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Science and technology for development

Impact of new biotechnologies, with particular attention to sustainable development, including food security, health and economic productivity

Report of the Secretary-General

Summary

Pursuant to General Assembly resolution 56/182 of 21 December 2001 on science and technology for development, the present report provides information on sectors and countries where biotechnology is making a significant contribution to economic productivity and human welfare. The report identifies measures that need to be taken in order to build indigenous capabilities in biotechnology. It addresses the impact of new biotechnologies, with particular attention to sustainable development, including food security, health and economic productivity, and puts forward proposals on the aspects of the transfer of such technologies, in particular to developing countries and countries with economies in transition, while taking into account the need to protect intellectual property rights and the special needs of developing countries.

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I. Introduction

1. At its fifty-sixth session, the General Assembly adopted resolution 56/182 of 21 December 2001 on science and technology for development, by which it recognized the role of the Commission on Science and Technology for Development in coordinating the activities of the United Nations system in the area of science and technology for development and the role of the United Nations Conference on Trade and Development (UNCTAD) as the secretariat responsible for the substantive servicing of the Commission. By the same resolution, the General Assembly recognized the importance of establishing and strengthening partnership and networking among the public and private sectors and academic institutions of all countries to build, transfer and strengthen the technological capabilities and skills needed, in particular for developing countries. It also recognized the need for dissemination of research knowledge, technology and expertise in the field of biotechnology, in particular in the areas of agriculture, pharmaceuticals and health care, that could benefit mankind.

2. The Secretary-General was requested to submit to the General Assembly, at its fifty-eighth session, a report on the impact of new biotechnologies, with particular attention to sustainable development, including food security, health and economic productivity, with the inclusion of proposals on the aspects of the transfer of such technologies, in particular to developing countries and countries with economies in transition, while taking into account the need to protect intellectual property rights and the special needs of developing countries, as well as on addressing constraints on the adequate utilization of such technologies. The present report has been prepared by the UNCTAD secretariat in response to that request.

3. The present report identifies sectors and countries where biotechnology is making a significant contribution to economic productivity and human welfare as well as the needs for capacity-building, technology transfer and political will. It develops models based on successful biotechnology development case studies in developing countries in relation to sustainable development and technology transfer and protection. The report also takes into account the work of the Commission on Science and Technology for Development on biotechnologies in developing countries and countries with economies in transition.

II. Global development goals and the biotechnology revolution

4. The major challenges faced by humanity are outlined in the Millennium Development Goals.[1] Admittedly, about a billion men, women and children still live under dehumanizing conditions despite the availability of modern technology that can bring relief to some of the many human sufferings. It is estimated that 95 per cent of the 840 million people that are undernourished live in developing countries. The World Food Summit noted that “hunger is both a cause and an effect of extreme poverty [that] prevents the poor from taking advantage of development opportunities”.[2] Given that about 52 per cent of the population of developing countries depends on agriculture in comparison with only 7 per cent in developed countries, developing agriculture in poorer countries will take many people out of extreme poverty.

5. Many people in developing countries still die from curable and preventable diseases despite the progress in medical sciences. Infectious and parasitic diseases account for about 52 per cent of all deaths in Africa compared with about 2 per cent in Europe. Many people still lack access to medical care, and the supply of drugs for some of the most devastating diseases remains limited. For example, there are more drug options for pain relief in developed countries than drugs for malaria in the tropics.

6. Biotechnology, a collection of techniques or processes that employ organisms or their units to develop useful products and services, has the potential to become a powerful tool in meeting the challenges posed by food insecurity, industrial underdevelopment, environmental degradation and disease. Traditional biotechnology includes plant and animal breeding and the use of micro-organisms and enzymes in fermentation, preparation and preservation of product as well as in control of pests among others. Modern biotechnology mainly refers to the use of recombinant deoxyribonucleic acid (DNA) techniques (the transfer of genetic material from one organism to another) and detailed analysis of the genetic information of organisms. However, the two are not mutually exclusive as modern techniques are used to empower traditional methods. For example, recombinant enzymes and genetic markers have been employed in traditional biotechnology methods, such as fermentation, plant and animal breeding.

7. The Millennium Development Goals may be more easily met with the extensive application of modern biotechnology in agriculture and health. New and more effective vaccines and drugs against diseases, such as human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS), malaria and tuberculosis, will be needed. Similarly, more food of high nutritional value has to be produced to meet the expanding needs of the world's rapidly growing population.

8. The main beneficiaries of the current biotechnology revolution are largely developed countries. For example, United States of America, Canada and Europe account for about 97 per cent of the global biotechnology revenues, 96 per cent of persons employed in biotechnology and 88 per cent of the total biotechnology firms.[3] Developing countries are lagging behind in adoption and development of biotechnology processes, products and services. Biotechnology has yet to deliver products in agriculture, health, industry and environment in developing countries.[4]

9. While an even distribution of technology is unlikely to be achieved, it becomes a source of concern when large sections of the population and of continents do not benefit from the existing biotechnology applications. Ensuring that those who need the technology have access to it remains a major challenge. Similarly, creating a conducive environment for the acquisition, adaptation and diffusion of biotechnology in developing countries remains a major challenge. Furthermore, the current debate over the safety of genetically modified organisms has swayed the attention of policy makers away from the wider benefits of biotechnology to transgenic crops. The term biotechnology has almost become synonymous with genetically modified organisms.

10. In order to bridge these gaps, Governments should take important steps. Firstly, developing countries have to increase the pace at which they pursue, acquire, adapt and diffuse new innovations. Secondly, developed countries should help developing countries to build the necessary capacity needed to develop, manage and

use biotechnology. Thirdly, developing countries and countries with economies in transition have to invest their limited resources in applications that generate wider, but also attainable, benefits for their economies. Finally, stable and beneficial strategic partnerships between developed and developing countries and among developing countries have to be established.

A. Overview of the global impact of biotechnology

11. In 2001, the biotechnology industry was estimated to have generated US$ 34.8 billion in revenues and employed about 190,000 persons in publicly traded firms worldwide. An estimated 4,200 public and private biotechnology firms were in operation. These are impressive results given that, in 1992, the biotechnology industry was estimated to have generated US$ 8.1 billion and employed less than 100,000 people.[5]

12. The number of modern biotechnology drugs and vaccines has increased, from about 23 in 1990 to over 130 by 2001. There are about 350 biotechnology-derived drugs and vaccines in clinical trials targeting over 200 diseases. A number of organisms have had their genomes (genetic material) sequenced or decoded. The human, mosquito and malaria-causing organism (*Plasmodia falciparum*) genomes are among those that have been sequenced. These activities are expected to accelerate the pace of drug and vaccine discoveries.

13. The area of farmland planted with transgenic crops or genetically modified organisms has increased from about 2.8 million hectares[6] in 1996 to about 52.6 million hectares[7] in 2001. Of this, transgenic soya was planted on 33.3 million hectares, accounting for about 63 per cent of the total area planted with transgenic crops. This growth is expected to continue as more countries commercialize transgenic crops.

14. The use of biological catalysts or enzymes has entered almost every industry. There are at least 600 different products and more than 75 types of enzymes that are used in industries. The major industries that already use biological catalysts include food processing, leather and textiles, personal care, pharmaceuticals and cleaning. The global market for industrial enzymes is worth about US$ 1.6 billion. The demand for other biotechnology-related products, such as feed additives, has continued to grow with vitamins and amino acids accounting for about US$ 3 billion and digestive enhancers for US$ 1.3 billion.[8]

15. Biotechnology has also been used to reclaim wasteland through the use of micro-organisms and plants that remove and/or degrade toxic compounds. Some firms have incorporated biotechnology techniques in their production to decrease energy and water consumption, improve productivity and reduce the number of processing steps. All these actions could lead to an improved environment, sustainable use of resources and increased productivity.

16. Biotechnology-related applications and products have penetrated many sectors of the economy. The technology has begun to overcome the bottlenecks that, in the last century, favoured chemical substitutes against biological ones. For example, aspirin is derived from a plant but is synthesized chemically owing to limitations with biological processing. It is clear that the economic, scientific and social impact of biotechnology is already being felt.

B. Impact of biotechnology in developing countries

(a) Agriculture

17. Current agricultural biotechnology products mainly involve crops that are engineered to resist pest attacks and to tolerate herbicides. The most widely grown crops globally include soybeans, maize (corn), cotton and canola, which, together, account for more than 90 per cent of the area planted with transgenic crops. The area planted with transgenic crops in developing countries has grown from 1.2 million hectares to about 14 million hectares over the last six years.

18. Developing countries are slowly but steadily adopting transgenic products. The number of developing countries growing transgenic crops has steadily increased, from three (Argentina, China and Mexico) in 1996 to seven (Argentina, China, Indonesia, Mexico, Romania, South Africa and Uruguay) in 2001.[9] Argentina accounts for about 80 per cent of the acreage in developing countries, and China has recorded increased growth (threefold) in acreage in 2001. India has approved the release of transgenic cotton, and Brazil is expected to commercialize transgenic soybeans once legal technicalities are resolved. This may increase the number of countries to nine and, more significantly, include some of the major food producers and exporters. This is encouraged by the positive impact of transgenic crops in terms of increased yields and reductions in pesticide applications.

19. Research into crops that are specific to developing countries is limited to a few public and non-profit institutions in developed and developing countries with a strong scientific base. Cassava, potatoes and rice are among the crops that are benefiting from alliances between developed and developing countries' institutions interested in generating products specifically for developing nations. There is limited interest from the private sector in developing transgenic crops of interest to developing countries.

20. There are no countries that have commercialized transgenic fish or transgenic animals as of now. Many countries, including developed countries, are yet to develop measures to ensure the safe production and use of transgenic animals. Transgenic fish are likely to reach the market earlier than transgenic animals. Cuba has developed a fast-growing tilapia by using another fish gene. China has developed a number of transgenic animals, while the Republic of Korea has the capacity to develop transgenic animals.

(b) Health

21. Developing countries such as Cuba and India are becoming major centres of health-related biotechnology research and development, production and marketing. Products developed in developing countries are likely to be of great value as those countries share many common health problems. For example, Cuban biotechnology institutions have developed or are developing vaccines, drugs and diagnostic kits for tropical diseases such as meningitis, cholera and malaria. Other developing countries represent one of Cuba's main markets.

22. There are also international public-private partnerships for vaccines and drugs development that are of great interest to developing countries. These public-private partnership ventures currently focus on developing drugs and vaccines against malaria, HIV/AIDS and tuberculosis with the aim of making the final products

affordable to developing countries and generate the needed products within a reasonable time. At least one vaccine candidate is currently undergoing the first phase of trials in Kenya, another targeting HIV is undergoing the first clinical trials in the United States and a malaria vaccine is also undergoing the first phase of trials in the Gambia. There are at least six HIV vaccine candidates under development.

(c) Industry

23. The biotechnology industry has expanded. For example, it is estimated that at least 43 companies and 41 research institutions in Africa, 90 companies and 500 research institutions in China and 50 companies and 40 research institutions in Brazil are involved in biotechnology. Similarly, the biotechnology sector employs about 12,000 scientists in Cuba and 9,000 researchers in the Republic of Korea.[10]

24. Biotechnology applications are being used in textiles, wood, pulp, leather, food and mineral processing and in the production of fine chemicals. South Africa developed the world's first biotechnology-based gold-processing system (bioleaching or use of micro-organisms in hydrolyzing mineral ore) called the Biox process. Biox has been used in Ghana's gold mines as well. The system has since been further developed and applied to other minerals, such as zinc and nickel. Chile and Zambia have also experimented with the use of biotechnology in processing copper.

25. It is estimated that Asia has the fastest-growing market for feed additives, followed by Latin America. The estimated global market for feed additives is about $6 billion. This growth is expected to continue as demand for animal products is expected to increase. In biofuels, Brazil remains the leader in production and consumption. However, China may be commissioning the world's largest biofuels plant. The use of biotechnology in industry is expected to increase in developed and developing countries.

(d) Sustainability

26. The United Nations Convention on Biological Diversity deals with issues of sustainability with respect to biotechnology. The Convention aims to protect biological diversity (biodiversity), promote its sustainable use and share the benefits arising from its use fairly and equitably on the basis of the mutual agreement of contracting parties. It promotes the safe use of biotechnology and recognizes the role of traditional knowledge and the value of biological resources that are the backbone of biotechnology inventions. This requires that exploitation of biological resources not result in the loss of those resources or a loss of variety and/or contamination.

27. The link between biotechnology and sustainability has been an issue of great interest and controversy. It is clear that biological processes used in industry and the environment may reduce waste generation, are easy to destroy, consume less water and energy and are user-friendly and cost-effective.[11] Similarly, the use of transgenic crops is improving yields and reducing the cost of production and the use of harmful chemicals on farms. In addition, biotechnology products are used in diagnosis of pollution and in bioremediation (recovery or cleanup of polluted areas) as well as breeding of endangered species.

28. However, there are legitimate concerns that genes in plants may flow to closely related plants, induce resistance in targeted organisms and could lead to dependency on a few biotechnology-derived high-performing crops. The deliberate release of genetically modified organisms could have devastating consequences. This scenario has been one of the bases of the controversy over genetically modified organisms.

29. Biotechnology may revolutionize the strategies needed to conserve biological diversity. These efforts are still very minimal but are likely to become routine procedures in many laboratories. However, this will only receive wide public support once the regulatory regimes operate on minimum agreed safety standards and provide balanced information on the benefits and risks of biotechnology. In many countries, regulatory regimes governing the development and use of biotechnology products are still in the early stages of development.

C. Concerns related to biotechnology

(a) Public awareness and participation

30. Many developing countries face a difficult task in raising public awareness of issues related to biotechnology. Common constraints include poor public access to the mass media, low levels of literacy and education, language differences within the same country and the costs associated with conducting sustained awareness programmes. The situation is compounded by the general low level of science education, public interest and the will to give the public a genuine voice in the policy-making process.

31. There is a need for scientists to actively engage with the public concerning biotechnology and its products. There is also a need for dialogue between the scientific community, the mass media, industry and the government in order to provide balanced information to the general public and receive feedback. With respect to biotechnology, public trust in government authorities and the mass media seems to be low, particularly in Europe. Restoring public trust requires that the authorities involved in raising awareness are perceived to be competent, knowledgeable and respectable. Governments may have to provide safety information on biotechnology products and services.

(b) Regulatory and management issues

32. The implementation of the Cartagena Protocol on Biosafety of the Convention on Biological Diversity and the establishment of biosafety review processes have been very slow. This situation has led to regulatory failures, indecisions and inconsistencies. Directives have often been made, sometimes with little regard to the biosafety review process or scientific recommendation, mainly in response to public concerns. These uncertainties have affected biotechnology development and increased safety concerns, especially in developing countries and countries with economies in transition that have a great deal of biological diversity.

(c) Economic risks

33. The current regulations on transgenic products differ from one region to another. The two main markets, the United States and the European Union, have

different regulations, which, in some cases, have been changing and have not been very clear with respect to genetically modified products. For example, the labelling requirements and the limits on foreign genetic materials in food products are unclear and impose an extra burden on poor farmers. In many cases, the facilities to follow and enforce these guidelines do not exist. Therefore, these measures may be perceived to discriminate against products from developing countries.

34. Biotechnology could potentially displace a number of chemical products, especially in agriculture, and possibly dislocate production bases as plants may grow well under previously hostile conditions. Those that depend on these markets for their livelihood are likely to be affected. Similarly, there are cases regarding the patenting of products that have already been used by people in developing countries for many years. This has tainted the image of the biotechnology industry. These issues constitute economic risks associated with biotechnology that need to be considered even when the products being displaced may be unfriendly to the environment or inferior in quality. Addressing economic concerns may be important in resolving some of the current issues surrounding biotechnology.

(d) Environmental and health risks

35. Although there has been no strong evidence to demonstrate the risk of biotechnology products to the environment or human health, the public in some countries are sceptical of the safety of transgenic crops. There are concerns that genes inserted in crops may migrate to related species, induce resistance in targeted organisms and induce crops to produce allergens or compounds with harmful effects. It is the assessment and management of risks that is of great concern to developing countries owing to an inadequate scientific foundation. It may not be possible for them to depend on the scientific base of developed nations for managing the risks posed by biotechnology products given the differences in lifestyle and the environment.

III. Factors affecting technology transfer to developing countries

A. Public consensus

36. While the benefits of biotechnology are recognized, public consensus has not matched the enthusiasm expressed in international forums. For example, in 1992, through Agenda 21, great enthusiasm and hope was placed on the ability of biotechnology to offer new opportunities for global partnerships and serve the needs of sustainable development. Since then, the controversy surrounding genetically modified organisms in agriculture has dampened the initial support. This has affected the implementation of some of the programmes articulated in Agenda 21, such as finance, technology transfer, capacity-building and management.

B. National research strength

37. The numbers of specialized biotechnology-related scientists remain very low, especially in Africa. The facilities that are needed for biotechnology product development do not exist or are in a poor state, while in a few countries they are just beginning to emerge. In some countries, they remain initiatives driven by a few

individuals or institutions working in isolation. Integration of these efforts is needed to make them competitive and effective.

C. Intellectual property rights

38. Intellectual property protection in biotechnology is applied through patenting in mainly developed countries. Many have argued that patents present a hurdle to developing countries wishing to acquire protected innovations, while others argue that, without patents, incentives to develop these innovations will be low.

39. For many developing countries and countries with economies in transition, patents may present a hurdle if a country is unable to meet licensing fees and/or royalties demanded by owners or if owners deny a country access at a reasonable price. Such a hurdle may also increase the price of the final product, making it unaffordable by consumers in less developed countries.[12] Patents on some biotechnology innovations remain contentious even in developed countries, especially as previously complex procedures become routine activities of standard laboratories. A continuous review of national patent regimes is required in order to match developments in technology.

40. However, for countries without biotechnology development plans or the capacity to utilize proprietary knowledge, patents are not yet an issue. These countries need to build a biotechnology research foundation to allow them to utilize innovations that are protected by patents. Therefore, countries may have to protect and respect intellectual property rights for them to be trusted by owners of such technologies to build useful partnerships and strategic alliances. It may then be possible to negotiate for access to technologies at a reasonable price based on economic realities and social needs, among other factors.

D. Traditional knowledge and biodiversity

41. The market for alternative and complementary medicine is estimated at US$ 2.4 billion in Japan and US$ 2.3 billion in the United Kingdom of Great Britain and Northern Ireland. The United States market of herbal medicines stood at US$ 5.4 billion in 2000, while at least 80 per cent of Africans use herbal medicine.[13] About 75 per cent of people in France have used alternative medicine. These are staggering figures that should have encouraged the formation of public-private partnerships to increase the consumption and safety of herbal medicine.

42. The Convention on Biological Diversity remains the main international regime that specifically addresses traditional knowledge. A voluntary guideline on the use and protection of traditional knowledge was established in 2002. However, the lack of international regimes that advocate respect and protection of traditional knowledge in a manner comparable to the Trade-Related Aspects of Intellectual Property Rights (TRIPS) remains a source of concern. Cases of biopiracy (accessing biological materials without permission) have been reported in Africa, Asia and Latin America.

43. The use of biological resources to acquire advanced technology through bioprospecting ventures remains very low. This situation has been compounded by weakness in the scientific base in developing countries, which is required in order to

add value to natural resources through isolation, identification, purification and primary functional analysis. Costa Rica is one country that has acquired some biotechnology capacity through bioprospecting contracts. Kenya and Nigeria have also entered into bioprospecting agreements. The effectiveness of these arrangements remains unknown. However, they represent an important opportunity in building public-private partnership.

E. The Biosafety Protocol

44. Article 22 of the Cartagena Protocol on Biosafety to the Convention on Biological Diversity provides for:

> "the needs of developing country Parties, in particular the least developed and small island developing States among them, for financial resources and access to and transfer of technology and know-how in accordance with the relevant provisions of the Convention, shall be taken fully into account for capacity-building in biosafety … include scientific and technical training in the proper and safe management of biotechnology".

Therefore, the Protocol included aspects of technology transfer.

45. The implementation of the Protocol has been slow and some countries see biosafety as running contrary to biotechnology development. By November 2002, 103 countries had signed the Protocol and 38 countries had either ratified or acceded to it. The United Nations Environment Programme (UNEP) and the Global Environment Facility (GEF) have a joint project that is helping developing nations to integrate biosafety issues related to biotechnology in their national legislation and to establish mechanisms for assessing and managing the use of biotechnology products.

46. The emphasis on biosafety has been driven by the belief that laws must be in place before the scientific base is developed. Countries are categorized into those without regulations, those with draft legislation and those with legislation, rather than the level of technical know-how required to implement or guide the development of these regulations. Therefore, the use of the Biosafety Protocol to transfer technology has largely not materialized given the fast pace of technological turnover.

F. Public pressure and interest

47. The current debate on biotechnology is seen as important in raising public awareness and participation in decision-making. However, this debate is not tailored to bring about a public consensus that encourages investment in biotechnology and technology transfer. The debate should have been helpful for technology transfer in general and not to those who are in favour of or against a specific biotechnology merely on the basis of trade interest or public opinion even without having the capacity to manage and handle biotechnology products. Governments have responded to the claims of each side by issuing a barrage of decrees, declarations and directives that have kept changing. This has been done at the expense of future technology advancements.

IV. Current biotechnology status in developing countries

48. Technology transfer in biotechnology may be seen occurring on at least three levels. The first involves the transfer of research techniques and procedures required in developing innovations. The second involves the transfer of knowledge for commercial scale processing and manufacturing technologies. The third involves the marketing of the biotechnology product and utilization either by secondary industries or other forms of consumers and markets.

49. The science of microbiology or the use of microbes in applications such as pest control or in medicine has a long history. Most countries possess such biological resources and some limited technology in dealing with them. However, the ability to identify useful strains and generate sufficient amounts of consistently high-quality organisms at an economical price is limited to a few countries. The use of tissue cultures for mass reproduction of some plants exists in some developing countries. However, its application to generating animal tissues (for example, skin used in treating burns) artificially, is not available in most developing countries.

50. There are other forms of biotechnology applications that are in limited use, which include the generation and use of antibodies (molecules that fight disease) for diagnosis of diseases; the use of molecular genetic markers to detect diseases in animals and plants; and the ability to screen, analyse and generate large amounts of genetic information (long DNA sequences). In addition, even the capacity to generate transgenic plants and animals (genetically modified organisms) is limited to a few countries.

51. Most developing countries are lagging behind in adopting, developing and using new biotechnologies. They are often using older technologies that are less productive. Many of these older technologies can be complemented with new biotechnologies, thus making them more productive. For example, in plant improvement, controlled and target-specific breeding employing modern biotechnology techniques is more successful and faster than traditional (that is, blind) breeding techniques alone.

V. Proposals for biotechnology development and technology acquisition

A. Possible models for technology transfer and development of biotechnology

(a) The public-private-academia approach

52. The national biotechnology programme, in this model, draws representatives from industry, government and universities/research institutions at home and abroad to form an advisory committee and a platform for execution of projects. It identifies areas of interests, challenges and opportunities. The body should oversee development and implementation of national biotechnology programmes. A government representative at the level of a Minister or Deputy Minister should represent the Government on this initiative.

53. Universities have abundant qualified manpower that could be harnessed to carry out most of the research activities. Industries could serve as product

development facilities while government provides the needed incentives. This could lead to quick transfer of technology between research institutions and industry.

54. National Governments should fund the development of biotechnology without a large increase in their national budget. The international community of donors should also be encouraged to fund biotechnology projects within their areas of cooperation, such as health, agriculture and education. The national programme has to ensure that biotechnology is part of bilateral and multilateral agreements.

55. Teams may be formed around technological and market niches. For example, a team of interested industries, academia and government experts may work together to develop biofertilizers for a given market or be contracted by a municipal council to manage a damping site using bioremediation technologies. Identifying projects at the national level based on economic and social relevance (for example, mining, manufacturing and health) but with the potential of exposing many teams to advanced technologies and partnerships at an economical price could help improve the development of local facilities, manpower and partnerships.

56. At the operational level, the body serves to develop timely policies, monitor resource use and implementation of projects. For example, manpower development is a major challenge but could be "created" or generated quickly by the introduction of course programmes that span subject and discipline boundaries at the graduate level. These include courses in biomanufacturing, bioengineering, bioentrepreneurship, bioprospecting and biopolicy among others. These courses may quickly upgrade competencies and numbers of scientists and researchers needed to develop a biotechnology sector. Such courses could be implemented through collaboration between universities (teaching/research), industry (industrial attachments and production) and government (favourable policies). Such courses could help in creating public-private partnerships rather than pure sciences.

(b) A modified incubator approach

57. Incubators are facilities where young firms could be nurtured to become independent and strong entities. Many developing countries have worked with incubators, such as "village industry development facilities", "small industries development organizations" and "farmers' training centres". These facilities were often located far away from research institutions or universities. The modified incubator model seeks the location of similar facilities inside or within walking distance from universities/research centres to encourage a constant exchange of knowledge.

58. National Governments, municipal councils, industry and academia could establish incubator facilities where scientists, industrial experts and students could develop their ideas into concepts and eventually into products and services. The incubators provide space, access to professional and technical advice, and management. University incubators are less costly and best suited for poor countries. Biotechnology incubators have been successfully used in Brazil, among others.

59. However, the success of an incubator is determined by the types of knowledge it packages into firms, the effectiveness of management and the ability to attract funding through its projects. Many projects may not be funded in isolation, irrespective of their value, but may be funded through incubators if the facility has

acquired a good reputation. Firms have to be encouraged or even assisted to grow so that they can move out of the incubator. The impact of incubators is measured by the number of successful firms graduated rather than the number of firms in residence. Generally, periods of about three to five years are required to graduate knowledge-intensive firms.

60. It is also important to note that these models are not mutually exclusive. For example, incubators exist in the Republic of Korea and India as part of their national biotechnology development programmes. Incubators are included as an independent model because they could be formed at the provincial, district and institutional levels. Furthermore, they allow the testing of ideas and products before national initiatives are launched. It is equally important to note that different versions and combinations of these models are likely to be formed on the basis of institutional strength, regulation and organization.

B. Examples of national efforts to acquire technology

(a) Biotechnology development in the Republic of Korea

61. The biotechnology development strategy of the Republic of Korea, as contained in the Korea Biotech 2000 plan, is composed of three main phases. The first phase (1994-1997) was aimed at acquiring and adapting bioprocessing and improving the performance of research and development investments. The second phase (1998-2002) focused on consolidation of the scientific foundation for development of novel products. The last phase (2003-2007) targets biotechnology market expansion locally and internationally.

62. To meet these goals, the Republic of Korea has since 1982 encouraged universities to open biotechnology-related departments and research institutions. The country has also established strategic partnerships with centres in China and the United Kingdom for research. The Government is estimated to have invested US$ 500 million while the private sector invested an additional US$ 1 billion in the first four years. It also set aside funds to help establish 600 biotechnology-related ventures by the end of 2003.

63. The Republic of Korea has developed a complete biotechnology industry strategy addressing all the core aspects, such as human resource development, research facilities, financial needs, marketing and management capabilities. The strategy relies on public and private sector partnerships to help local institutions access international centres to stay abreast of new developments. The biotechnology sector has imported most of the enabling technologies such as fermentation, vaccine and drug production know-how.

(b) Cuban biotechnology sector

64. Cuba has established a number of specialized institutions, which includes the Centre for Genetic Engineering and Biotechnology, in immunology, biomass conversion, animal production and tropical medicine. Since 1980, the biotechnology industry has expanded from a single laboratory to over 190 research units. Cuba developed a competent manpower base in medical sciences through training programmes at home and in countries such as France, Mexico, Japan, Switzerland

and the United States. This manpower formed the backbone of the biotechnology industry. Some of the equipment was also imported from abroad.

65. Cuba's research and development expenditure as a percentage of its gross domestic product was estimated at 1.2 per cent, and the country is thought to have invested about $1 billion over the last 20 years in biotechnology. In return, Cuba's biotechnology centres have produced at least 160 medical products, 50 enzymes and probes for diseases among others. By 1998, the biotechnology sector was making up to $290 million in sales, making the sector the fourth largest foreign exchange earner after tourism, tobacco and nickel exports.

66. The Cuban biotechnology industry is a network or cluster of supportive institutions. It comprises research and development, exports and imports, manufacturing, information and communication, maintenance, advisory and policy, and regulatory institutions. This structure promotes recombination of knowledge and is cost-effective. Although the Cuban biotechnology is government-managed and driven, it has all the characteristics of a mature privately managed business cluster.

C. The role of different players in these models

67. *National Governments*. The government in most developing countries is the main source of policy and funding irrespective of its economic strength. Governments may provide support that may save money, such as relaxed tax policies for the biotechnology industry or incentives for investment and the creation of new jobs and a market for biotechnology and its products.

68. *Private sector*. The private sector provides entrepreneurship and the industrial leadership required to move innovations into marketable products and services. They should also fund innovations and advise the government in setting policies for the biotechnology industry.

69. *International community*. Bilateral and multilateral donors and non-profit funding agencies continue to play an important role in providing development assistance to developing countries. However, most donors' position on biotechnology is unclear. For nations that are more dependent on foreign aid, biotechnology development may be slowed or hindered without donor support.

D. National biotechnology development strategy

70. The most common features of successful biotechnology development programmes include the following:

(a) Clear government plans to develop a biotechnology industry with benchmarks on objectives to be attained by each stage of development (number of scientists trained, products developed and technologies acquired);

(b) Establishment of biotechnology-related programmes (research, development and marketing) in universities and national research institutions;

(c) Involvement of the private sector in planning the biotechnology development agenda through matching funds, sharing facilities and technologies;

(d) Establishment of international collaboration and partnerships for research and development, production and marketing (for example, technical cooperation);

(e) Provision of public venture capital to fund small start-up firms and the commercialization of research products;

(f) Policies and programmes that stimulate entrepreneurship in public institutions and investments. These include policies on commercialization and ownership of knowledge and allowing scientists to interact freely with industry;

(g) Incentives for public-private partnerships. These include government contracts, directives on publicly funded projects and international strategic partnerships.

VI. Proposed role of the United Nations

71. An integrated framework for biotechnology development could be helpful to developing countries. It could be implemented in similar fashion to the UNEP-GEF biosafety programme but focusing on technology development. The plan should have three components: (a) *policy development*, focusing on the ability of national, regional and international regimes to generate policies that accelerate technology development and commercialization; (b) *private sector involvement*, focusing on national and international firms with an interest in biotechnology development; and (c) *training*, with a focus on universities and research facilities by helping to develop programmes in selected national universities.

72. It is important to ensure that this initiative does not overlap or conflict with existing programmes focusing on biosafety and bioethics. The initiative would focus on all aspects of biotechnology, that is, industry, health, agriculture and environment. It could also serve as an advisory unit for developing countries on new trends in biotechnology innovations, and on policy and trade. This may help developing countries to become leaders in formulating policies as the technology develops.

73. Setting up such an initiative would require financing. Special consideration will have to be given to the needs of the least developed countries and small island developing States to help them develop the basic foundation for manpower training and research and development initiatives. The initiative should be designed to bring benefits not only to the various programmes within the United Nations system, but also to programmes at the national and regional levels.

VII. Conclusion

74. Biotechnology has become an important component of the scientific, economic and social life of society. It cuts across all areas of human activities. Its impact on agriculture, health, environment, manufacturing, energy and mining among other sectors is already being felt, and the economic and social benefits have become a reality. For these reasons, biotechnology presents unique opportunities for developed and developing countries and small and large enterprises.

75. Developing and implementing science and technology policies that encourage the adoption, use and development of innovations in developing countries to meet

their needs are required. Such policies could take into account the provision of incentives, such as public funding, formation of public-private partnerships, technology acquisition, market access and protection of innovations.

76. In this way, biotechnology will become part of the global fight against poverty, hunger, disease and underdevelopment, which have a direct bearing on school attendance, infant mortality, maternal health and freedoms associated with a decent standard of living. It is not a question of whether it will deliver the promises but how the promise of biotechnology will be shared. It is in the interest of humanity, in developed and developing countries, that safe biotechnology applications are used as widely as possible.

77. Similarly, the policies governing biotechnology have to be harmonized so that they do not disadvantage developing countries and countries with economies in transition. Biotechnology has the potential to dislocate the production base, wipe out some industrial platforms and displace products in the market place. Some developing countries lost their sisal market to synthetic fibres and sugar to artificial sweeteners. Unless developing countries keep up with advances in biotechnology, they may lose out again. The cost of leaving some countries behind may be higher than the cost of empowering them to become players in mastering and benefiting from biotechnology.

Notes

[1] Development goals contained in the United Nations Millennium Declaration adopted by the General Assembly at its fifty-fifth session.

[2] See Food and Agriculture Organization of the United Nations, Committee on World Food Security; World Food Summit and Millennium Development Goals, CFS:2001/2-Sup.1.

[3] See Ernst & Young (2002), *Beyond Borders: Global Biotechnology Report 2002*.

[4] Ibid.

[5] Ibid.

[6] See C. James (1997), *Global Status of Transgenic Crops in 1997*, International Service for the Acquisition of Agri-biotech Applications Brief No. 5.

[7] See C. James (2001), *Global Review of Commercialized Transgenic Crops, 2001*, International Service for the Acquisition of Agri-biotech Applications Brief No. 24.

[8] United Nations Conference on Trade and Development, 2002, “The new bioeconomy: industrial and environmental biotechnology in developing countries” (UNCTAD/DITC/TED/12).

[9] See C. James (2001), *Global Review of Commercialized Transgenic Crops, 2001*, International Service for the Acquisition of Agri-biotech Applications Brief No. 24.

[10] United Nations Conference on Trade and Development, 2002, “The new bioeconomy: industrial and environmental biotechnology in developing countries” (UNCTAD/DITC/TED/12).

[11] See Organisation for Economic Cooperation and Development (2001), *The Application of Biotechnology to Industrial Sustainability*.

[12] For example, patent-protected (prescription) drugs cost many times more than generic drugs owing to the value attached to technology. Many useful products (for example, HIV retroviral therapies) stay above the reach of consumers in poor countries.

[13] See World Health Organization, *Traditional Medicine Strategy 2002-2005* (WHO/EDM/TRM/2002.1).