BIOTECHNOLOGY FOR SUSTAINABLE DEVELOPMENT

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INTRODUCTION

The rate at which information is being generated has indeed no parallel in earlier human history. The ease with which one can access available information is just as impressive. It has been estimated that, whereas the total knowledge-pool will double in six to seven years, for life sciences such doubling time is estimated to be nearly three years. This new scenario provides an extremely rich and almost unmanageable store of data, but also poses the serious challenge for an effective and meaningful approach towards a focused discussion.

Thus, for scientists, academicians and policy makers, there is a dire need to realise that computers and other highly sophisticated devices have dramatically changed our ability to acquire, store and retrieve information. So, how do we cope with this explosion of knowledge? Internet, ISP's enable us to download enormous amounts of data in no time – that fact alone poses a serious challenge of how to manage, coordinate, analyse, draw conclusions, develop guidelines and then formulate effective strategies to cope with future challenges.

The information that is becoming available on the role of science and technology in economic development is certainly a very useful and rich source – the recent Human Development Report released by UNDP is one such example. The conclusions of this report could be summarised as follows:

Technology networks are transforming the traditional map of development, expanding people's horizons and creating the potential to realize, in a decade, progress that required generations in the past. Throughout history, technology has been a powerful tool for human development and poverty reduction. Today people all over the world have high hopes that new technologies, such as information and communications technology and biotechnology, will lead to healthier lives, greater social freedoms, improved knowledge and more productive livelihoods. The possibilities are great: new technologies and globalization are creating a network-age that is simultaneously changing the way technology is created, diffused and used. No country, at any level of development, can afford not to participate in these networks.

The report 2001 looks at how the advent of new technologies will affect developing countries and poor people. Technology is a tool, not just a reward, for development. Technological change can advance human development by improving human health, nutrition and knowledge and by enabling communication, participation and economic growth. Yet, many fear that new technologies may be of little use to the developing world, or that they might actually widen global inequalities. Indeed, without innovative public-policy, innovative technologies could become a source of exclusion and conflict, not a tool for progress. If any form of development is empowering in the 21st century, it is the acquisition of knowledge and the creation of technological capacity." The above statement is such that no one will disagree with its contents and the conclusions drawn. With all the above in mind, an effort is made to examine the role of biotechnology in achieving sustainable development.

It is in the light of the above realities that the topic for the present seminar will be discussed. Needless to state that, for the interested reader, there is absolutely no dearth of related reading material and only a few key references have been provided at the end.

One needs to start this discussion by precisely defining the two basic ingredients – Biotechnology and Sustainable Development. It is also important to emphasize that the different technologies being discussed in the present seminar, such as nuclear technology, nano-technology, information technology, again closely interact with each other to finally determine the ultimate impact on socio-economic scenario.

Outline History of Biotechnology

The term Biotechnology was coined in 1919 by Karl Ereky, a Hungarian engineer. He envisioned a

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biochemical age similar to the stone and iron age. Breaking the word biotechnology into root words we have: **"Bio"** the use of biological processes and **"Technology"** to solve problems or make useful products. A more appropriate definition of biotechnology, in the new sense of the word is: *"New" Biotechnology --- the use of cellular and molecular processes to solve problems or make products.* Thus, Biotechnology is broadly defined to include any technique that uses living organisms or parts of organisms to make or modify products, to improve plants or animals, or to develop micro-organisms for specific use. It ranges from traditional biotechnology to the most advanced modern biotechnology. Some of the more significant milestones are listed below (Table 1):

Table - 1

Date	Event
1750 B.C.	The Sumerians brew beer.
500 B.C.	The Chinese use moldy soybean curds as an antibiotic to treat boils.
250 B.C.	The Greeks practice crop rotation to maximize soil fertility.
1590 A.D	The microscope is invented by Janssen.
1663	Cells are first described by Hooke.
1675	Leeuwenhoek discovers bacteria.
1855	The *Escherichia coli* bacterium is discovered. It later becomes a major research, development and production tool for biotechnology. Pasteur begins working with yeast, eventually proving they are living organisms.
1863	Mendel, in his study of peas, discovers that traits were transmitted from parents to progeny by discrete, independent units, later called genes. His observations laid the groundwork for the field of genetics.
1869	Miescher discovers DNA in the sperm of trout.
1878	The first centrifuge is developed by Laval. The term "microbe" is first used.
1883	The first rabies vaccine is developed.
1914	Bacteria are used to treat sewage for the first time, in Manchester, England.
1919	The word "biotechnology" is first used by a Hungarian agricultural engineer.
1928	Fleming discovers penicillin, the first antibiotic.
1938	The term "molecular biology" is coined.
1941	The term "genetic engineering" is first used by a Danish microbiologist.
1943	Avery demonstrates that DNA is the "transforming factor" and is the material of genes.
1944	DNA is shown to be the material substance of the gene.
1953	Watson and Crick reveal the three-dimensional structure of DNA.
1970	Specific restriction nucleases are identified, opening the way for gene cloning.
1973	Cohen and Boyer perform the first successful recombinant DNA experiment, using bacterial genes.
1976	The tools of recombinant DNA are first applied to a human inherited disorder. Molecular hybridization is used for the prenatal diagnosis of alpha thalassemia. Yeast genes are expressed in E. coli bacteria.
1980	The U.S. Supreme Court, in the landmark case Diamond v. Chakrabarty, approves the principle of patenting genetically engineered life forms. The U.S. patent for gene cloning is awarded to Cohen and Boyer.
1981	The North Carolina Biotechnology Center is created by the state's General Assembly as the nation's first state-sponsored initiative to develop biotechnology. Thirty-five other states follow with biotechnology centers of various kinds. The first gene-synthesizing machines are developed.
1982	Humulin, Genentech's human insulin drug produced by genetically engineered bacteria for the treatment of diabetes, is the first biotech drug to be approved by the Food and Drug Administration.
1984	The DNA fingerprinting technique is developed. The first genetically engineered vaccine is developed. Chiron clones and sequences the entire genome of the HIV virus.
1986	The first field tests of genetically engineered plants (tobacco) are conducted. Ortho Biotech's Orthoclone OKT3, used to fight kidney transplant rejection, is approved as the first monoclonal antibody treatment. The first biotech-derived interferon drugs for the treatment of cancer - Biogen's Intron A and Genentech's Roferon A - are approved by the FDA. In 1988, the drugs are used to treat Kaposi's sarcoma, a complication of AIDS. The first genetically engineered human vaccine - Chiron's Recombivax HB - is approved for the prevention of hepatitis B.

1987	Humatrope is developed for treating human growth hormone deficiency. Advanced Genetic Sciences' Frostban, a genetically altered bacterium that inhibits frost formation on crop plants, is field tested on strawberry and potato plants in California, the first authorized outdoor tests of an engineered bacterium. Genentech's tissue plasminogen activator (tPA), sold as Activase, is approved as a treatment for heart attacks.
1988	Congress funds the Human Genome Project, a massive effort to map and sequence the human genetic code as well as the genomes of other species.
1993	Chiron's Betaseron is approved as the first treatment for multiple sclerosis in 20 years. The FDA declares that genetically engineered foods are "not inherently dangerous" and do not require special regulation. The Biotechnology Industry Organization (BIO) is created by merging two smaller trade associations.
1994	Genentech's Nutropin is approved for the treatment of growth hormone deficiency. The first breast cancer gene is discovered. Calgene's Flavr Savr tomato, engineered to resist rotting, is approved for sale.
1995	The first baboon-to-human bone marrow transplant is performed on an AIDS patient. The first full gene sequence of a living organism other than a virus is completed for the bacterium *Hemophilus influenzae.*
1996	Biogen's Avonex is approved for the treatment of multiple sclerosis. The company builds a $50 million plant in Research Triangle Park, N.C., to manufacture the recombinant interferon drug. Scottish scientists clone identical lambs from early embryonic sheep.
1998	University of Hawaii scientists clone three generations of mice from nuclei of adult ovarian cumulus cells. Embryonic stem cells can be used to regenerate tissue and create disorders mimicking diseases. The first complete animal genome for the elegans worm is sequenced. A rough draft of the human genome map is produced, showing the locations of more than 30,000 genes.
1999	The rising tide of public opinion in Europe brings biotech food into the spotlight. See our publication.
2000	A rough draft of the human genome is completed by Celera Genomics and the Human Genome Project. Pigs are the next animal cloned by researchers, hopefully to help produce organs for human transplant. "Golden Rice," modified to make vitamin A, promises to help third-world countries alleviate blindness.
2001	The sequence of the human genome is published in *Science* and *Nature*, making it possible for researchers all over the world to begin developing treatments.

Some 7000 years ago in Mesopotamia, people used bacteria to convert wine into vinegar. Sumerians and Babylonians were drinking beer by 6000 BC. Egyptians were baking bread by 4000 BC and wine was known in the near east by the time the Book of Genesis was written. Theophrastus – an ancient Greek who lived 2300 years ago---swore that broad beans left magic in the soil. In 1885, a French chemist Louis Pasteur suggested that some soil-organisms might be able to fix the atmospheric nitrogen into a form that plants could use as fertilizers.

The term “Classical biotechnology” can be used to describe the course of development that fermentation has taken since the ancient biotechnology period. Ethanol, acetic acid, butane and acetone were produced by the end of nineteenth century by open *microbial fermentation processes.* In the 1940s complicated engineering techniques were introduced into the mass cultivation of microorganisms to exclude contaminating microorganisms.

Modern Biotechnology

The latest biotechnology revolution began in the 1970s with the arrival of: Applied Genetics and Recombinant DNA technology. This genetic engineering had a profound impact on almost all areas of traditional biotechnology and further led to breakthroughs.

The major strength of biotechnology is its multidisciplinary nature and the extremely broad range of scientific approaches that it encompasses. This is graphically represented below Figure-1:

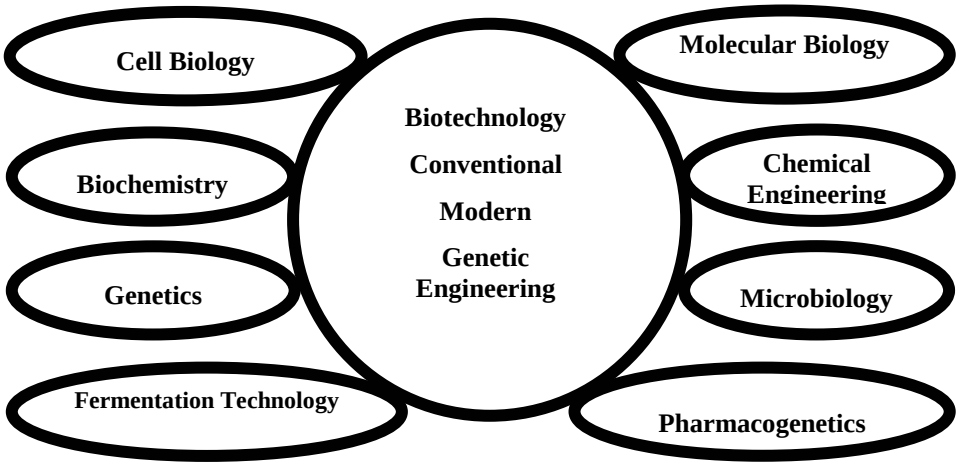

Figure-1

The same is true for the very large number of products that biotechnology can provide (as shown below) Figure-2.

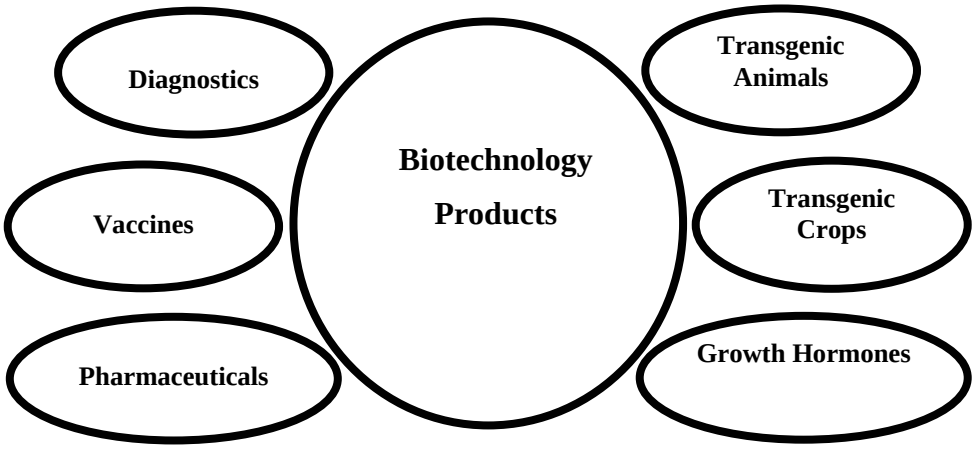

Figure-2

As a result of the above two aspects, biotechnology has become a pivotal tool for sustainable development in such diverse areas as Agriculture, Environment, Industry and Human Health. Biotechnology, the application of an explosion of biological knowledge, gives humankind the ability to alter the structure of life itself. Whether biotechnology proves to be a miracle or a menace depends on how it is used and controlled?
It is a combination of these two aspects i.e. the multidisciplinary nature and the wide range of products produced which now, using genetic modification make, it possible to apply all this know how to achieve the following. These are only a few examples.

Currently, we are using genetic modification to:

- Produce new and safer vaccines.
- Treat some genetic diseases.

- Provide new and better medicines.
- Increase crop-yields and decrease production-costs.
- Improve food nutritional value.
- Increase livestock productivity.
- Develop biodegradable plastics.
- Decrease water and air pollution.

Commercial biotechnology consists of an expanding range of interrelated techniques, procedures and processes for practical applications in the health care, agriculture, industrial and environment sectors. Commercialization of biotechnology ranges from research to products and services. These are powerful technologies, supported by complementary bioprocess-engineering, to help translate new discoveries of life-sciences into practical products and services. As such, biotechnology should also be seen as an integration of the new techniques emerging from modern biotechnology with the well-established approaches of traditional biotechnology, such as plant breeding, food fermentation and composting.

In view of time-constraints, it seems appropriate to illustrate the potential economic impact of biotechnology by using agriculture as an example.
Number of international organizations: IUCN (The World Conservation Union) UNEP (United Nations Environment Programme), WWF (World Wide Fund for Nature) jointly organized a seminar in 1991 which was later published as “Caring for the Earth, a Strategy for Sustainable Living”. Among the several definitions of sustainable development, the one given in ‘Caring for Earth’ is the most appropriate. It says, “*Improving the quality of human life, while living within the carrying capacity of supporting ecosystems”.*

Sustainable Development

Economic prosperity, development and, more so, sustainable development are complex issues, which are the end-result of a whole set of interacting factors. The concept of sustainable development was launched by the World Commission on Environment and Development in the report ‘Our Common Future’ in 1987, and reinforced by the UN Earth Summit in Rio de Janeiro (1992). The concept of sustainable development is based on the conviction that it should be possible to increase the basic standard of living of the world's growing population, without unnecessarily depleting our finite natural resources and further degrading the environment in which we live. Emerging biotechnologies, based on new scientific discoveries, offer novel approaches for striking a balance between developmental needs and environmental conservation. A wider diffusion of the technology is thus seen as the key to directing its positive impacts onto the world's society as a whole. Biotechnology is continuously and rapidly developing in an increasing number of sectors that improve the effectiveness of the way in which products and services are provided. However, the transfer and development of biotechnology, in an environmentally sound manner, requires a variety of conditions, including capital inputs that, in the case of many developing countries, are not readily available.

One of the important aspects of biotechnology is its role in the sustainable development of various sectors. Sustainability is fast becoming the corner stone of economy of many countries, both developed and developing. Such a development, in turn, depends upon the use of new technologies, innovations, entrepreneurship and utilization of inexhaustible supply of renewable resources. Biotechnology is one such technology, which has rapidly developed over the past few decades and has great potential for solving many problems pertaining to Agriculture, Industry, Environment and Health, which have direct relevance to sustainable development. These features and potentials of biotechnology have generated great interest among the developing countries, many of which have embarked on various programs in biotechnology at various levels.

In the majority of developing countries, agriculture is the mainstay of the economy. Any improvement in agricultural productivity directly helps in improvement of the economy. The role of new biotechnology in agriculture has been described as a precursor to another Green Revolution that would help eliminate the world’s hunger. The conventional methods of genetic improvement resulted in significant increase in grain production over the past few decades.

In addition, industrial processes based on biotechnology, are often economical as they consume less energy and use raw material more effectively. The largest contribution of biotechnology is in the pharmaceutical industry, where various drugs are being produced by genetically engineered microorganisms (GEMs). The best known examples are human insulin, interferon and growth hormones.

Transgenic Crops

The modern powerful techniques of gene-manipulation have now made it possible to move genes between different species. By using this approach, transgenic crops have been constructed. At present these include Maize, Rice, Cotton and Soybean. The steps involved in this process are graphically depicted in Figure-3.

TRADITIONAL PLANT BREEDING

DNA is a strand of genes, much like a strand of beads. Traditional plant breeding combines many genes at once.

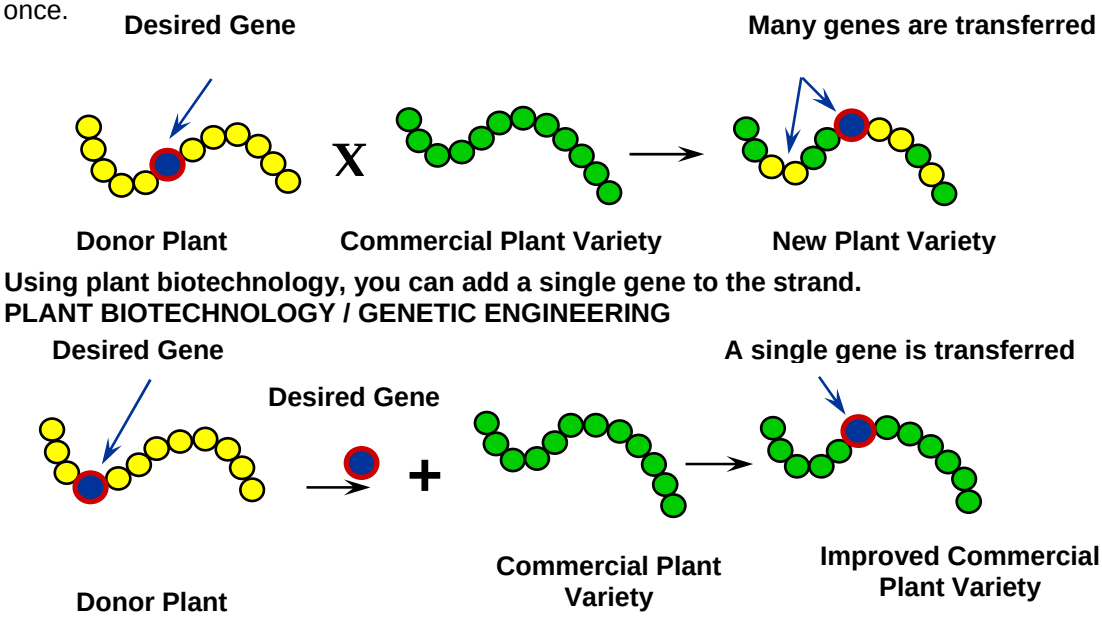

Figure-3

The global challenges that we presently face in the area of food-security are indeed frightening. At present, some 480 million people go hungry every day and at least 1.3 billion live on less then US$1 per day. If the world can't make progress against hunger and poverty by year 2025, there could be 4 billion people living on less than US$2 per day and more than 2 billion living in extreme poverty. Scientific research serves the cause of the poor and the hungry. At a time when science is moving at a spectacular pace, it is essential that the new and exciting possibilities for increased agricultural productivity and sustainable natural- resources management are realized in the developing countries. One promising approach is to have transgenic crops, showing increased yield and enhanced resistance to disease.

Table - 2: Global Area of Transgenic Crops, 1996 to 1999(million hectares/acres)

Year	**Hectares** (million)	**Acres** (million)
1996	1.7	4.3
1997	11	27.5
1998	27.8	69.5
1999	**39.9**	**98.6**

Increase of 44%, 12.1 million hectares or 29.1 million acres between 1998 and 1999.

In the light of the above table, one can briefly discuss the correlation between biotechnology and sustainable development in the following manner that sustainable development has become a priority for the world's policy makers. Among the broad range of technologies with the potential to reach the goal of sustainability, biotechnology could take an important place, especially in the fields of food-production, renewable raw-materials and energy, pollution- prevention and bioremediation. However, technical and economic problems still need to be solved. The environmental impact of biotechnological applications has to be very carefully examined, in the light of bio-safety guidelines developed by different national and international committees. It is really important to critically asses the risks and benefits, paying specific attention to the environmental impact of the release of any micro organisms or crops.

Any strategy has to be a guide rather than a prescription. The world thus needs a variety of sustainable societies, achieved by many different paths. Each nation and the communities living there must find their own specific solutions and develop extremely well-defined national strategies. All countries require appropriate infrastructures that permit them to acquire, absorb and develop technology, to manage it properly and systematically, and to build up local scientific and technological competence. The resultant ability of any country and of a developing country, in particular, to discern, choose and adapt an environmentally sound emerging biotechnology can serve as a measurement of sustainable self-reliance that will allow it to participate fully in worldwide efforts to achieve sustainable development. The creation of such enabling conditions poses new challenges that must be addressed, for developing countries to fully realize the potential benefits of biotechnology and minimize any possibly adverse socio-economic or environmental effects.

It is this ambition and commitment to acquire, sustain and establish enabling conditions which pose new challenges to the developing countries. Such crucial questions have to be aggressively addressed, before one can realistically expect to benefit from such frontier technologies, without in any way having to compromise with any deterioration of the environment.

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