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PANEL ON CAPACITY-BUILDING IN BIOTECHNOLOGY

11-13 April 1999
Tehran, Islamic Republic of Iran

Summary report prepared by the UNCTAD secretariat*

* This paper summarizes the panel's discussions; it does not necessarily reflect the views of the UNCTAD secretariat.

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EXECUTIVE SUMMARY

A. Objective of the panel

The meeting of the Panel on Capacity-Building in Biotechnology of the Commission on Science and Technology for Development (CSTD) was held in Tehran, Islamic Republic of Iran, from 11 to 13 April 2000. It was the first of three substantive panel meetings on national capacity-building in biotechnology organized by the CSTD. The main objective of the panel was to identify key priorities and steps for developing countries and countries with economies in transition to build their capacity to:

- monitor, assess, regulate and manage the impact of biotechnology applications and ensure their safety;
- generate knowledge for the development of biotechnology by developing human resources through education, training and research.

B. Participants

The meeting of the panel was attended by the following member countries of the CSTD: Angola, China, Ghana, Greece, Guinea, Islamic Republic of Iran, Pakistan, Republic of Korea, Romania, Slovakia, Sri Lanka and United Republic of Tanzania. A representative from South Africa attended the panel as an observer. Three resource persons as well as a number of Iranian scientists and representatives of international organizations with offices in Tehran also attended the panel meeting (see Annex I).

C. Programme

The opening session took place at the Ministry of Foreign Affairs of the Islamic Republic of Iran. Opening statements were made by Dr. S.A. Motamedi, Deputy Minister of Science and Technology of the Islamic Republic of Iran; Ambassador Štefan Morávek, Chairman of the CSTD; and Dr. Mahmoud Molanejad, Vice-Chairman of the CSTD. The other sessions took place in a number of universities and institutions working on biotechnology.

The panel addressed a wide range of issues and identified a number of areas of core capacities, key priorities and steps for developing countries and countries with economies in transition. It also explored other issues, including facilitating information-sharing, identifying problems and setting priorities, complying with biosafety standards, and building public awareness about the potential benefits and possible risks of biotechnology. Panel members presented papers which outlined the capacity-building activities in their countries. It was clear from these that there are considerable differences among developing countries and countries with economies in transition in the development and application of biotechnology. These country experiences may serve as useful “models” for debate on the specific areas of capacity-building – regulation and public participation in decision-making – to be discussed at the next two CSTD panel meetings.

D. Recommendations

It was emphasized that biotechnology offers potential opportunities to improve agricultural production and sustainability and to assist in the creation of drugs and vaccines. It was also emphasized that it presents challenges for developing countries and countries with economies in transition to acquire, adapt and develop the technology needed to meet their specific priorities and the specific problems in their agricultural sectors. Bearing in mind that advanced biotechnologies are largely under development in the private sector in the industrialized countries, which may not be commensurate with developing country needs and concerns, capacity-building to manage both the positive and negative potential of these technologies is now imperative. The panel made the following recommendations for action at national, subregional, regional and international levels.

(a) National level

To help build an enabling environment for biotechnology development and management, and to make efficient use of existing and future resources, it was proposed that capacity needs assessments should be undertaken to build national strategies, policy regimes and action plans, which address:

- the identification of priority needs in the areas of food production, health care and the environment, including the conservation of biological resources;
- the existing national policy and regulatory frameworks for the identification, evaluation, acquisition, adaptation, development and management of biotechnology;
- the compatibility between existing intellectual property rights (IPRs) regimes, the requirements for the acquisition and development of advanced biotechnologies, and the protection of traditional indigenous knowledge;
- financial provision for biotechnology development and management;
- technical and human resource needs, including education and training to enhance scientific, legal and managerial skills, and bearing in mind the need to harness the expertise gained by nationals based overseas;
- institutional structures and linkages, at both national and international levels, and paying particular attention to public−private sector cooperation;
- information needs, particularly with respect to monitoring global developments in biotechnology; and
- infrastructural requirements and the broader policy context in which biotechnology development and management will take place.

It was emphasized that, in these endeavours, mechanisms should be developed to sensitize both the policy community and the general public, and to ensure the widest participation in national policy debate.

(b) International, regional and sub-regional levels

The CSTD was requested, in cooperation with other appropriate UN agencies, including UNU/INTECH, UNEP, UNIDO, FAO and WHO, to promote capacity-building in

biotechnology. Emphasis was placed on creating and enhancing networks to seek and diffuse information, building awareness, mobilizing financial resources and sharing expertise. North−south, south−south and intraregional cooperation were all identified as important in these respects. Two mechanisms were proposed for undertaking activities to support capacity-building at these levels:

(c) Regional and subregional biotechnology centres

These might be existing institutions, or focal points. The CSTD is requested to establish criteria to identify suitable centres to:

- promote regional and international cooperation;
- develop mechanisms and initiate activities to monitor, locate and promote the international diffusion of appropriate biotechnologies, including the encouragement of strategic alliances;
- enhance resource availability for the development and management of biotechnology through the mobilization of financial resources, and where feasible through education and training; and
- act as focal points for information-networking, in cooperation with appropriate organizations, and paying particular attention to the use of the Internet as a means of information-sharing.

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The centres identified should be networked with other international centres of excellence in biotechnology and national agencies working on biotechnology.

(d) Workshops

The CSTD is requested to facilitate the organization of workshops, where country representatives are able to:

- raise awareness of biotechnology development, and issues arising from it, at international and regional levels;
- share experiences and expertise in policy formulation, regulation, and institution-building;
- facilitate harmonization of biotechnology policy at regional and subregional levels, on issues such as biosafety; and
- promote the building of strategic alliances to diffuse appropriate biotechnologies.

A summary of the main issues discussed by the panel is provided in this report.

The report contains:

- background information on global developments in biotechnology and an overview of the involvement in those developments by developing countries and countries with economies in transition;

- a review by the panel's resource persons of key areas of capacity-building for biotechnology development in those countries;
- information provided by the panel members' own countries on their current situations with respect to biotechnology development and management; and
- the panel's recommendations emerging from the capacity-building issues discussed.

1. INTRODUCTION

Biotechnology has a wide range of applications in agriculture, health care, food-processing and environmental protection. Applications which can now or in the future provide enormous benefits include:

- improving and increasing food production capacity;
- faster breeding of new crop varieties which are more tolerant of climatic and other stresses;
- development of cheaper, more accurate and stable diagnostics and vaccines for both humans and animals;
- production of biological fertilizers and pesticides which will reduce the need for damaging chemical agricultural inputs; and
- use of microbes to clean up industrial and other pollution of land and water resources.

If biotechnology is to contribute significantly to achieving the objectives mentioned above, capacity must be built to select, acquire, manage and further develop those technologies which are most appropriate to national needs. This will require bringing together a wide range of scientific, managerial, legal and political expertise to develop a coherent set of policies which are compatible with existing sectoral policies and objectives, and which take into account cross-sectoral synergy.

In developing countries, successful biotechnology transfer and application will depend on access to information, appropriate national policies and the recognition by policy makers of the central importance of science and technology in national economic and social development. It will also depend on the level of awareness about the potential benefits and hazards of biotechnology.

Biotechnology and its increasing application are transforming agricultural, pharmaceutical, medical and other sectors of national and global economies in very profound ways. In agriculture, for example, the technology has enhanced the ability of society to produce higher-quality foods in environments that were perceived as having low or no productive potential. It is now possible to cultivate tropical crops in temperate zones. New varieties resistant to such ecological phenomena as drought are being developed through biotechnological techniques. In the medical and veterinary sectors, the development of diagnostics, vaccines and biopharmaceuticals is broadening the ability to manage diseases that were until very recently considered incurable.

The volume of basic and applied scientific knowledge in the field of biotechnology has grown rapidly in the past decade or so. The capacity of countries, particularly the industrialized ones, to engage in research and development (R&D) in biotechnology has also grown considerably, thus making it possible to commercially exploit related new technologies quite quickly. However, it has been emphasized that the evolution and growth of biotechnology, including its application are characterized by uncertainty. There is uncertainty about socio-economic and ecological benefits and risks from the technology. Public debate and anxiety about the potential negative environmental, economic and human health impacts

of some of the products and processes of biotechnology have intensified in the past decade or so. This has been so mainly because of the limited scientific knowledge about the nature of the risks. Indeed, while the stock of scientific knowledge about how to develop and apply biotechnology products has grown, our understanding of the risks, from a scientific viewpoint, is still limited.

Biotechnology is driving a rapid and radical transformation in agriculture. It is being used to produce new plants, processes and food products that are changing the nature and practice of agriculture. Plants and crops resistant to disease and environmental stress have been produced and are now being applied in agricultural and food production systems in some of the developing countries. The application of biotechnology in agriculture is of several types:

- genetic engineering of crops to enhance their productivity and quality even under conditions of stress from pests, diseases and environmental conditions;
- use of more mature biotechnological techniques such as tissue culture, embryo transfer and molecular markers for crop improvement and conservation of biodiversity;
- development of microbial-based herbicides and pesticides which are likely to change the commercial landscape of agrochemicals;
- creation of new diagnostic tests for detection of crop and livestock diseases; and
- development of vaccines to protect livestock from deadly diseases.

The human health care sector−pharmaceuticals and diagnostics−has also experienced rapid technological growth stimulated by advances in biotechnology. Biotechnology applications in the human health sector and its products have acquired a global commercial outlook.

The capacity to search, assess, acquire or develop, and utilize biotechnology is one of the most important factors accounting for differences in nations' competitiveness in the technology. It is the existence or absence of that capacity in developing countries that will determine whether they engage effectively in the application of biotechnology to address their national needs. The capacity is articulated in human skills, the existence of dedicated centres or programmes, the availability of adequate financial resources, the formulation of systemic and long-term policies, the existence of scientific and technological infrastructure, and appropriate institutional structures and linkages (for example, within and between research bodies, and between research and industry) for biotechnology R&D.

2. BIOTECHNOLOGY IN DEVELOPING COUNTRIES AND COUNTRIES WITH ECONOMIES IN TRANSITION

Over the past two decades, a number of developing countries, particularly in Asia and Latin America, have invested considerably in biotechnology R&D. Publicly funded research institutions and a few private companies in developing countries have established projects and/or programmes on biotechnology R&D. The nature of the activities and the level of investment in the technology vary from one country to another, and from one sector to

another. These initiatives are managed by a variety of institutional forms—for example, laboratories in established national agricultural research bodies, national biotechnology centres, national biotechnology programmes managed in sectoral research agencies, and international research bodies such as those of the Consultative Group on International Agricultural Research (CGIAR).

Some countries in the Asian region have identified priorities and are targeting their biotechnology R&D to address specific needs or objectives. For example, China has focused its biotechnology efforts on the development of two-line hybrid rice, transgenic cotton, and recombinant drugs for a number of critical diseases. A target-directed non-viral vector system, which can efficiently transfer exogenous genes into a tumour cell *in vivo* and significantly inhibit the growth of the tumour has been developed, thus achieving a major breakthrough in the area of gene therapy.

In Latin America, leading actors in biotechnology include Argentina, Brazil and Cuba. Argentina is one of the major exporters of genetically modified crops. Cuba and Brazil have also invested considerably in the genetic engineering of crops for export. In 1998, the Government of Cuba allocated a budget of over US$ 50 million to biotechnology R&D with emphasis on the development of genetically modified crops and products. The country's biotechnology R&D activities are conducted and coordinated by the Centre for Genetic Engineering and Biotechnology (CIGB) and the Centre for Molecular Immunology (CMI).

In Africa, countries which are involved in biotechnology activities fall into three categories:

- those that are generating and commercializing biotechnology products and services using third-generation techniques of genetic engineering – including Egypt, Zimbabwe and South Africa;
- those that are engaged in third-generation biotechnology R&D but have no products and/or processes yet – including Kenya, Uganda and Ghana; and
- those engaged in second-generation biotechnology (mainly tissue culture) – including the United Republic of Tanzania and Zambia.

Most of the biotechnology activities have focused on enhancing agricultural productivity.

Countries with economies in transition are at different stages with respect to biotechnology development and applications. The Czech Republic, Hungary and Poland are leading actors in several areas related to biotechnology, while countries such as Romania and Bulgaria have begun to develop their biotechnology industry. The main areas of focus of biotechnology R&D in central and eastern Europe are development of vaccines and diagnostics, and also more general application in the food sciences.

Most countries of central and eastern Europe are members of the International Centre for Genetic Engineering and Biotechnology (ICGEB) and are thus starting to develop biotechnology programmes and capabilities with ICGEB's support. The region constitutes a major focus of ICGEB activities, accounting for about 20 per cent of the Centre's work.

On the whole, developing countries and countries with economies in transition are all at different stages in the development and application of agricultural biotechnology. Some have moved up quite rapidly in biotechnology applications and are applying more sophisticated techniques such as molecular markers, while others are still at the tissue culture level of application. For example, Argentina, China, Cuba, Egypt, Hungary, Indonesia, Mexico, South Africa and Thailand have moved rapidly into such areas as gene sequencing, characterization of pathogens and gene promoters, while countries such as the United Republic of Tanzania are still concentrating on less complex biotechnology applications.

Experts stressed that in addition to the financing constraints that many developing countries face, there is a shortage of scientists in new areas of biotechnology in general and agricultural biotechnology in particular. However, the pool of scientists in such areas as molecular biology is growing. For example, the number of researchers in agricultural biotechnology is estimated to have doubled in Indonesia and Kenya between 1985 and 1996. It quadrupled in Mexico and Zimbabwe, with at least a fivefold increase in Ph.D. holders.

3. MANAGING AND REGULATING BIOTECHNOLOGY IN DEVELOPING COUNTRIES: KEY STEPS TO BUILDING NATIONAL CAPACITY

The resource person[1] shared his views on and experience with approaches related to the management and regulation of biotechnology, and addressed the challenges and opportunities for using these approaches in developing countries. He noted that early applications of "modern"[2] biotechnology, which include plant tissue culture, micro-propagation, molecular diagnostics of crop and livestock diseases, artificial insemination of livestock, and the development of recombinant vaccines for humans and animals, have already been adopted in many developing countries. These are simple to use, often inexpensive, and relatively free of regulatory requirements and public controversy.

The next generation of tools and products, based on advanced molecular techniques, takes advantage of revolutionary advances in genetic knowledge and the ability to manipulate DNA, but can require more complex skills and upgraded research laboratories, as well as the capacity to ensure food and environmental safety, and to manage intellectual property. The new knowledge allows scientists to create transgenic varieties, popularly called genetically modified organisms (GMOs).

To date, applications of genetic modification to crops have been limited to a small number of traits of interest to farmers in a few countries. Very few applications with direct benefits to consumers, or to small-scale farmers in developing countries, have been introduced. However, it is possible to envisage realistic possibilities for medium- to long-term benefits to developing countries.

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[1] Dr. Peter Gregory, Director, Biotechnology, Novgen Science, Inc., Washington, DC, USA

[2] The term "modern" is used here to differentiate between new techniques developed in the second half of the twentieth century (often known as "third generation" biotechnology) and those of the "first" and "second" generation biotechnologies – for example, traditional food fermentation, and antibiotic and vitamin production, respectively.

3.1 Benefits

(a) More nutritious and less expensive food

- broader array of more nutritious and safe foods; and
- improved food quality due to:

  (i) added nutritional factors (e.g. provitamin A and iron traits in rice);
  (ii) reduced saturated fatty acids and increased unsaturated fatty acids;
  (iii) elimination of allergens in foods; and
  (iv) introduction of factors that reduce the incidence of cancer;

- fresher and longer-lasting produce through improved shipping and storage quality;
- healthier animal products (e.g. leaner meats); and
- lower overall cost of food due to higher productivity and reduced losses throughout the marketing chain.

(b) Higher and more stable rural incomes

- more productive crops and animals;
- more stable yields and healthier livestock due to increased tolerance of constraints such as drought, flooding, heat, cold, pests, diseases and weeds;
- reduced input costs resulting from the incorporation of pest and disease resistance in crops and animals;
- reduced post-harvest losses;
- enhanced marketability and bargaining power resulting from better storability; and
- new products (e.g. plant-based replacements for petrochemical-based products such as lubricants and plastics).

(c) Less environmental damage even as populations grow

- reduced conversion of forest and marginal lands as production increases in existing fields;
- reduced use of chemical pesticides since the desired resistance is instead achieved through transgenic modifications; and
- reduced soil erosion as farming practices involving reduced tillage are made more feasible by the introduction of herbicide-resistant crops.

(d) Improved conservation of biodiversity

- use of a wide range of cellular and molecular tools (including genomics) to conserve, characterize and utilize plant collections in a more efficient way.

3.2 Possible risks and concerns

The resource person stressed that biotechnology, and particularly the introduction of transgenic varieties, may also involve risks and give rise to several important issues. Some of these are listed below and can vary with the product, the economy, and the ecology of the environment into which they are introduced.

(a) Agro-ecological and economic risks

- adverse impacts on beneficial insects and other organisms (e.g. the impact of transgenic corn pollen on certain butterflies);
- development of resistant weeds, pests or diseases that would reduce production or force farmers to replace currently used products with more harmful or more costly alternatives;
- spread of genes into wild plants and animals; and
- pest/disease outbreaks resulting from genetic uniformity.

(b) Human health risks

- introduction into food of substances that, although useful to most consumers, might be allergens to some;
- introduction into food of substances that, although intended to be toxic only to certain pests and extensively tested to ensure food safety, might still have adverse impacts on human health when consumed in large quantities over long periods;
- adverse consequences of residual antibiotic marker genes in food; and, more hypothetically,
- possible development of harmful organisms resulting from the exchange of genes between transgenic crops and wild organisms.

(c) Marketing and agricultural choice risks

- loss of market(s) that ban or avoid transgenic crops;
- reduced competition in input supply resulting in fewer choices or higher prices for farmers; and
- reduced efforts to seek other solutions if biotechnology is overemphasized.

(d) Legal and political risks

- Disputes about intellectual property issues, including patenting of life, especially where the interests of client countries differ from those of multinational suppliers; and
- disputes about accountability and liability regarding food safety and biosafety due to the lack of clear and broadly accepted technical standards.

3.3 Proposed policies and actions

To maximize the benefits of biotechnology, and to minimize risks to human health, the environment and the economy, Governments of developing countries should consider the following suggested policies and actions:[3]

(a) Develop coherent and consistent policies

A Government-wide approach to policy development should be taken that is consistent across ministries and government departments in terms of national principles and practices.

(b) Establish desired priorities and outcomes

The desired outcomes of biotechnology research and development should be clearly defined in consultation with all relevant stakeholders (in the public and private sectors). Scientific priorities should then be identified and addressed. Steps should be taken to ensure that priorities are consistent with overall government efforts to improve people's livelihoods.

(c) Ensure the safe use of biotechnology

An efficient and transparent regulatory system that meets international standards and enjoys public confidence should be established to assess risks associated with national or imported biotechnological products and to provide accurate information to the public (including suitable product labelling).

(d) Manage intellectual property

Legislation should be enacted to ensure that farmers and entrepreneurs benefit from local inventions. Introduction, evaluation and use of overseas inventions should be encouraged.

(e) Encourage private sector investment

Investment by local and overseas investors should be catalysed through fair tax regimes and other financial incentives

(f) Increase support for public sector research and development

Support should be generated at the national, regional and global levels to develop public goods and to provide access for the poor to biotechnological products and processes

(g) Support education and public awareness

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[3] Gabrielle J. Persley, ed. *Biotechnology for Developing-Country Agriculture: Problems and Opportunities, 2020 Vision Focus 2* (A collection of 10 briefs.) Washington, DC:, International Food Policy Research Institute, 1999.

There should be action at all levels to ensure that the country will have a highly skilled biotechnological workforce as well as informed public debate on risks *versus* benefits of biotechnology.

(h) Establish and maintain infrastructure

Investment in biotechnology-based industries will be encouraged only if there is adequate infrastructure to ensure that products are delivered to those who need them.

(i) Monitor overseas technology developments and encourage international Collaboration

Extensive networking and collaboration at the national and international levels should be undertaken to keep track of new developments around the world and to mobilize the best available technology to solve specific national problems.

4. MONITORING AND ASSESSMENT OF BIOTECHNOLOGY

Biotechnology is a knowledge-intensive technology. Successful entry into the technology—that is, the acquisition, development and application of the different techniques associated with the biotechnology—is largely dependent on a country's abilities to search, acquire, use and manage the growing body of scientific knowledge in such areas as molecular biology. Many developing countries and countries with economies in transition may not be able to easily access information about emerging knowledge. These countries' information technology infrastructure may be poor and many of the national biotechnology R&D agencies may not possess the necessary equipment and human resources to search, store and manage scientific information.

The ability of developing countries and countries with economies in transition to search, assess and acquire agricultural biotechnology is dependent on whether they monitor trends in the technology's development. Most of the countries do not have programmes and systems to monitor biotechnology and its development. In addition, many do not undertake technology assessments and are thus not able to make informed decisions on specific areas of entry into the technology.

In addressing the issue of building capacity for biotechnology monitoring and assessment in developing countries, the resource person[4] emphasized the need to have a transparent, science-based framework to monitor and assess risks while taking into account the views of all stakeholders. She noted that there is a lack of information other than that provided by self-interested actors. Much of what we were told earlier about the lack of environmental risks in the diffusion of GMOs has turned out to be untrue: genes can inadvertently transfer and may mutate. In these circumstances, pests may become resistant to existing management technologies, and weeds may grow stronger.

It was pointed out that in some cases ill-advised pressures for immediate implementation and a lack of monitoring and continuous assessment set up a structure

[4] Professor Lynn Mytelka, Director, INTECH, Netherlands

leading to undue haste in the application of GMOs and their widespread diffusion. It was also pointed out that if and when problems arise, this haste is likely to increase the social as well as the economic costs of "cleaning up" or "undoing" a problem. The "technological fixes" that are called upon for this purpose are themselves very costly—in R&D, for example. The process, moreover, sets us moving along the same technological trajectory instead of considering the full range of alternatives from the start. For example, the development of large-scale commercial farming led to the adoption of herbicide-intensive weed management systems, which were highly damaging to soils and very labour-intensive. It has been argued that *Bt*[5] insecticides— the biotechnological solution—were more knowledge-intensive and are now thought to stimulate selection in favour of stronger weeds, while genetically engineered *Bt* cotton or corn was an even more expensive product to develop and reinforces continued dependence upon the current technological trajectory marked by the privatization of knowledge, a narrow window of choice of technique and ever more oligopolistic markets for the provision of inputs and the use of outputs.

It was pointed out there was also some evidence that pressures arising from the above are also contributing to a circumvention of democratic processes and the erosion of support for public institutions. The lack of trust shown by people in Europe after the United Kingdom Government's attempts to suppress information about bovine spongiform encephalopathy (BSE) and its ability to "jump" the species barrier[6] is one such consequence. So too is the current reaction to GMO food. Key challenges and reflections on what needs to be done in order to build capacity to undertake an effective and a continuous process of monitoring and assessment were identified. They include the following:

- Policy makers will need to reconceptualize biotechnology as a system that includes all actors involved in generating supply or demand for knowledge, goods and services in the life sciences and those upon whom these products and services will have an impact.
- Once this has been done, a longer-term strategy for the biotechnology system as whole will have to be developed. It should include what the acceptable environmental and health, as well as the social and economic, costs of adopting GMOs and foods will be compared with alternatives.
- A programme of monitoring and assessment will clearly require training of local biotechnology researchers, social scientists and public servants. But it must also address the development of procedures, management practices and organizational routines within agencies entrusted with the tasks of monitoring and assessment.
- To avoid self-interested monitoring and assessment, efforts will need to be made to include actors from outside the specialized expert community and the commercial procedures of the technology. This should extend as well to people from social and geographical communities likely to be affected by the introduction of the technology.

[5] *Bacillus thuringiensis*, soil bacteria which have insecticidal properties

[6] BSE, or "mad cow disease", has been found to have a human variant, CJD (Creutzfeldt-Jakob disease), which is believed to be contracted from contaminated meat from BSE-infected animals.

- For monitoring and assessment to be affordable, linkages to others in the international biotechnology system engaged in monitoring and assessment will need to be created.
- For monitoring and assessment to be effective, closer ties to the domestic policy-making system will be required.
- Lastly, Governments should consider endorsement of the precautionary principle in the face of incomplete or conflicting data concerning the possible environmental and health effects and social and economic impacts of introducing genetically modified seed or genetically modified foods. When in doubt, the process should be slowed down and alternatives. Problems should be solved before GMOs are used and diffused.

5. STRATEGIC CAPACITY-BUILDING CONSIDERATIONS

In discussing ways and means of building and/or strengthening the capacities of developing countries and countries with economies in transition to effectively engage in the safe development and application of modern biotechnology, the resource person[7] identified different forms of institutions for biotechnology R&D in developing countries. He also addressed the role of international, regional and national centres of excellence in agricultural biotechnology and how such centres constitute important institutional avenues for strengthening countries' capacities to technologically forecast, monitor, assess, harness and apply biotechnology. In this connection, he stressed the need to promote linkages and partnerships among public and private sectors and centres of excellence and networks in developed and developing countries with the objective of strengthening national research capability and capacity in developing countries.

The resource person provided an overview of the biotechnology R&D efforts of developing countries as well as those of countries with economies in transition. He mapped out the institutional landscape for biotechnology and factors that prevent those countries from harnessing and applying the technology. Many countries are making entries into the technology and some have established centres or departments dedicated to agricultural biotechnology R&D. Examples of centres of excellence in biotechnology around the world were provided. A number of measures that would strengthen the capacity of developing countries and countries with economies in transition to effectively engage in the safe development and application of biotechnology were outlined. It was recommended that national biotechnology capacity needs assessments should be conducted in order to provide an informed basis for investing in capacity-building. Also, it was suggested that training be provided in bio-informatics, molecular biology and biotechnology policy as some of the areas in which the existing centres of excellence could contribute to the strengthening of developing countries' capacity in biotechnology.

5.1 Institutional base

The growth of biotechnology has been associated with the emergence of a variety of institutional arrangements for R&D and commercialization. Since the mid-1970s, key

[7] Dr. John Mugabe, Executive Director of the African Centre for Technology Studies (ACTS), Nairobi, Kenya.

institutional actors have been universities and public research bodies and more recently—in the 1980s—private firms have emerged as major players in biotechnology research and in the commercialization of the technology.

In general, three categories of private companies have been responsible for the rapid growth of biotechnology. In the first category are those companies that had already accumulated substantial capabilities in second-generation biotechnology, i.e. in fermentation and products such as antibiotics, vaccines and enzymes. The second category is made up of those companies that were specifically created to engage in modern biotechnology and had to build capabilities in areas such as genetic engineering. The last category comprises those companies that had no prior engagement in biotechnology but perceived the potential of the technology and were willing to invest in its development, sometimes with the aim of diversifying their products. All these companies have played a major role in the development of biotechnology, although their strategies and levels of engagement varied across sectors, countries and time.

In most industrialized countries, biotechnology R&D is dominated by the private sector. In developing countries and countries with economies in transition, private sector investment in biotechnology R&D is small. Nevertheless, in recent years a number of developing country private firms have begun exploiting the technology's potentials and are increasing their investment in biotechnology R&D. In the developing countries most of the R&D is still dominated by public sector agencies. This may well explain why in most of the countries there is limited, if any, generation and commercialization of biotechnology innovations.

Universities have often been the sources of scientific and technological breakthroughs in modern biotechnology. National and international public research organizations are also key players in biotechnology R&D. In Western Europe, Japan and the United States, the mid-1980s saw the emergence of biotechnology programmes to foster national competitiveness in the development and application of the technology. These programmes were established and managed in publicly funded agencies responsible for research in agriculture, environment, mining and human health. Cross-sectoral committees were formed to ensure that there was coherence and synergy in national biotechnology activities.

There are now a number of international organizations that have become major actors and sources of knowledge in biotechnology. Some promote the transfer of scientific knowledge and information about biotechnology. The United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP) and the United Nations Industrial Development Organization (UNIDO) have made significant contributions to the facilitation of transfer of knowledge and information on biotechnology. They have facilitated international cooperation and development in biotechnology. For example, UNESCO and UNEP established the international network of microbiological resources centres (MICRENS) that were instrumental in training scientists from developing countries in microbial topics associated with biotechnology.

6. CENTRES OF EXCELLENCE IN BIOTECHNOLOGY

6.1 National centres of excellence in biotechnology: Selected examples

Public universities and national research institutes have had considerable involvement in, and made contributions to, the evolution and development of biotechnology in a variety of scientific areas. Some universities have established faculties and programmes dedicated to biotechnology R&D, while others have continued to engage with the new technologies through specific projects within their conventional departments in such areas as biochemistry and microbiology. There are today many public universities in the United States, Europe and the developing world that have departments or institutes which qualify as centres of excellence in biotechnology. Indeed, there are literally hundreds of public centres of biotechnology around the world, and it would call for a more detailed project to document their activities. Some of these centres play or could play important roles in building the capacities of developing countries and countries with economies in transition.

There are a number of national centres of excellence in biotechnology in the Latin America region. These include the Oswaldo Cruz Foundation (FIOCRUZ) in Brazil, the Centre for Genetic Engineering and Biotechnology (CIGB) in Cuba, the Biotechnology Institute at the Autonomous University of Mexico (IBT-UNAM) in Mexico, and the Centre for Research and Advanced Studies (CINVESTAV) in Irapuato, Mexico.

In Africa, although a growing number of biotechnology activities are conducted in national public universities there are few centres dedicated to biotechnology R&D. The latter is largely undertaken by departments in universities and national agricultural research bodies. Some of the universities have established units or programmes that are now dedicated to biotechnology R&D. Many of these have not yet grown into centres of excellence.

Asia has a growing number of centres of excellence in biotechnology. Thailand's National Centre for Genetic Engineering and Biotechnology (BIOTEC) is one of the leading biotechnology institutes in the region. Founded in 1983 with funding from the Government of Thailand to conduct and coordinate research in frontier areas of biotechnology, the Centre has implemented many national and regional research projects and programmes.

In central and eastern Europe the Agricultural Biotechnology Centre (ABC) in Hungary is a centre of excellence in agricultural biotechnology. Established in 1986 by the Ministry of Agriculture of Hungary, ABC has grown into a regional centre engaged in cutting-edge scientific research in various areas of agricultural biotechnology. Its research and training activities include the following: recombination in transgenic plants between transcripts of viral transgenes and the genome of an infecting virus, development of monoclonal–antibody–based ELISA tests, and molecular biology of livestock. It receives funding from the Ministry of Agriculture, although it has recently received research grants from the Hungarian Science Foundation and the National Committee for Technical Development as well as from such international donors as the World Bank. The World Bank has provided the Centre with research grants totalling US$ 4.7 million.

6.2 International centres of excellence in biotechnology: Selected examples

A number of well-established and relatively dynamic international research centres now engaged in agricultural biotechnology R&D were identified. The International Rice Research Institute (IRRI), a member of the Consultative Group on International Agricultural Research (CGIAR), is one such centre. IRRI was established to conduct green revolution-based research for the improvement of rice production to meet global needs. Although its activities continue to concentrate on the conventional rice research technologies, it has established an elaborate international rice biotechnology programme with financial support from the Rockefeller Foundation.

In the 1980s, UNIDO took the lead in the creation of the International Centre for Genetic Engineering and Biotechnology (ICGEB) with headquarters in Trieste, Italy. The ICGEB is engaged in the building of national capacity in industrial, agricultural, pharmaceutical, animal and human health biotechnology. It now has more than 30 affiliated centres around the world, some of which have become into centres of excellence.

Other international centres are also actively engaged in biotechnology development and applications. CGIAR has a number of centres that are engaged in agricultural biotechnology R&D. The International Centre for Tropical Agriculture (CIAT) in Colombia, the International Maize and Wheat Improvement Centre (CIMMYT) in Mexico, the International Potato Centre (CIP) in Peru, and the International Livestock Research Institute (ILRI) in Kenya are among the leading international public biotechnology R&D institutes.

In the area of biotechnology policy, leading actors include the International Service for National Agricultural Research (ISNAR). ISNAR was established in 1979 to support the institutional development of agricultural research in developing countries. It is one of CGIAR's centres and receives funding from the World Bank and a number of bilateral donors, including the Governments of the Germany, Japan, the Netherlands, Sweden and the United States. It conducts research and training in various aspects of agriculture, and its annual budget is about US$ 10 million.

7. CAPACITY BUILDING ASSESSMENT NEEDS

7.1 Assessing national biotechnology capacity needs

The building or development of capacity involves a variety of interrelated processes, including:

- the identification and/or creation as well as appropriate management of R&D institutions;
- training and/or retraining of scientists in new areas such as molecular biology;
- the training of policy makers (or decision makers) in various policy and legal aspects of the technology;
- training in technology forecasting and assessment techniques; and
- mobilization of financial resources for R&D.

Experts stressed that in order to make informed decisions on the specific areas of capacity-building, it is important that each country undertakes a *national biotechnology capacity needs assessment*. Such an assessment would provide the necessary detail about areas in which countries should be investing in their capacity-building efforts. It was suggested assessments should be carried out through or with the support of such agencies as UNCTAD, the International Service for Agricultural Research and other appropriate agencies. Over the past five years or so, UNCTAD has been conducting reviews of national systems of innovation, focusing on such sectors as agriculture. The methodological approach and some of the information generated during those reviews may be useful for the proposed national biotechnology capacity needs assessments. The African Centre for Technology Studies (ACTS) is implementing a two-year project with funding from the Rockefeller Foundation to assess the national agricultural biotechnology capacities of Ethiopia, Kenya, South Africa, Tanzania, Uganda and Zimbabwe. This project will generate information about those countries' capacities engaging in the safe development and application of modern biotechnology in agriculture. Similar initiatives on national biotechnology capacity assessment could be launched in many developing countries and countries with economies in transition.

It was suggested that the CSTD may wish to consider initiating national workshops for representatives from various ministries (such as finance, national planning, science and technology, industry, and environment), non-governmental organizations (NGOs) and the private sector to discuss specific national strengths and weaknesses in the area of biotechnology. Such workshops may provide the necessary basis for undertaking detailed assessments of biotechnology capacity needs, where necessary. Also they would identify specific ways and means of mobilizing and/or building the specific components of biotechnology capacity that may be required in countries.

7.2 Building national capacity in biotechnology

Many developing countries, particularly those in Africa, tend to spread thinly their limited financial and human resources across biotechnology sectors and research agencies. While many have recognized the importance of setting biotechnology priorities and consolidating resources in a few research institutions that have the potential to grow quickly into centres of excellence in biotechnology, most countries have not yet established and applied strategies for identifying such institutions and ways of setting priorities. They continue to operate with isolated, competing and often scientifically weak research agencies.

The development and the commercial application of biotechnology present new challenges for those responsible for formulating public policies generally and science and technology policy in particular. New policy questions such as those relating to biosafety, access to genetic resources and transfer of biotechnology, distribution of benefits from biotechnology, privatization of scientific knowledge and intellectual property protection have to be addressed by decision makers in developing countries and in countries with economies in transition. However, many of the decision makers in these countries do not have an adequate understanding of, and information on, the wide range of fairly complex biotechnology policy issues. Building both their understanding of the issues and the skills needed to analyse and make informed decisions is one of the contributions that centres such

as ISNAR and ACTS can make to overall capacity-building as regards the biotechnology agenda. There are, however, relatively few centres organized courses in biotechnology policy. An international training programme on biotechnology policy could be established within one of the existing centres. It would aim at providing short- and medium-term training in selected key policy issues.

It was emphasized that there are many international and national centres that could contribute to the building of capacity in biotechnology for developing countries and countries with economies in transition. Some of those centres are already engaged in various efforts that contribute to capacity-building. There is a need to enlarge and to support these efforts to address countries specific capacity needs and priorities. The CSTD and UNCTAD could play a major a role in promoting targeting by facilitating the carrying out of national biotechnology capacity needs assessments, and by making information on the research and training activities of the centres of excellence available to developing countries and countries with economies in transition. A number of capacity-building activities and processes to which the centres of excellence could contribute have been proposed here. Emphasis has been placed on training, information management, institutional development and enlarging decision makers' understanding of the wide range of policy issues associated with modern biotechnology.

8. EXPERIENCES OF DEVELOPING COUNTRIES AND COUNTRIES WITH ECONOMIES IN TRANSITION

CSTD members shared their views and experiences with the use of biotechnology in their home countries. Country review papers were presented by China, Ghana, the Islamic Republic of Iran, , Pakistan, the Republic of Korea, Romania, Sri Lanka and the United Republic of Tanzania (see annex II). All these countries recognize the important role of biotechnology in national development and some of them have committed significant financial and human resources to develop biotechnology. China, the Islamic Republic of Iran and the Republic of Korea have allocated substantial resources for the development of infrastructure and capacity-building in biotechnology, and now have relatively advanced biotechnology industries. Speakers identified a number of obstacles to biotechnology development in their countries—inadequate financial resources, shortage of skilled manpower, poor infrastructure, difficulty in obtaining the necessary equipment and lack of clear strategies to advance the use of modern biotechnology. Intellectual property management was considered to pose a difficult challenge for most countries; a number of them do not have regulatory systems in place.

Issues of common concern to most countries were discussed. These include improving food security, increasing crop productivity, conserving biodiversity, reducing pest management costs, building institutional capacity for risk assessment, accessing information and developing human resources. Discussants also identified other impediments common in most developing countries. These include the lack of public awareness about the potential benefits and possible risks of biotechnology applications, and the lack of capacity to monitor and assess as well as manage and regulate biotechnology.

China has invested heavily in modern biotechnology and currently has about 20,000 research and development staff working in biotechnology. It has made technological breakthroughs in terms of plant genomics, two-line hybrid rice, animal and plant transgenic technology, gene therapy technology and disease-related gene research. It has commercialized several transgenic crop varieties and has a large number of GMOs in the process of being commercialized.

The Islamic Republic of Iran has allocated substantial financial and human resources to develop biotechnology programmes. The Biotechnology Centre of the Iranian Research Organization for Science and Technology (IROST) is one of the leading biotechnology institutions in the country. It provides education and training in modern biotechnology relevant to the country's needs and priorities, with particular emphasis on bioprocessing, fermentation, health care, environmental monitoring, food and beverages, agriculture, energy and biochemicals. It has acquired knowledge and built capacity in biopesticide production, feed production from agricultural waste, production of biofertilizers and revival of saline and desert lands using biopolymer superwater absorbent and biosaline agriculture. The National Research Centre for Genetic Engineering and Biotechnology (NRCGEB) is another advanced biotechnology institute working in such fields as medical genetics and biotechnology, agricultural biotechnology, veterinary and marine science, molecular microbiology, industrial and environmental biotechnology, biochemistry and molecular biology.

The Republic of Korea has a fairly advanced modern biotechnology industry. Policy makers support biotechnology as one of the highest priorities in R&D investment in order to enhance the nation's technological and industrial competitiveness. The Biotech 2000 programme, which was set up by the Government in 1994, aims to achieve for the country's biotechnological capabilities levels which are competitive with the most advanced countries in the world by the year 2007. Under the programme, the Government plans to invest about US$ 15 billion for the period 1994-2007.

In Pakistan, biotechnology and genetic engineering have been recognized as one of the important emerging technologies. Despite resource constraints, the Government encourages cutting-edge research in biotechnology and provides adequate funding to a number of biotechnology institutes to undertake major projects, particularly with regard to transgenic plants, microbial fermentation of lignocellulosic biomass for production of fuel, and genetically engineered microbes.

In Romania, while biotechnology has long been used, it was not until 1989 that wider use of modern biotechnology applications began to be promoted and supported by the Ministry of Science and Technology. A national institute of biotechnology and a faculty of biotechnology were created with the aim of ensuring the development of a scientific basis for the biotechnology programme in Romania as well as higher education in this field. In 1998, the National Agency for Science, Biotechnology and Innovation (ANSTI) took over the functions of the Ministry of Science and Technology and is currently developing a national strategy in accordance with the 5th RTD Framework Programme of the European Union. Furthermore, in September 1999, the Romanian Government issued a decision (project) aimed at research, into GMOs, and their testing, utilization and commercialization. The project also offers a legal framework for scientific activities, ensures safety and encourages

the use of biotechnology products in conformity with the decision of the Administrative Council of the United Nations Environment Programme.

In Sri Lanka, capacity-building has been achieved in some biotechnology fields, particularly fermentation technology and tissue culture. However, human resources and research capacity in molecular biology in universities and research institutes are limited. The Asian Development Bank (ADB) has recently provided soft loan funding for capacity-building for education in biotechnology. These funds are being used to build infrastructure in the universities and for overseas training of teaching staff for those universities. The country has no legislation on biosafety and no legal control over the import of genetically modified materials or the introduction of biotechnology in agriculture.

In Ghana and the United Arab Republic of Tanzania, while the potential of biotechnology is recognized as very important in national development strategies, there is no national policy to govern biotechnology development, and biotechnology programmes are still in their infancy. The major challenges identified were lack of infrastructure and equipment, lack of trained manpower and inadequate financial resources allocated to science and technology development. Ghana has begun to invest in biotechnology development. In agriculture, major staples such as cassava, maize, potatoes, plantains, rice and wheat are being genetically modified to improve their resistance to insects and abiotic stresses. Furthermore, Ghana initiated in 1999 a capacity-building programme (the Biotechnology Development Programme) which has already held a stakeholders' conference for the setting of priorities. However, in both Ghana and the United Republic of Tanzania, as in many other African countries, no legislation specific to biotechnology management has yet been enacted.

ANNEX I

List of CSTD panel members and experts

CSTD panel members

Dr. Pedro Teta	Angola
Professor Sun Wanhu	China
Dr. Liu Jun	China
Dr. Joseph R. Cobbinah	Ghana
Dr. Lena Tsipouri	Greece
Mr. Cece Kpohomou	Guinea
Dr. Mahmoud Molanejad	Iran (Islamic Republic of)
Dr. Sang-Ki Rhee	Republic of Korea
Dr. Tariq-ur-Rahman	Pakistan
Professor Lucian Gavrila	Romania
Professor. Štefan Morávek (CSTD Chairman)	Slovakia
Professor Vijay Kumar	Sri Lanka
Dr. Titus Mteleka	United Republic of Tanzania

United Nations agencies

Mr. Galileo Violini
United Nations Educational, Scientific and Cultural Organization

Mr. Fereydon Bokaei
United Nations Development Programme

Dr. Ali Y. Hakimi
Food and Agriculture Organization of the United Nations

Mr. Hossein Fadaei
United Nations Environment Programme

Resource persons

Dr. Peter Gregory
Director, Biotechnology
Novgen Science, Inc.
Washington, DC, USA

Dr. John Mugabe
Executive Director
African Centre for Technology Studies (ACTS)
Nairobi, Kenya

Professor Lynn Mytelka
Director, INTECH, Netherlands

Other speakers

Dr. S. A. Motamedi
Deputy Minister of Science
Research and Technology of the Islamic Republic of Iran

Dr. Mahmoud Molanejad
Acting President and Director of International Relations
Iranian Research Organization for Science and Technology

Professor S. Semnanian
Chancellor of Tarbiat Modaress
University in Tehran

Dr. N. Moazami
Director of the Department of Biotechnology
Iranian Research Organization for Science and Technology

Dr. M. H. Sanati
Director of the National Research Centre for Genetic Engineering and Biotechnology
Islamic Republic of Iran

ANNEX II

List of documents and presentations

"Biotechnology in developing countries and countries with economies in Transition: strategic capacity building consideration", by John Mugabe

"Building capacity for biotechnology monitoring and assessment", by Lynn Mytelka

"Managing and regulating biotechnology in developing countries: key steps to building national capacity", by Peter Gregory

"Capacity building in China", by Sun Wanhu

"Strategies for biotechnology development in Ghana", by Joseph Cobbinah

"Two decades of scientific research activities of the biotechnology centre of the Iranian Research Organization for Science and Technology", by Dr. N. Moazami

"Biotechnology at National Research Centre for Genetic Engineering and Biotechnology of the Islamic Republic of Iran", by Dr. Mohammad H. Sanati

"Biotechnology in the Republic of Korea", by Sang-Ki Rhee

"Biotechnology in Pakistan", by Tariq-ur-Rahman

"The biotechnologies in Romania: past, present and future", by Lucian Gavrila

"Capacity building in biotechnology in Sri Lanka", by Vijay Kumar

"Policies and strategies being undertaken in Tanzania with respect to capacity building in biotechnology", by Titus Mteleka