Group for International Agricultural Research (CGIAR);
UNIDO's Genetic Engineering and Biotechnology Monitor;
The role of ICGEB as a network, "Helix" Newsletter and ICGEBnet;
The World Bank - CGIAR-IARCs network, linking to traditional agricultural research services;
UNESCO MIRCEN;

2.17 Databases

A number of databases have been established or are in the final stages of preparation. Others are under consideration or in early stages of development. The databases relate to regulation, introduction or releases, microbiology, molecular biology, cell lines and hybridomas, sequence data, bibliographic and general biotechnology information. The major databases are: OECD's Bio-track on the Use and Release of Organisms; culture collection catalogues (United States, European countries, Japan, Brazil) including the World Data Centre's Directory of Culture Collections of Micro-organisms; national and regional microbial strain databases (MiCIS, MINE in Europe); Hybridoma Data Base, Immunocline Database, Interlab Animal Cell Database; sequences databases (EMBL, Seqnet, Can/Snd, Gen Bank); botanic databases (ILDIS; taxonomic databases (Biosis, ICECC); plasmids/vectors/ gene libraries (NIH Repository of Human DNA Probes); bibliographic (Datastar, Dialogue); general biotechnology (Bio-Industry Association databases, BIKE, BIOREP); Biotechnology Information Knot for Europe of GBF in Germany. Many of these are linked through the internationally sponsored information and communications Microbial Strain Data Network (MSDN).

In addition, a database containing information on national and international safety standards, training materials, studies and other publications concerning safety in the workplace in biotechnology is held in the International Occupational Safety and Health Information Centre (CIS) of the ILO. The future of biotechnology will involve reliance on large amounts of shared data and hence international agreements on data sharing are important.

Other international and regional organizations

2.18 Commission of European Community (EC)

The EC has a very active programme in the area of biotechnology. A Bio-Molecular Programme, and a Biotechnology Action Programme (BAP) have been in progress from 1982 and 1985 respectively. The Community has initiated some pioneer projects such as the following:

BAP pioneered the concept of "European Laboratories without Walls" and the involvement of "Industrial Platforms" of interested companies. Project BRIDGE (Biotechnology Research and Innovation for Development and Growth in Europe) supports programmes like the following:

- the characterisation of industrial lipases
- the sequencing of the yeast genome (starting with one small chromosome)
- the molecular identification of new plant genes
- the technology of lactic acid bacteria
- the regeneration of cultured plant cells.
- automated microbial identification
- animal cell biotechnology

Targeted projects will receive approximately half the programme's resources for cost-shared research contracts; the other half being devoted to N-projects (for "networking").

In the third Framework Programme, the new BIOTECHNOLOGY programme (164:MECU:1991-94) will address the need to increase basic knowledge and applicable technologies, and has three parts:

1. Approaches at the molecular level: deepening knowledge of the structure and function of a whole series of proteins (enzymes, hormones, receptors, etc.) involved in the essential functions of living cells; study of the structure and function of genes (sequencing of the entire genome of yeast, and of

other model organisms): 35-40 per cent of total expenditure;

2. Approaches at the cell and organism level: study of cell regeneration mechanisms, knowledge and control of cell development, methods of in vitro testing of the toxicity of new molecules, improvement of knowledge of the metabolism of plants, micro-organisms and animal livestocks and of intercellular communication systems (particularly in the nervous and the immune systems): 45-55 per cent.

3. Ecology and biology of populations: Impact of bio-technology on the environment (determination of the impact of genetically modified organisms on ecosystems, etc.); problem of conservation of genetic resources (evaluation and systematic analysis of the problem of the loss of genetic diversity connected with modern agricultural and stock breeding practices): 10-15 per cent.

The programme will include consideration not only of industrial relevance, but of ethical and social implications of the work. It will also reinforce activities in bio-informatics within the above areas.

In addition to the above, the Community has launched a special programme for linking agriculture and industry through research. An area of great interest to developing countries is the field of post-harvest technology and the promotion of bio-energy and bio-refineries programme. The Community has a special interest in promoting biotechnology research in view of its assessment that future market impact on biotechnology will be dramatic in the following areas:

(a) The SAGB projects the total value of biotechnology products and processes by the year 2000 at 83.3 billion ECU.

(b) Biotechnology products and processes are expected to account for 8 per cent (weighted average) of all target markets by the year 2000.

(c) Market sectors most highly impacted will be:

Pharmaceuticals/health care
Chemicals
Agriculture
Food
Environment

The most advanced current commercial applications of biotechnology are in the chemical, pharmaceutical and instrumentation/electronic sectors, because the technical hurdles have been more rapidly overcome.

Commercial applications in food and agriculture will develop more slowly until the mid-1990's because significant technical hurdles must still be overcome.

2.19 Role of Regional Development Banks

In addition to the above, regional development banks like the Inter-American Development Bank, Asian Development Bank and African Development Bank are supporting activities in the area of biotechnology. ADB is supporting the preparation of pilot biovillage projects in Asia. This programme emerged from a Dialogue held at Madras, India, in January 1991 under the auspices of the M. S. Swaminathan Research Foundation on taking the benefits of biotechnology research to the rural poor. A biovillage is one where the best in modern biological technology is integrated with the best in traditional wisdom, tools and practices. Pilot biovillage projects are currently under development in China and India with ADB support (Swaminathan, 1991). Regional political groups such as ASEAN and SAARC have also been concerned with issues relating to biotechnology.

The Inter-American Development Bank has been looking for new approaches as well as more advanced strategic and modern technologies to better serve the member countries. The general orientation is now to emphasize agricultural development, taking into consideration conservation and management of natural resources and eco-regional development. This new orientation encourages the use and application of biotechnology and genetic engineering as components of the Bank's project, when relevant. The IDB is of the view that biotechnology efforts at national, regional and international levels has clearly helped some Latin American countries.

2.20 Non-governmental Organizations

The International Council of Scientific Unions (ICSU) has a working committee for biotechnology (COBIOTECH) which is focussing on discussions on biotechnology and sustainable development. COBIOTECH has been sponsoring regional and international symposia and conferences designed to discuss and promote opportunities for collaboration between East and West. National organizations have been the most important sources of activity within countries. Several of them have very extensive programmes. For example, the 25 May 1991 issue of **Current Science, India**, has an excellent summary of the state of biotechnology research in India.

The European Confederation of Biotechnology has been actively concerned with a large number of issues, including the legal framework for ensuring bio-safety.

2.21 European Biotechnology Information Service (EBIS)

EBIS is also an important source of news and views in the area of biotechnology. Various advisory groups functioning under the EC and EBIS give up-to-date information on their activities.

United Nations Conference on Environment and Development (UNCED)

Agenda 21 of UNCED includes programmes relating to the speedy and effective transfer of environmentally sound technologies. In this connection, a workshop held in New Delhi, India, from 23-35 October 1991 has suggested the following five principal objectives and five major programme areas for inclusion in Agenda 21.

(i) **Objectives:**

a. Increase food productivity in sustainable agricultural systems through the use of modern biotechnology applications in combination with conventional/traditional methods, techniques and technologies.

b. Contribute to improvements in human health globally.

c. Reduce environmental degradation, and preserve environmental integrity by the judicious application of biotechnology and facilitate the provision of safe, clean, reliable water supplies.

d. Implement internationally-agreed safety procedures.

e. Stimulate the development and transfer of bio-technology applications.

(ii) **Programmes:**

a. Increasing plant and animal productivity.

b. Promoting improved human health.

c. Enhancing protection of the environment.

d. Enhancing safety in biotechnology and developing international mechanisms for cooperation.

e. Establishing enabling mechanisms for the environmentally sound application of biotechnology.

The PREPCOM III of UNCED considered the report of the Secretary General and agreed with the following objectives and activities:

Objectives

a. Increase plant and animal productivity by 25 per cent by the year 2000.

b. Reduce dependence on pesticides for food, feed and fibre by 25 per cent by the year 2000.

c. Increase productivity on marginal lands through the use of nitrogen fixation and mycorrhiza and reduce dependency on chemical fertilizers.

Activities

The proposed activities of this programme include:

a. Use of conventional technolcgy and biotechnology to develop transgenic (genetically modified) plants that are resistant to biotic and abiotic stresses.

b. Use of traditional techniques ot nitrogen fixation and myccorhiza in conjunction with advanced molecular biology techniques, to improve nitrogen fixation efficiency of symbiotic organisms in legumes and grasses, and phosphorous uptake capacity by crops.

c. Use of conventional technology in conjunction with animal reproduction and animal health biotechnologies to accelerate animal breeding for specified needs and rescue endangered native livestock for breeding purposes.

d. Provide adequate institutional infrastructure.

e. Address issues related to germplasm resources, intellectual property rights, and harmonize bio-safety procedures.

2.22 Biotechnology and health for all

The protection and enhancement of human health is one of the most important objectives of development. The degradation of environmental quality, for example, by air and water pollution, soil contamination, toxic chemicals and hazardous wastes, is of increasing concern. There is also an increase in communicable and vector-borne diseases compounded by malnutrition, inadequate human settlements and lack of sanitation facilities. The health and well-being of people are therefore expected to be subjected to increasing risks, which in turn would affect the productivity and innovations of the individual.

a. **Universal Immunisation**

Develop new and improved vaccines against major communicable diseases that are efficient, safe and protect the individual with least number of doses. The vaccine should be stable to higher temperatures and preferably orally delivered. It should also be possible to combine and deliver a number of vaccines in a single dose for multiple disease protection at birth.

Control of disease vectors, such as mosquitoes, through the use of biological control agencies.

b. **Development and use of specific diagnostics**

Develop and utilise new diagnostics based on monoclonal antibodies and DNA probes for the early, accurate solution of various diseases for enabling prompt treatment.

Facilitate use of diagnostics under unsophisticated conditions by semi-skilled personnel.

c. **Development of new therapeutic and growth promoting agents**

Develop and facilitate the use of hormones and its agonistics and antagonists (e.g.) insulin, growth hormone).

Develop agents that promote cell growth and modulate immunity systems (e.g. cytokinins, TNF, ECG).

d. **Development of new population control agents** using natural body mechanisms and biotechnology leading to safe, reversible, and long-lasting methods.

e. **Development of new drugs** based on molecular designing: Develop new pesticides and other chemicals designed through computer simulation and modeling using receptor-drug/receptor-pathogen interactions.

Develop new drug delivery systems to deliver drugs to target sites and which are useful in the treatment of problematic diseases and organs (e.g. cancers, brain tissues).

f. **Development of safe and effective methods of detection and treatment** of genetically inherited and inborn diseases using DNA probes and gene therapy.

The above are some of the priority tasks in the international research agenda proposed for consideration at UNCED.

2.23 Call of PREPCOM of UNCED

The paper "Environmentally sound management of biotechnology: options for Agenda 21" dated 27 September 1991 (A/CONF. 151/pc/WG.1/L.30), prepared for the UN General Assembly with regard to the work of PREPCOM 3 for UNCED, brings out the significance of biotechnology for a better quality of life for all. The paper has stressed that the environmentally sound and safe application of biotechnology has the potential for addressing issues such as health care, levels of food security, the efficiency of industrial development processes, the purity of water supplies and environmental problems arising from water pollution, pesticide residues and soil degradation. The paper has underlined the need to accelerate the development and application of biotechnologies, particularly in developing countries.

For this purpose, the paper calls for a major effort to build up institutional capacities at national and local levels, especially in terms of research and training, raising public awareness, the development of human resources and information facilities, matched by appropriate levels of financial support and backed by equivalent development and support for traditional methods and techniques as practised by local and indigenous communities.

The call for a major effort in the biotechnological transformation of the quality of life of rural and urban poor in developing countries needs for its realisation new patterns of international cooperation backed by appropriate institutional structures. It calls for action at the local, national, regional and global levels. It may be worthwhile to review some of the major components of a "Biotechnology for a better common future" programme.

CHAPTER III

International cooperation in biotechnology for a better common future

3.1 International cooperation: Need for a new vision

The cooperation has to be viewed at three levels:

a. Technology: Development and dissemination
b. Training: Degree and non-degree
c. Trade: Home and international trade

The existing situation in these areas has been reviewed earlier.

A few suggestions are offered here for the further development of on-going collaborative efforts, both in the short and longer term perspectives.

a. **Technology**: This is the prime mover of economic and ecological change, either for the better or for worse. In view of the dominant role of the private sector in the biotechnology industry of developed nations, it is difficult to suggest global mechanisms which will be considered satisfactory by all. However, the following steps will be relevant.

(i) Immediately, ICGEB already exists. Its research and training programmes have the support of scientists worldwide. In order to ensure that its research has the desired impact it would be useful to link ICGEB in global networks such as those operated by CGIAR institutions. Since ICGEB's activities also cover the medical field, it is important that it has symbiotic linkages with WHO's medical networks.

A list of CGIAR centres is given in Table 7.

The following centres of CGIAR have active programmes in agricultural biotechnology:

a. CIAT, Cali (Colombia)
b. CIMMYT, El Batan (Mexico)
c. CIP, Lima (Peru)
d. IBPGR, Rome (Italy)
e. ICARDA, Aleppo (Syria)
f. IRRI, Los Banos (Philippines)
g. ICRISAT, Hyderabad (India)
h. IITA, Ibadan (Nigeria)
i. ILRAD, Nairobi (Kenya)

The New Delhi centre of ICGEB is already playing an active part in the international rice biotechnology programme. The specialised expertise of ICGEB will be of much benefit to the

International Agricultural Research Centres (IARC's). In turn, ICGEB's work will find immediate application at the field level through the networks of IARC's. Hence, a suitable Memorandum of Understanding could be developed between ICGEB and CGIAR institutes.

(ii) **At the regional level**, several networks already exist, some of them with support from regional development banks. These networks should be designed to forge a trilateral partnership among academic and research institutions, private and public sector industry and user groups. It is important to have user representatives in coordinating committees so that fears about the environmental safety and wholesomeness aspects can be addressed effectively. Regional Development Banks and regional political structures could jointly promote the growth of government-industry-academe coalition for the purpose of promoting the field application of the results of biotechnological research.

(iii) **At the national level**, different countries have different mechanisms at the governmental level to stimulate and sustain bio-technology research and development. Such mechanisms should be sensitive to public apprehensions on issues relating to safety and equity. In case there is an overall mechanism for giving high level political consideration to sustainability issues, such as a Cabinet Committee on Sustainable Development, a standing committee of that body could deal with biotechnology, biodiversity and sustainable development. Pioneer projects like the biovillage programme supported by the Asian Development Bank in India and China need urgent support (Swaminathan, 1991).

There is also a need for specialised genetic resources centres for assisting genetic engineers. For example, the Centre for Research on Sustainable Agricultural and Rural Development at Madras is establishing two specialised gene pools for use in recombinant DNA experiments. One gene pool deals with the assembly of candidate genes which can confer tolerance to sea water intrusion. Another gene pool is an assembly of genotypes having a bearing on sustainability factors, such as the following:

* Germplasm of nitrogen fixing tree species and shrubs, stem-nodulating legumes like *Sesbania rostrata*, as well as of Azolla and blue green algae.

* Plant species of importance in pest control including tree species, annual plants, fungi and bacteria which can serve as repellents of pests and those which control soil nematodes and weeds.

* Germplasm of species which can enhance the efficiency of fertilizer use including Neem (*Azadirachta indica*) and other tree species whose seed cakes have a nitrification inhibition capacity.

* Species which can help to prevent/reduce soil erosion and protect local food security, often referred to as ecological or economic key species, such as vetiver grass (Vetiveria zizanoides), Chenopodium species, and grain and leaf Amaranths.

* Tree species and shrubs of value in agroforestry and alley farming practices and in restoring the fertility of degraded and waste lands.

* Plant species of value in veterinary and human medicine.

Such a specialised genetic garden for sustainable agriculture is currently being established at Madras. In addition to such specialised genetic gardens, we also need genetic enhancement centres where novel genetic combinations can be developed for distribution among field-level plant and animal breeders. ICGEB in association with IBPGR and other IARC's could develop a global grid of specialized genetic resources and enhancement centres.

There is also need for national, regional and global efforts in promoting basic research on topics of relevance to the application of biotechnology. The Rice Genome Research Advisory Committee, organised by Japanese scientists, is a good example of the kind of initiative which ICGEB and IARCs should foster.

3.2 Dissemination of information and awareness generation

In the area of dissemination of research results, several mechanisms already exist, as indicated earlier. Nevertheless, there is need for special information centres at the regional level for giving credible information to financial institutions on the cost, risk and return aspects of new biotechnological innovations. UNIDO can help to establish such a network in collaboration with FAO, UNESCO, UNEP, WHO and UNCTC, as well as the Economic Commissions for Africa, Latin America and the Caribbean and Western and Southern Asia. Such Regional Information Centres for the commercialization of biotechnology should have a network of sources of credible information.

Another area where there is need for public awareness and action is the protection of habitats rich in biological diversity. The pressure of population as well as some of the pathways of development chosen have resulted in a gradual destruction of major ecosystems like hill, wetland and coastal ecosystems and to the loss of habitats rich in fauna and flora. Because of the diversity of soil, climate and growing conditions, India is rich in its endowments of plant species. Habitat destruction and the extension of agriculture to forest areas promote species extinction. But for the green revolution, more forest land would have got diverted for the cultivation of annual crops. For example, India produced 12 million tonnes of wheat from 14 million hectares in 1964. In 1990, 55 million tonnes of wheat were produced from 24 million ha. Hereafter, the additional food requirements will have to come from higher productivity per crop and higher intensity of cropping. Higher yield has to come from higher biomass production and better harvest index. Such progress will be possible only with the help of biotechnology.

Thus, sustainable advances in biological productivity are essential for meeting the food, fuel, fodder and other needs of our growing population. Biological diversity is essential for achieving sustainable gains in productivity per units of land, water, energy and time. We can neither sustain national food security systems nor face the challenge of climate change if we fail to conserve and utilize in a sustainable manner the global genetic wealth in flora, fauna and micro-organisms through the tools of biology and biotechnology.

Even protecting the protected areas is becoming a major challenge. The number of species entered in Red Data Books is growing. There is need for a special international programme on <u>Biotechnology for preserving biological diversity</u> in order to save endangered species of plants and animals through cell and tissue culture and cryo-presentation techniques. The Department of Biotechnology of the Government of India is launching such a programme.

b. **Training:** Training at the level of professionals, political leaders and the public is important if we are to promote sustainable development with the help of new technological tools including biotechnology, space technology and information technology. Special training seminars will be necessary to sensitize political leaders on the opportunities and limitations of biotechnological innovations. At the same time, the training of high-level professionals requires urgent attention in developing countries. Specialised short-term, non-degree training and re-training programmes will be particularly valuable. A systems approach in training will help to promote an awareness of the sustainability considerations which must underpin all developmental activities.

c. **Trade:** Thus far, the debate on trade related intellectual property rights has divided negotiating countries into separate groups. A large number of developing countries believe that establishing an international IPR standard is likely to be detrimental to their growth and development. They believe that since new technologies are largely being developed in industrialised countries, the developing countries will find it harder to gain access to these new technologies. Nevertheless, many developing countries are willing to examine the issue of counterfeit trade and negotiate a multilateral framework to regulate and reduce trade in counterfeit goods. It is to be hoped that the UNCED negotiations may lead to a satisfactory arrangement. Third World farmers and small-scale manufacturers need the support of biotechnology most. They are well endowed in biological diversity and can derive immense benefit from molecular biology. The rural economy is largely biomass-based in many developing countries and it will be sad if the fruits of biotechnological research do not reach them.

3.3 An international initiative for the application of biotechnology for sustainable development for inclusion in Agenda 21 for UNCED

The foregoing account of the wide range of research and development activities currently under way would serve to provide a glimpse of the excitement, hope and fear that biotechnology research has generated. The hope is particularly great in the area of overcoming some of the ecological ills associated with earlier technologies. Bioremediation involving the use of micro-organisms to get rid of toxic chemicals will find increasing application. Rapid afforestation of degraded forests can be undertaken with the help of micro-propagation of trees of suitable species. Biomass refineries will help to produce energy and value-added products. Thus, there is every hope that even a 10 billion population can be supported within the carrying capacity of supporting ecosystems. The time has therefore come for a bold and imaginative international initiative for the application of biotechnology for sustainable development. Such an initiative could be supported by a global institutional arrangement similar to that of CGIAR where the membership could be open to governments, multilateral donors, foundations and private and public sector industries. A Consultative Group for Biotechnology (CG-Biotech) could bring about the necessary convergence and synergy among academic, business, government, non-governmental and international institutions. The major aim of CG-Biotech should be to assist developing countries to achieve the threshold essential for deriving economic and ecological benefits from the wide range of techniques associated with modern biotechnology. It could thus promote a new paradigm of biotechnology development and extension based on considerations of economic efficiency, ecological sustainability, equity and employment intensity.

3.4 Rationale for a CG-Biotech

Even the brief review presented in this paper on the wide spectrum of problems in agriculture, industry, medicine and energy now being studied with the help of the tools of molecular biology and biotechnology would suffice to convey a sense of hope and optimism in relation to the potential for improving the quality of life for humankind during the remaining years of this century. It is equally obvious that biotechnology is one area of research that has attracted widespread interest among both private industry and the academic world. The implications of modern biotechnology research for human welfare are far-reaching. The very power of the new tools of genetic engineering make the adoption of codes of ethics and safety imperative. Earlier in this paper methods of imparting a pro-poor bias in the choice of research problems have been described. Biotechnology also helps to increase the carrying capacity of supporting ecosystems through new opportunities for employment generated by the efficient use of biomass and by higher crop and animal productivity.

The time is opportune for organising a CG-Biotech to serve as a global coalition for the application of biotechnology for sustainable development. Such a global coalition of private and public sector industry, foundations, academic institutions, government agencies and international research institutions/ organizations can help to stimulate, support and spread environmentally friendly biotechnologies worldwide. It can promote the blending of traditional and frontier biological technologies.

3.5 Structure of CG-Biotech

A few suggestions on how to structure the proposed CG-Biotech are given below:

Members: The following could provide the initial membership:

a. Interested UN agencies and other international institutions
b. Interested bilateral and multilateral donors, including IFAD and Regional Development Banks
c. Foundations
d. Representatives of private and public sector industry
e. International Council of Scientific Unions and Science Academies
f. Representatives of Governments representing the different regions according to the formula generally adopted in the United Nations.

Members of the CG-Biotech will meet annually to review progress and accelerate the dissemination of ecologically desirable technologies.

Co-sponsors: The CG-Biotech could be co-sponsored by UNIDO, FAO, UNESCO, IBRD, UNDP, UNEP and IFAD.

Secretariat: UNIDO could provide the secretariat for the Scientific and Technical Advisory Committee for CG-Biotech, since UNIDO is already servicing the Panel of Scientific Advisors for ICGEB.

Fiduciary agent: UNDP could serve as the fiduciary agent, as it has a global network of offices and programmes.

Scientific and Technical Advisory Committee (STAC): A multi-disciplinary STAC with a widely respected biotechnologist as chairman should be established to assist the CG-Biotech in choosing priorities and in making investment decisions. STAC should pay particular attention to the development and dissemination of "green" or environmentally benign biotechnologies in agriculture, industry and medicine. It should also advise CG-Biotech on the following issues:

a. Biosafety
b. Wholesomeness
c. Intellectual property rights
d. Biological diversity and biotechnology
e. Bioremediation

f. Human resource development
g. Data base development and information exchange
h. Recognition of informal innovations, and
i. Ethical and equity issues

STAC could have about 15 members drawn from the academic world as well as industry, representing the spectrum of expertise essential for promoting a dynamic biotechnology industry in all parts of the world.

3.6 Method of operation

CG-Biotech could implement its mandate through mechanisms such as the following:

a. Global and regional networks of existing private and public sector institutions, including appropriate CGIAR, FAO, UNESCO and WHO Networks.

b. ICGEB and its global outreach centres.

c. Individual national, regional and international research centres.

d. Newly established centres of excellence.

e. A global grid of genetic enhancement centres, and

f. Information centres for commercialisation of new innovations.

The aim should be to optimise the benefits of existing centres and to fill critical gaps in on-going work, with particular reference to research areas of particular relevance to the economically and ecologically handicapped sections of the human population.

3.7 Extending the benefits of "green technologies"

New biological technologies are by and large "green" or environmentally friendly. A priority item on the agenda of CG-Biotech should be extending the benefits of the new technologies already on the shelf among developing countries. The following areas need particular attention:

a. Improving the productivity, profitability, stability and sustainability of major farming systems.

b. Enlarging biomass-based energy production on the lines of the work already underway in EC countries, under the Large European Bio-energy Network (LEBEN) programme and promoting ecologic bioprocessing.

c. Combating desertification through the rapid spread of suitable leguminous and other tree species, using mist and micro-propagation techniques.

d. Spreading the benefits of new developments in improving human and animal health.

e. Control of pollution including the use of micro-organisms through bioremediation techniques.

The above activities can be packaged in a "biovillage" module form, as described in detail in the book "Biotechnology in Agriculture" (see Swaminathan, 1991). The establishment of pilot biovillage projects to achieve the triple goals of higher productivity, income and employment opportunities should be accorded priority. For this purpose the CG-Biotech could establish a Biovillage Science and Technology Coalition consisting of industry, research and training institutions, institutional credit agencies, representatives of women's and social science organizations and representatives of mass media. Such a coalition in collaboration with appropriate government and non-governmental agencies can foster the growth of biovillages in all parts of the world, based on the principle of integrating the best in modern biological technologies with the best in traditional wisdom and technology.

3.8 Conclusion

The establishment of a CG-Biotech for Sustainable Development is an idea whose time has come. If implemented, this will be one of the most significant contributions in the area of promoting the quality of human life within the limits of the carrying capacity of the supporting ecosystems. The experience gained from the operation of the CGIAR during the last 20 years indicates that a flexible dynamic system of organization coupled with effective mechanisms for priority setting, policy oversight, extension and monitoring will help to generate the confidence of both donors and developing countries. It would hence be appropriate to organise soon a "Bellagio-type" conference to develop this idea further and make it into an operational entity. UNIDO could take the lead in organising such a Bellagio conference on the establishment of a CG-Biotech.

APPENDICES

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GLOSSARY

ADB	-	Asian Development Bank
AGRIS	-	International Information System for the Agricultural Sciences and Technology
ATAS	-	Advanced Technology Assessment System
ASEAN	-	Association of South-East Asian Nations
BAP	-	Biotechnology Action Programme
BIOROR	-	Bioremediation and oil recovery
BITES	-	Biotechnological Information Exchange
BRIDGE	-	Biotechnology Research and Innovation for Development and Growth in Europe
CAANAPS	-	Computer Assisted Analysis of Nucleic Acids and Protein Sequences
CDD	-	Diarrhoeal Diseases Control Programme
CB-BIOTECH	-	Consultative Group on Biotechnolgoy
CIAT	-	Centro Internacional de Agricultura Tropical
CGIAR	-	Consultative Group on International Agricultural Research
CIMMYT	-	International Maize and Wheat Improvement Centre
CIP	-	International Potato Centre
CIS	-	International Occupational Safety and Health Information Centre
COBIOTECH	-	Committee for Biotechnology
CSTD	-	Centre for Science and Technology
DNA	-	Deoxyribonucleic acid
EBIS	-	European Biotechnology Information Service
EC	-	European Community
ECG	-	Electrocardiogram
ECU	-	European Currency Unit
EDF	-	Environmental Defence Fund
FAO	-	Food and Agriculture Organization of the United Nations
GATT	-	General Agreement on Tariffs and Trade
GAW	-	Global Atmospheric Watch
GMO	-	Genetically modified organism
HDI	-	Human Development Index
HRP	-	Special Programme of Research Development and Research Training in Human Reproduction
IAEA	-	International Atomic Energy Agency
IARC	-	International Agricultural Research Centres
IBPGR	-	International Board for Plant Genetic Resources
IBRD	-	International Bank for Reconstruction and Development
ICARDA	-	International Centre for Agricultural Reseaarch in the Dry Areas
ICGEB	-	International Centre for Genetic Engineering and Biotechnology
ICRISAT	-	International Crops Research Institute for the Semi-Arid Tropics

ICSU	-	International Council of Scientific Unions
IDB	-	Inter-American Development Bank
IFAD	-	International Fund for Agricultural Development
IITA	-	International Institute for Tropical Agriculture
ILO	-	International Labour Organisation
ILRAD	-	International Laboratory for Research in Animal Diseases
IPR	-	Intellectual property rights
IRRI	-	International Rice Research Institute
ISNAR	-	International Service for National Agricultural Research
IUCN	-	International Union for the Conservation of Nature
LEBEN	-	Large European Bio-Energy Network
MIRCEN	-	Microbial Resource Centres
NARS	-	National agricultural research systems
NEST	-	New and emerging science and technology
NGO	-	Non-governmental organization
NIMBY	-	Not in my back yard
OECD	-	Organization for Economic Co-operation and Development
PBR	-	Plant breeders' rights
PGR	-	Plant genetic resources
PSA	-	Panel of Scientific Advisors
RFLP	-	Restricted fragment length polymorphism
SAGB	-	Senior Advisory Group on Biotechnology
SAARC	-	South Asian Association for Regional Cooperation
STAC	-	Scientific and Technical Advisory Committee
TDR	-	Special Programme for Research and Training in Tropical Diseases
TMV	-	Tobacco mosaic virus
TNF	-	Tumour necrosis factor
TRIPS	-	Trade-related Intellectual Property Rights
UNCED	-	United Nations Conference on Environment and Development
UNCTAD	-	United Nations Conference on Trade and Development
UNCTC	-	United Nations Centre on Transnational Corporations
UNDP	-	United Nations Development Programme
UNESCO	-	United Nations Educational, Scientific and Cultural Organization
UNEP	-	United Nations Environment Programme
UNIDO	-	United Nations Industrial Development Organization
UNU	-	United Nations University
UPOV	-	International Union for the Protection of New Varieties of Plants
WCED	-	World Commission on Environment and Development
WHO	-	World Health Organization
WIDER	-	World Institute for Development Economics Research

WIPO	-	World Intellectual Property Organization
WMO	-	World Meteorological Organization
WWF	-	World Wildlife Fund
YAC	-	Yeast artificial chromosome

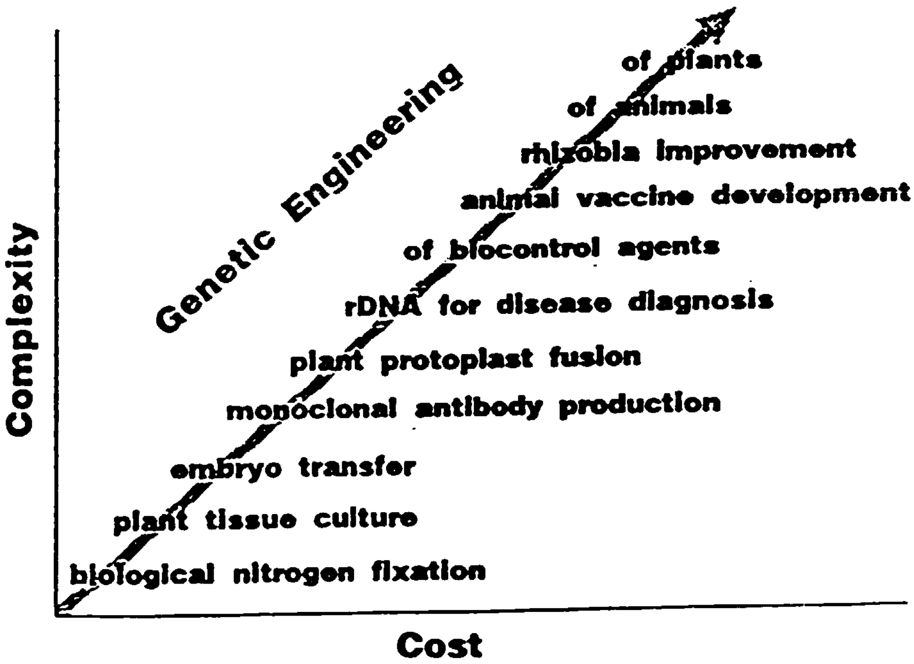

Figure 1. Classifying biotechnologies

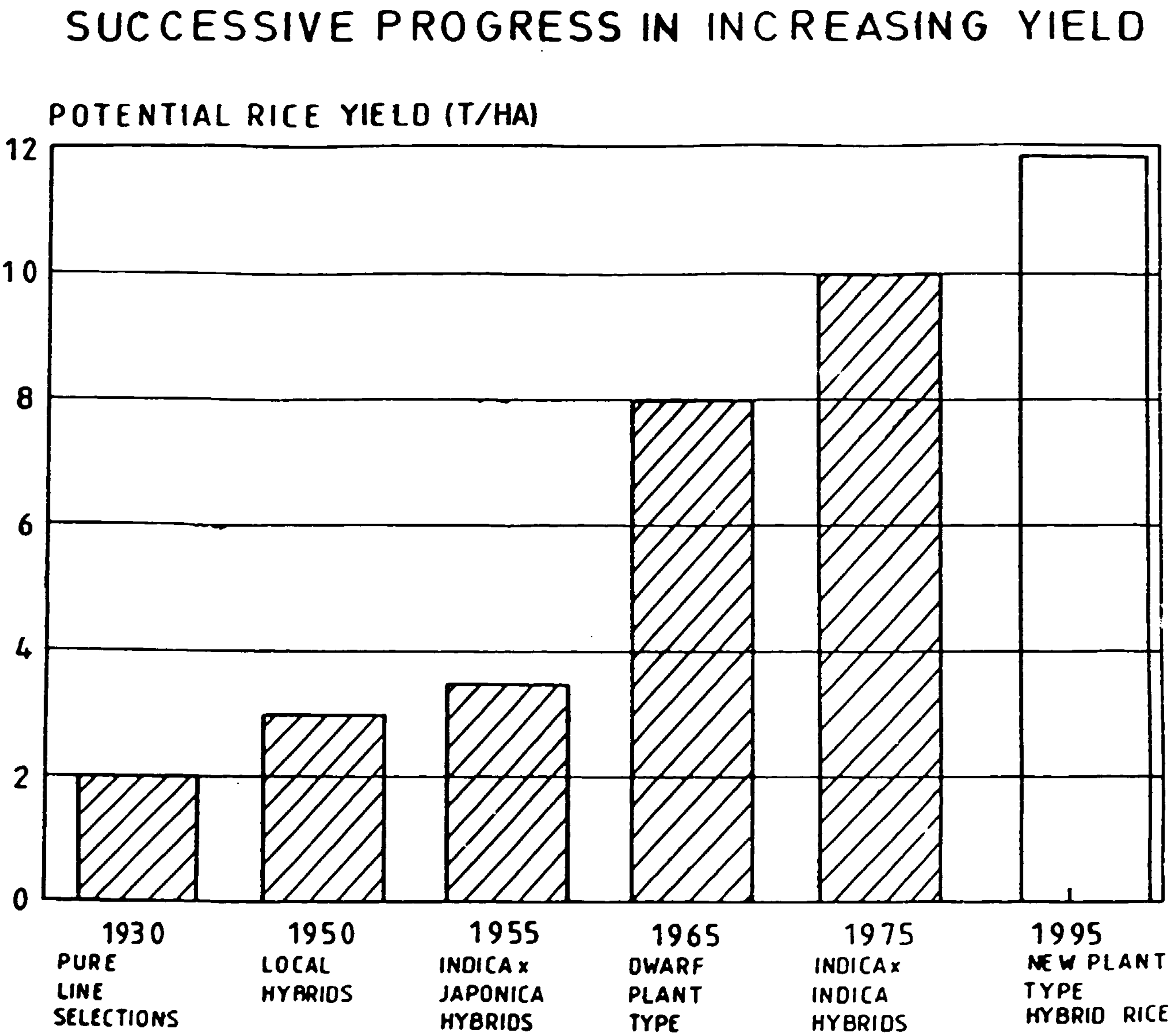
SUCCESSIVE PROGRESS IN INCREASING YIELD
POTENTIAL RICE YIELD (T/HA)
12
10
8
6
4
2
0
1930
PURE
LINE
SELECTIONS
1950
LOCAL
HYBRIDS
1955
INDICA x
JAPONICA
HYBRIDS
1965
DWARF
PLANT
TYPE
1975
INDICA x
INDICA
HYBRIDS
1995
NEW PLANT
TYPE
HYBRID RICE

Fig. 2

Table 1

Timeframe of application of two main categories of biotechnologies to selected commodities and corresponding value of affected exports of developing countries and territories

A. Tissue and cell culture techniques

Timeframe for routine use [a]	Value of exports (US$ billions)	Commodities [b] affected (no. of developing-country/ territory exporters [c])
Up to 1995	20.9	Coffee (28), bananas/plantains (16), rice (6), rubber (5), tobacco (2), vanilla (2), cassava (1), potatoes (1)
1995-2000	21.2	Sugar cane/sugar beet (16), cocoa (15), tea (4), soyabeans (3), oil palm (3), wheat (3), maize (1), sunflower (1), pineapple (0), sorghum (0), barley (0), sweet potatoes (0), yams (0)
After 2000	3.4	Cotton (15), coconut (10), rapeseed (0), millet (0)

B. Transgenic plants

Timeframe for routine use [a]	Value of exports (US$ billions)	Commodities [b] affected (no. of developing-country/ territory exporters [c])
Up to 1995	6.4	Rubber (5), tobacco (2), maize (1), potatoes (1), tomatoes (0)
1995-2000	17.5 [d]	Sugar beet (16), cotton (15), bananas/plantains (16), rice (6), soyabeans (3), cassava (1), sunflower (1), barley (0), rapeseed (0), sweet potatoes (0), yams (0)
After 2000	21.7	Coffee (27), sugar cane (16), cocoa (15), coconut (10), tea (4), oil palm (3), wheat and flour (3), pineapple (0), sorghum (0), millet (0)

Source: Trade figures and sources used in assessment as in table 1.

a The timeframe for application of tissue and cell culture techniques is obtained from table 1 by making the following assumption: Up to 1995: the techniques depicted in table 1 can be routinely used "3" (in column (5)); 1995-2000: the techniques depicted in table 1 are close to being routinely used "2" (in column (5)); after 2000: all other cases.

b For commodity categories, see annex table II.

c Includes countries for which share of exports in total exports is above 5 per cent, as in annex table 1.

d Includes total value of sugar exports. Impact in this case would be in the form of substitution.

Source: TD/B/C.6/154, page 11

Table 2. Market predictions for implementing production based on genetic engineering

	Number of compounds	Current market value in millions of dollars	Selected compound of use	Time needed to implement genetic production (years)
Amino acids	9	1 703	Glutamate	5
			Tryptophan	5
Vitamins	6	667.7	Vitamin C	10
			Vitamin E	15
Enzymes	11	217.7	Pepsin	5
Steroid hormones	6	367.8	Cortisone	10
Peptide hormones	9	268.7	Human growth hormone	5
			Insulin	5
Viral antigens	9		Foot-and-mouth disease virus	5
			Influenza viruses	10
Short peptides	2	4.4	Aspartame	5
Miscellaneous proteins	2	300	Interferon	5
Antibiotics	4 a/	4 240	Penicillins	10
			Erythromycins	10
Pesticides	2 a/	100	Microbial	5
			Aromatics	10
Methane	1	12 572	Methane	10
Aliphatics (other than methane)	24	2 737.5	Ethanol	5
			Ethylene glycol	5
			Propylene glycol	10
			Isobutylene	10
Aromatics	10	1 250.9	Aspirin	5
			Phenol	10
Inorganics	2	2 681	Hydrogen	15
			Ammonia	15
Mineral leaching	5		Uranium	
			Cobalt	
			Iron	
Biodegradation			Removal of organic phosphates	

Source: Alan Bull, Geoffrey Holt and Malcomb D. Lilly, Biotechnology: International Trends and Perspectives (Paris, Organisation for Economic Co-operation and Development, 1982).

a/ Figure indicates classes of compounds rather than number of compounds.

Table 3. New bioengineered products in agriculture and their displacement of existing products in the United States economy

(Millions of dollars)

Products	1983	1987	1992
New bioengineered products			
Seeds	2	20	436
Fertilizers	-	219	319
Crop protection chemicals	-	134	231
Total	2	373	986
Markets lost			
Fertilizers	-	145	360
Crop protection chemicals	-	67	231
Total	-	212	591

Source: Technology Update, 14 May 1983.

Table 7. Forecast of world market growth in selected biotechnology products

(Millions of dollars)

	Current	1990	2000
All biotechnology products - world wide	10-60	500-27 000	65 000
All biotechnology products - Japan			16 000-24 000
Food and pharmaceutical biotechnology products	7 000		
Agricultural products (cumulative 1980-2000)			50 000-100 000
Medical products based on genetic engineering			5 000-10 000
Monoclonal antibody diagnostic products		600	
DNA probes		360	
EPO hormone		200	
Waste treatment processes			
Single-cell protein	900	1 500	
Enzymes	500	750	
Ethanol	200	350	
Chemicals	80	250	
Microbial cultures	15	200	

Source: "Biotechnology in Wales", Winvest, 1986, p. 5.

Table 4

The world network of Microbial Resource Centres (MIRCENs)

Speciality	Location	Place and Country
Rhizobium	Department of Soil Science and Botany, University of Nairobi	Nairobi, Kenya
Rhizobium	Instituto de Pesquisas Agronomica	Porto Alegre, Brazil
Fermentation, food and waste recycling	Thailand Institute of Scientific and Technological Research	Bangkok, Thailand
Biotechnology	Ains shams University	Cairo, Egypt
Biotechnology	Central American Research Institute for Industry	Guatemala City, Guatemala
Rhizobium	NifTAL project, College of Tropical Agriculture	Hawaii, USA
Biotechnology	Karolinska Institute	Stockholm, Sweden
World Data Centre	Life Science Research Information Section, RIKEN	Saitama, Japan
Rhizobium	Centre National De Recherches Agronomiques	Bambey, Senegal
Biotechnology	Planta Piloto de Procesos Industriales Microbiologicos (PROIMI)	Tucuman, Argentina
Rhizobium	Cell Culture and Nitrogen Fixation Laboratory	Maryland, USA
Fermentation technology	Institute of Biotechnology, University of Osaka	Osaka, Japan
Biotechnology	International Institute of Biotechnology, Canterbury	Kent, UK
Mycology	CAB International, International Mycological Institute	Surrey, UK
Biotechnology and agriculture	University of Waterloo and University of Guelph	Waterloo/Guelph, Ontario, Canada
Marine biotechnology	Department of Microbiology, University of Maryland	Maryland, USA
Biotechnology	Centre de Transfer	Toulouse, France
Biotechnology	University of Queensland	Brisbane, Australia
Microbial technology	Institute of Microbiology, Academia Sinica	Beijing, China
Microbial biotechnology	Caribbean Industrial Research Institute	Tunapuna, Trinidad and Tobago
Culture collections and patents	German collection of Microorganisms and Cell Culture	Braunschweig, FRG
Culture collections	Department of Microbiology, University of Horticulture and Food Industry	Budapest, Hungary
Biotechnological Information exchange Systems (BITES)	Unesco International Centre for Chemical Studies	Ljubljana, Yugoslavia

Source: Biotechnology and Development Monitor No. 6, March 1991

Table 5

Genetic engineering activity and breakthroughs world-wide by agronomic trait, crop, sponsor and potential benefits

Agronomic trait	Genetic engineering breakthrough	Sponsor	Crops affected	Potential benefits for poverty alleviation
Insect resistance*	Immunity from Bollworm and Budworm by incorporating genetic material.[1]	Calgene	Cotton	- Cost saving (pesticides) - Reduces crop losses
	Kills 2 types of caterpillars	Agracetus, Wisconsin		- Nearly a third of worldwide chemical insecticides worth worth $5 billion is applied to cotton
	Gene inserted from one bacteria into another bacilus thuringienis producing toxin which kills corn borers tunnelling into stalks causing corn ear to fall off.[1] Field trials of the same genetically-engineered micro-organism as was used on corn to protect against rice stem borers proposed at the Ingleside, Maryland Research Farm[2]	Crop Genetics	Corn Rice	"
	Genes for natural toxin introduced into tomato kills hornworms when they bite a leaf.[3]	Monsanto	Tomato	"

Agronomic trait	Genetic engineering breakthrough	Sponsor	Crops affected	Potential benefits for poverty alleviation
	A gene inserted from a bacteria bacilus thuringiensis into another called endophyte and introduced into cracks of corn seed reproduces naturally. When European corn borer bites into it, it cripples the insect's intestinal muscles. They stop eating and die.[4]	Crop Genetics International, Hanover, Maryland	Corn	- Crop damage in the US $400 million despite $50 million expenditure on chemical control - Two-thirds US corn fields affected by it - One season's corn surplus in Kenya turned into a health hazard - Same microbe can colonise 83 other plant varieties - Costs half of chemical sprays[5] - Has potential to spread and benefit poor farmer neighbours
	Pea Lectingene from pea inserted into potato interferes with digestive process of pests like colorado beetle or tubermoth. Available as seeds.[6]	Nickerson International Ltd. Norfolk (UK) (Seed Company)	Potato	- Emerging as a major food source in Africa and Asia, particularly India, China, Vietnam and Sri Lanka - Would increase labour use through multiple cropping
	Resistance to cotton bollworms, tobacco budworms, beet armyworms.[7]	Monsanto	Cotton Tobacco Beet	- Cost reducing - Crop losses reduced
	Gene transferred from Cowpea to tobacco enabled production of protein which disables an enzyme (trypsin) used by tobacco bud worm to digest food. As the insect bites into the transgenic plant, it is unable to digest the food and starves to death.[8]	-	Tobacco	"

Agronomic trait	Genetic engineering breakthrough	Sponsor	Crops affected	Potential benefits for poverty alleviation
	Toxic gene ex'-acted from bacterium bacilus thurriengensis being inserted into rice within 1991 for protection against rice stem borers and leaf folders.[9]	IRRI	Rice	- World-wide rice accoutns for one-fifth of humanity's calorie intake; in some Asian countries leading source of calorie intake[10] - Potential yields 6 bushels per hectare as against only 3 bushels currently achieved average[10]
	Genetic engineering is being explored in rice plants to introduce bacterial insecticides that kill insects that feed on rice plants. It has already been applied as a spray for years but considered as expensive and inefficient.[10]	University of Ghent, Belgium	Rice	
Disease resistance	Genes for protection against tobacco mosaic virus inserted into chromosome of tomato cell.[11]	Monsanto	Tomato	- Increases yields by 25%
	Transform rice plants within 2 years by genetic engineering to resist especially destructive disease rice tungro virus that stunts growth in rice plants.[12]	University of Nottingham (UK)	Rice	- The virus can devastate whole fields
	Gene incorporated into cucumber protects the plant from the cucumber mosaic virus which distorted leaves.[13]	Cornell and New York State Agricultural Experiment Station	Cucumber	- The virus reduces crop yield and quality - Potential benefit for both developed and Third World countries

Agronomic trait	Genetic engineering breakthrough	Sponsor	Crops affected	Potential benefits for poverty alleviation
	Russet Burbank potato genetically engineered show resistance to potato viruses X and Y.[14]	Plant Genetics Subsidiary of Calgene, Davis, California	Potato	- Russet Burbank potatoes account for more than 40% of the North American commercially produced potato - Valued at US$2 billion per year[14] - Viruses X and Y reduced crop yields by 10% each year
Herbicide resistance**	Plant grown from single cells carrying a gene for herbicide resistance.[15]	Belgium	Sugar beet	- Displaces labour, especially women - Raises farmer's costs - If poorer farmer's fields without herbicides suffer increased weed growth (pollinating agents move there from the herbicide affected fields) yield there falls[16]
	Imida Zolinone herbicide resistance controlled by a single dominant gene patented in 1988 incorporated into 100 maize lines commercially available in 1992[17]	Pioneer H-Bred International Co. USA (largest seed company)	Maize	"
	"Monocot barrier" broken by genetically engineered herbicide resistance to produce transgenic fertile corn.[18]	-	Corn	"
	Monsanto scientists have genetically engineered cotton for tolerance to the company's non-selective roundup herbicide[19]	Monsanto	Cotton	"

Agronomic trait	Genetic engineering breakthrough	Sponsor	Crops affected	Potential benefits for poverty alleviation
	Gene for herbicide resistance inserted into commercial tobacco[20]	Du Pont	Commercial tobacco	"
	Gene transferred for resistance to broad spectrum herbicide Basta[21]	Plant Genetic Systems	Tomato, potato, tobarco	"
	Gene inserted into tobacco resistant against Monsanto produced herbicide roundup[21]	Monsanto	Tobacco	"
Nitrogen-fixation	Ongoing research to shift 20 genes from nit-ogen fixing bacteria into crops.[22]	Sussex	Crops	- Reduction in average cost of production of poor farmers
	For creating symbiosis between cereals and NIF bacteria stimulated nodule-like structures in rice and wheat roots containing rhizobia in 1989.[23]	University of Nottingham (Ted Cocking)	Rice, wheat	"
	In 1988 complete sequence DNA in NIF cluster of 20 genes all in a row in klebsiella pneumoniae. Worked out how NIF regulated in sufficient detail. Promising source for transfer. This method already used to create new NIF bacteria.[24]	Germany (Alf Pühler)		- Reduction in average cost of production of poor farmers

Agronomic trait	Genetic engineering breakthrough	Sponsor	Crops affected	Potential benefits for poverty alleviation
Drought resistance	Since large number of separate traits help withstand drought, it is difficult and complex to isolate and transfer as many as 50 genes. Each of several mechanisms which the plant uses to overcome drought controlled by a set of genes (50) now breaking down traits for drought tolerance into its biochemical and physiological components viz deeper roots, thicker cuticle covering the plant, chemicals in plant that help reduce water loss. Each of these make modest contribution but cumulatively could make a major contribution.[24]	-	Numerous crops	- Area expansion - Multiple cropping - Cost reduction - Risk averse small farmers feared the higher fluctuations in output for Green Revolution crops compared to lower fluctuations of traditional varieties when the volume and timing of water was not appropriate
	Gene inserted from petunia growing in desert into normal petunia reduced water requirement by 40%.[25]	-	Petunia	"
	Genetic engineering will allow the insertion of cactus genes into wheat, corn, or soybeans to produce "less thirsty" grain crops.[26]	California	Grain	"
Processing and canning	Modify texture, taste, colour, shape. Roughly 70% tomato crop in the US processed. Commercial processors interested in fleshy and solid parts (95% liquid) of tomato.[27]	H.J. Heinz Co. & Campbell Soup Co.	Tomato	- 1% improvement in the proportion of solid part of tomato would add $77 million to annual value of processed tomato[27]

Agronomic trait	Genetic engineering breakthrough	Sponsor	Crops affected	Potential benefits for poverty alleviation
Bakeries	Genetically engineered yeast (gene inserted from another yeast) modified the genes to produce carbon dioxide more quickly, and so make the bread rise faster[28]	Gist Brocade UK	Bread making	- Approved for commercial use
Seedless orange	"Gene shears" used to switch off specific genes which lose their functions. Block development of seeds in fruits like citrus.[29]	-	Fruits	- Could benefit both Third World and industrialised countries - Problem of legal and monetary barriers (associated with patents) to access by LDCs
Pasture crop	Gene for sulphur rich amino acid transferred from a pea seed to the leaves of a pasture crop.[30] Sheep grow 30% more wool by feeding on the genetically engineered diet	The Commonwealth Scientific & Industrial Research Organisation (CSIRO), Canberra, Australia	Pasture crops, tropical legumes	- Australian wool production could increase by 5% bringing in an extra Australian $300 million annually - LDCs would benefit through (a) grazing land saving, and (b) higher production
Decorative value	Luminosity (luciferane) gene of the fire fly inserted into the tobacco plant that glows in the dark[31]	University of California, San Diego	Tobacco	- Ornamental and commercial value mainly in industrialised countries

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Agronomic trait	Genetic engineering breakthrough	Sponsor	Crops affected	Potential benefits for poverty alleviation
Microbes for cold tolerance	With the deletion of the gene for ice nucleition protein (ice negative bacteria) sprayed on leaves of crops could prevent wild-type ice-positive bacteria from gaining foothold on leaves of crops.[32]	Advanced Genetic Sciences Inc./ University of California, Berkeley	Strawberry Potato	- Spring crops in the US $1 billion in frost damage[33] - Benefits confined to temperate zones - Trials show that treated plants had only 1/3 of the frost damage on unprotected plants and the genetically engineered microbe did not spread beyond 30 metres test area
	Genetically altered bacteria baculovirus to control insect cabbage looper[33]	Cornell University	Cabbage and a dozen different vegetables	- US authorities authorised field tests
Microbial fungicide	Fungal disease attacks roots, afflicts wheat fields around the world, cuts crop yields by 50%. Cultured microbes attack the fungus and can be applied to the wheat seeds.[35]	Monsanto[34] Agricultural Co.	Wheat	- Spread to poor people's soils and fix nitrogen or reduce disease/pests there - Crop losses reduced - US Environmental Protection Agency has given permission to Monsanto to field test in Pullman, Washington State
Microbes attack disease	Crown gall disease affects stone fruits, nuts and roses caused by bacteria A. tume faciens in soil. Genetically engineered bacteria solution (10 billion bacteria packed in one litre) soaked in roots of seedlings. Marketing began by Bio-care Australia in 1989.[36]	Bio-Care Australia	Stone fruits, nuts, roses	- $150 million losses world-wide - Could spread to poor neighbour's soils, multiply and protect crop there - Costs US$1.20 per litre[37] - Bio-Care has already begun marketing this transgenic bacteria known as NoGall in 1989[38]

Agronomic trait	Genetic engineering breakthrough	Sponsor	Crops affected	Potential benefits for poverty alleviation
Microbes for nitrogen-fixation	Bacterium Klebsiella oxytoca associated with rice genetically engineered to increase nitrogen content in rice by 30 per cent.[37]	Department of Agriculture, Tokyo University	Rice	- Rice provides half of total calorie intake for 2 billion people in the world; nearly 70 per cent of the protein is provided by rice in the diet of the population of some parts of Asia (Walgate 1990, p. 6)
Quality of crop ripening	Genetically engineered "antisense" gene into tomato which blocks formation of enzyme involved in the softening of tomato ripening. Field trials ongoing in Mexico reported to be successful.[38]	Calgene funded by Campbell Soup	Tomato	- Given inadequate marketing infrastructure potentially valuable for Third World but patency costs would pose a barrier - Prolongs shelf life (reduced rotting) - Increases total solid content and displays viscosity and consistency - US patency (No. 5,801,540) obtained[38]
	Produce tomato ripening characteristics which facilitate canning.[39]	ICI	Tomato	- Of primary interest to developed countries but processors in the Third World could benefit
Microbes destroy insects	Genetic engineering increased the virulence level of a virus 100 fold to control insect Diatrea Saccharalis[40]	University de Campinas and PLANALSUCAR, Brazil	Sugarcane, soybean, millet, garden vegetables	- Cost of application of the virus is $10 per hectare to prevent crop losses from insect attack to the extent of $100 a hectare[30]
	Genetically engineered micro-organism Bacillus thuringiensis is two to three times more effective against caterpillars[41]	Repligen Sandoz Research	Various crops	- Reduces costs of farming and replaces chemical insecticides

Notes

* Cost of producing a new chemical insecticide is 100 times greater than the cost of genetically engineering a crop with a single gene, toxic for a specific pest.

** It is estimated that at least 40 herbicide resistance projects are in progress (Hobbelink, p. 6).

1 Financial Times, 4 April 1989 and Biotechnology Bulletin, Vol. 7, No. 10, Nov. 1988.

2 Chemical and Engineering News, 6 March 1989, p. 28.

3 USA Today, Wednesday 28 September 1988.

4 The Economist, 16 April 1988.

5 Sundquist, W.B., Emerging maize biotechnologies and their potential impact, Paris, OECD, Technical Paper no. 4, October 1989.

6 New Scientist, 8 September 1990.

7 UNIDO, December 1989.

8 The Daily Telegraph, 12 November 1987.

9 Biotechnology and Development Monitor (The Hague), No. 4, September 1990.

10 The New York Times, 6 February 1990.

11 USA Today, Wednesday 28 September 1988.

12 The New York Times, op. cit.

13 Chemical and Engineering News, 28 August 1989, p. 21.

14 Chemical Week, 30 August 1989.

15 New Scientist, 18 August 1988.

16 Lipton, Michael A., R. Longhurst, New Seeds and Poor People (London, Unwin Hyman, 1989), p. 372.

17 Sundquist, op. cit.

18 A dramatic breakthrough has been achieved by which De Kalle Genetics, Biotechmed International (Cambridge Massachusetts) and Monsanto has introduced a gene into corn, the transgenic plant can then be grown producing seeds European Chemical News, 5 February 1990). Although this can be used for numerous manipulations, not surprisingly De Kalle Genetics has started off with application for herbicide resistance while Monsanto has successfully incorporated a gene from the fire fly (Chemical Engineering News, 30 April 1990, p. 26).

19 Chemical and Engineering News, 28 November 1988, p. 21.

20 Chemical and Engineering News, 2 February 1987, p. 28.

21 European Chemical News, 2 February 1987.

22 New Scientist, 31 March 1990.

23 New Scientist 3 February 1990.

24 New York Times, op. cit.

25 USA Today, 28 September 1988.

26 International Herald Tribune, New York, 17 March 1986.

27 Goodman, D., Sorj, B., Wilkinson, From Farming to Biotechnology: A Theory of Agroindustrial Development (Oxford, Blackwell, 1989).

28 Watts, Susan: "Have we the stomach for engineered food?", in New Scientist, 3 Nov. 1990, p. 24.

29 New Scientist, 26 May 1988.

30 New Scientist, 10 March 1988 and 13 November 1986.

31 New Scientist, 6 October 1990.

32 New Scientist, 26 May 1988, McGraw Hill's Biotechnology Newswatch, 4 May 1987 and Chemical and Engineering News, 21 November 1988, p. 26.

33 The Wall Street Journal, 29 Mar. 1989.

34 Biotechnology Bulletin, Vol. 7, No. 9, Oct. 1988.

35 International Herald Tribune, 12 July 1990.

36 New Scientist, 4 March 1989 and Greenfield, P.F. 1990, p. 3.

37 Bio/Technology, Vol. 8, June 1990.

38 Chemical Week, 22 February 1989 and Scientific American, May 1990, Chemistry and Industry, 19 Sept. 1988 and Chemical Week, 13 Sept. 1989.

39 The InterAmerican Development Bank: Economic and social progress in Latin America, 199 Report, Washington D.C., p. 245.

40 Financial Times, 4 April 1989.

41. European Chemical News, 1 Oct. 1990.

Table 6. The shifting focus of agricultural research and development

Past objective	Additional emphasis
CROPS	
Non-food and cash crops	Upgrading subsistence food crops
Large-scale producers	Small-scale producers
Prime land	Marginal land
Increased productivity	Sustainable production
Higher-yielding cultivars	Stress-resistant cultivars
Mechanization	Animal traction
Monocultures	Intercropping
Irrigation	Rain-fed agriculture
Mineral fertilizers	Nutrient recycling
Chemical pesticides	Integrated pest control
Limited number of crops	Crop diversification
LIVESTOCK	
Cattle	Small ruminants and other small livestock/poultry species
Large-scale producers	Small-scale producers
Traditional pastures	Improved dryland pastures
Capital-intensive production	Extensive production
	Improved food quantity and quality
FISH	
Off-shore fisheries	In-shore, inland fishing, aquaculture
Increased production	Replenishment of stocks
	Increased fishing efficiency
	Lower post-harvest losses
Development of boats and gear	Improved monitoring of resource stocks
	Enhancement of marine environments
	Alternative energy propulsion
TREES	
Single species plantations	Multipurpose tree crops
Industrial forestry	Community forestry, agroforestry
Harvest mechanization	Animal traction
	Trees for watershed management
	Trees for environmental improvement
	Management of protected areas
	Tree products for women

Source: The State of Food on Agriculture, 1987-1988: Changing Priorities for Agricultural Science and Technology in Developing Countries (Rome, FAO, 1988).

Table 7. The Seventeen IARCs & Their Main Focus

CIAT	International Centre for Tropical Agriculture (Cali, Colombia) *Cattle and pig breeding; cassava, common bean, maize, rice; pasture crops; farming systems. Emphasis on lowland tropical regions, especially in Latin America.*
CIMMYT	International Wheat and Maize Improvement Centre (El Batán, Mexico) *World cultivation of wheat, maize, barley and triticale.*
CIP	International Potato Centre (Lima, Peru) *World cultivation of potato.*
IBPGR	International Board for Plant Genetic Resources (Rome, Italy) *World conservation of plant genetic resources.*
ICARDA	International Centre for Agricultural Research in Dry Areas (Aleppo, Syria) *Farming systems of West Asia and North Africa, with emphasis on improving wheat, barley, chickpea, lentil, faba bean and pasture and forage crops.*
ICLARM	International Centre for Living Aquatic Resources Management (Manila, Philippines) *Sustainable management of aquatic resources.*
ICRAF	International Council for Research in Agroforestry (Nairobi, Kenya) *Developing methods of evaluating agroforestry technologies.*
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics (Hyderabad, India) *Farming systems of the semi-arid tropics with emphasis on sorghum, millets, chickpea, pigeonpea and groundnut.*
IFPRI	International Food Policy Research Institute (Washington DC, USA) *Worldwide study of food policies and programmes.*
IIMI	International Irrigation Management Institute (Colombo, Sri Lanka) *Research and information on improved irrigation management.*
IITA	International Institute of Tropical Agriculture (Ibadan, Nigeria) *Farming systems of lowland tropical regions, especially in Africa; emphasis on rice, maize, cowpea, pigeonpea, common bean, soybean, cassava, yam and sweet potato.*
ILCA	International Livestock Centre for Africa (Addis Ababa, Ethiopia) *Animal production systems and improvement of agropastoral economies in tropical Africa.*
ILRAD	International Laboratory for Research on Animal Diseases (Nairobi, Kenya) *Research on trypanosomiasis (sleeping sickness) and theileriosis (East Coast Fever).*
INIBAP	International Network for the Improvement of Banana and Plaintain (Montpellier, France) *Promoting research and scientific cooperation in banana and plaintain improvement worldwide.*
IRRI	International Rice Research Institute (Los Banos, Philippines) *Improvement of irrigated and rainfed rice, especially in Asia.*
ISNAR	International Service for National Agricultural Research (The Hague, Netherlands) *Advising governments on research policy, organisation and management issues worldwide.*
WARDA	West African Rice Development Association (Bouake, Ivory Coast) *Adaptation of research in rice cultivation for 15 Member States of West Africa.*