VIDYASAGAR UNIVERSITY

Fifth Convocation

Address by

Dr Manju Sharma

Eminent Scientist and Secretary,
Biotechnology Division

Government of India

10 March 2000

SAHEED PRADYUT SMRITI BHAVAN, ZILLA PARISHAD
MIDNAPORE 721 102
WEST BENGAL

Harnessing Biotechnology Research and Application for Human Welfare – An Agenda for the 21st Century

His Excellency, Hon'ble Chancellor, Shri V.J. Shahji, Hon'ble Vice Chancellor, Prof. Mukhopadhyay, the distinguished faculty of the University, other guests, media personalities and my dear students,

Let me at the onset thank the Hon'ble Chancellor and the Vice Chancellor for giving me this opportunity to give the Convocation Address at the Vidyasagar University, named after one of the greatest personalities this country Shri Ishwar Chandra Vidyasagar. He was as an educationist and a social reformer. By giving this University his name, I believe, that the direction and the principles which the University should follow have been made abundantly clear. How compassionately and vehemently, as a social reformer, he pleaded for the remarriage of widows. I quote :

"Oh poor India! .....you think the woman whose husband dies immediately turn into a stone; she does not have sorrow anymore, cannot feel pain any more and all her senses of passions and sensualities disappear without trace suddenly! But you will know that such notions are based on false pretences as evidence to the contrary abounds. Just think how these erroneous notions are poisoning this world. How sad! The country, whose male population is unkind, unreligious and unaware of the distinction between the good and the evil and don't care about justice and fairness and where abiding the rituals is the chief preoccupation of religion, should not give birth to girls!

The subject I have chosen for this address would somewhat reflect the philosophy of this great man. How can biotechnology can be harnessed to benefit the humankind and alleviate the sufferings of poor.

The university located in the rural surroundings represents a very important Centre of activity not only for the young students and scientists and faculty members, but a great source of inspiration for the people living in this region. Knowledge always shines and

lights the path of others who are less privileged; who need to know and learn a lot.

"Prajnanam is Brahma – Knowledge is God"

Frontiers in Biotechnology : Some Events

The integration of natural resources and engineering in order to achieve the application of microorganisms as well as parts thereof and molecular analogues for products and services is the field of biotechnology - the greatest intellectual enterprise of humankind. According to a business corporate, it is also defined as "Making money with biology". Let me briefly present some major landmarks in research and technology development since 1953 :

- Watson and Crick elucidated the double helix structure of DNA – March 1953
- The first letter of the genetic code was deciphered – 1961
- Existence of messenger RNA and its elucidation – 1961
- Discovery of restriction enzymes and their application to problems of molecular genetics – 1970
- A technique for recombining genes was patented – setting the stage for the biotechnology industry – 1973
- Need for biosafety guidelines felt at a meeting in Asilomar, California – 1975
- Genetech Inc., the first genetic engineering company was founded in South San Francisco – 1976
- The first cancer causing gene was identified – 1976
- A human hormone was successfully produced in bacteria using rDNA techniques – 1977
- A method was developed for rapidly determining the sequence of the 'bases' that carry the genetic code in a DNA molecule – 1977
- The gene for human insulin was cloned – 1978
- A powerful technique based on the Polymerase Chain Reaction (PCR) was developed – 1985
- The genetic marker for cystic fibrosis was found – 1985
- The first genetically engineered tomato to be grown in open air was produced –1987

§ A patent was awarded for the first genetically altered mouse – 1988

§ The National Centre for Human Genome Research was created in USA. The first successful gene therapy was conducted on children with immune disorders – 1990

§ The discovery of the gene behind Lou Gehrig's disease was announced – 1993; and reported in 'Nature" (Science, March 1993).

Looking at these phenomenal developments in modern biology, Crick had predicted :

> "In 5 years the impact on medicine will be big; in 10 to 15 years, it will be overwhelming."

Further, Leon Jaroff stated :

> "Finally discerning the double helix structure of deoxyribonucleic acid (DNA), the giant molecule of heredity, had cleared the way for a great leap forward in human understanding of the process of life".

The basic discoveries blossomed after these events into a powerful new tool which revolutionised medicine, agriculture, environmental aspects, health, and industrial development. There has been a major impact of biotechnology on social, economic and ecological conditions in the developed world and also in many developing countries. Altering the genetic make up of micro-organisms in a directed manner has opened up new vistas. This method can be extended to higher organisms, plants and animals.

Specific Areas

I will briefly touch upon some frontiers of biology representing excitement of research, application and relevance to society and economic development. The highest quality of research would lead to products, processes and technologies to benefit the society.

Biosystematics

In the context of patenting, Convention on Biological Biodiversity, global recognition of conserving the biological diversity and biological resources and their sustainable utilization, biosystematics have assumed enormous significance. Major initiatives have been launched by international bodies such as Bionet International, Species 2000 Programme of indexing the world's known species by IUCN and Systematics Agenda 2000 International. It has become essential to develop a framework for data bases of the species, do the correct classification, identification and inventorization, carry out phylogenetic research and link it up with the evolutionary biology. We need highly trained professionals for the purpose. This must be treated as one of the challenging areas for the next millennium. In fact, internationally senior scientists have expressed their view that this field is facing unparallel problem in science. Since the turn of the century, the field of systematics has grown beyond just collecting and cataloguing the data. It is now the use of molecular approaches, fingerprinting, mathematical modeling, creation of computerised data base, information systems etc. It is basically a DNA systematic work. Universities are the best centres for furthering biosystematics.

Agriculture

The agriculture biotechnology is growing from 8% in USA; 20% in Europe; 28% in Canada to at least 20% higher growth. Areas of transgenic research, biological pest control, micropropagation and tissue culture technique, use of microbial products, genetic mapping of crops etc. are gaining momentum.

It is only about 12% of the world's total land surface which is used for growing crops; 13% of forest or woodland and 26% is pasture or meadows; about 1/3rd is used for other purposes. Therefore, about 68% of the land in the world is under different types of agriculture related activities and to this vast area, research on all aspects of life sciences would give the needed boost. Three crucial inputs in addition to water for enhancing the agricultural productivity

per acre would be:

- high quality planting material;
- soil nutrients;
- biofertilisers; and
- disease/pest control measures

Improvement of the health of the soil and preventing the use of agricultural land for non-agricultural purposes, development and application of different biological softwares, biofertilisers, biological control agents for pests and diseases for retaining the soil fertility would be essential.

Bio-engineering technology which has been perfected by the scientists, needs to be applied for gene transformation and for development of gene markers to produce disease resistant varieties. With the advent of biotechnological tools, we can expand the plant capacity and provide better planting material to the farming community. We can transfer the genes to crop varieties independent of their origin. Modern biotechnology has helped us to have tools to transfer bacterial and animal genes to improve the crop variety and give a new architecture to crops.

Manipulation of plant metabolism, disease and pest resistance, and the use of plants to produce valuable heterologous molecules, will yield many products for society and industry over the next few years.

Plant improvement, whether as a result of natural selection or the efforts of plant breeders, has always relied upon creating, evaluating and selecting right combination allels. New valuable allels can be tracked in segregating population using genetically linked molecular markers. Extensive sets of genetically mapped molecular markers such as RFLP, RAPD, AFLP have been produced for many species. These mapped markers are enabling geneticists to direct the control of complex traits into component genetic units much more precisely. They are providing the breeders with newer tools to manage these units more efficiently in breeding programmes.

A conservative estimate of the demand of the food grains by 2000 and 2010 would be 240 million tonnes; with the major share of rice and wheat.

About 56 transgenic plants in 38 countries are under field trials. According to a recently published report about 40 million hectares of transgenic crops such as soybean, corn, canola, potato have been harvested.

Another important aspect is conservation of the genetic diversity for retaining and enhancing the productivity. The ultimate objective in the area of agriculture would be to enhance the productivity through an integrated farming system along with the management of natural resources for the conservation of biodiversity. The recent developments in biology would contribute significantly towards this strategy.

Let me cite some examples.

- Recently, the US Department of Agriculture and University of Wisconsin, USA have inserted a gene for green fluorescent protein derived from jelly fish (Aequorea victoria), as a reporter gene into the orange tree cells. This is a unique combination of agricultural and marine biotechnology.
- Research work done by a group of US and Australian researchers has produced through genetic engineering the first pest resistant seeds by creation of a strain of garden pea which can resist the attack by two weevil species (Science, Volume 265, August, 1994). This research is of relevance to the development of new varieties of weevil protected legumes.
- Scientists at the University of Leeds and some scientists from Japan together have worked on the innovative approaches of gene cloning in plants, namely, the shot gun rescue and chromosome oriented approaches with regard to the isolation of genes, development of artificial plant chromosomes, their possible uses and chromosome mediated transformations.
- The growing interest of the developed countries in commercialisation of agricultural products is evident from the increasing number of genetically engineered products being released. According to a recent report, as of May 1996, there are about 32 products of which 18 have been approved for sale in 1995.

It is important to work on plant genomes as on human genome programme, particularly for a country like India with rich crop diversity. For the important species like mustard, wheat, rice, some coarse grains etc., the mapping of the plant genome must become a priority. The mapping and sequencing of the genomes of the higher plants can provide a complete category of all the genes involved in the life cycle of a plant from seed to flowering and fruiting stage. Such results can revolutionise the agricultural productivity and give economic benefits. Arabidopsis thalaliana is a model organism for plant genetic research belonging to mustard family and has one of the smallest plant genomes and the highest gene density identified in a flowering plant. Martienssen has entered into a global collaboration to determine the entire genome of this plant by 2004.

Over the next ten years, it is likely that some plant genomes will be completely sequenced, and the function of a large number of genes regulating plant development will be analysed. A comprehensive molecular map consisting of 1383 DNA markers has been developed under the Rice Genome Research Programme in Japan (Supported by Rockefeller Foundation). The availability of a well saturated, high density molecular map of rice is of interest as the basis of studies of genome organization, gene mapping, molecular aided selection and map based cloning.

DBT has taken an initiative in setting up Plant Genome Research Centre (PGRC) at JNU. During the years ahead it is hoped that there will be an increase in knowledge about the genetic and biochemical determination of plant processes, plant development and the synthesis of economically valuable plant molecules. This progress will be driven by discovery and channelization of genes and gene product of known function in model and economically important plants and the ability to design and insert new genes. The teaming of molecular biologists with agricultural scientists would pave the way for many productive future endeavours and frontiers in this field.

Aquaculture and Livestock

The sea food demand world wide is expected to increase by 70% in the next 35 years. Therefore, there will have to be at least a seven fold increase by 2025.

With 8,000 Km coast line, we are very well poised for fresh water, brackish water and coastal aquaculture. The new technologies for seed production, disease control, integrated management practices, have already demonstrated the increase in the prawn production to the tune of 10 tonnes/ha/year. Application of biosciences including the genomic studies would provide enormous employment opportunities. The global economic losses from aquaculture production due to disease have been approximately US$ 5-7 billion per year. Therefore, pathological conditions need to be intensively studied including the biology and biochemistry of the pathogen and the hosts. With the accelerated research on fisheries through molecular tools and judicious utilisation of new and traditional species for aquafarming, we would usher in an era of blue revolution in the 21st century.

Livestock has a very important contribution to the Indian agriculture through the share of animal husbandry which is about 15.5%. There has been an annual growth rate of 4.8% in the dairy sector. Today, India is the largest producer of milk in the world but we have to do a lot more. May be take up the genome mapping of buffalo which is our own animal and apply the embryo transfer technology to some important animals which form basis of the livelihood security of millions in the country. Disease control, waste recycling, value addition and improvement of genetic stock are very relevant research areas. These sectors offer direct benefit of employment and nutritional security to people.

Health Care System :

With the world policy makers and scientists assembled in Alma-Ata, the goal of health for all by the year 2000 was established in 1978 at this historic conference. The goal was defined as "The attainment by all peoples of the world by the year 2000 of a level of

health that will permit them to lead a socially and economically protective life." The latest WHO report, 1999 entitled "Making a difference" however, also states that over a billion people will enter the 21st Century without having benefited from the health revolution. The picture is true : HIV epidemic, the resurgent malaria, consequences of tobacco use, malnutrition, etc. are looming large on our horizon. Briefly, let me mention the challenges which need to be addressed to improve the health of the people in the world as outlined by WHO.

- Need to reduce burden of excess mortality and morbidity suffered by the poor; women and children deserve maximum attention
- Need to encounter potential threats to health from economic crisis and unclean environment or risk behaviour
- Need to develop more effective health systems
- Need to invest in expanding the knowledge base.

The 20th century has seen a major transformation globally in the health care systems. Thanks to very rapid advancement in science and technology, life expectancy has increased which is related to the economic and industrial development in many cases. Better nutritional status, immunisation programme on large-scale and greater urbanisation also helped to some extent. But if we look at the emerging and re-emerging infections, there has been a steady increase.

If we compare 1909 and 1999 estimates, the position is as follows:

	% increase in 1909	% increase in 1999
Diarrhoea	4.8	0.3
Tuberculosis	8.9	0.6
Respiratory Diseases	20.1	8.5
Other Infectious Diseases	12.8	11.5
Cancer	1.9	22.8
Cardio-Vascular	12.9	30.4
Injuries	3.5	8.5
Other Diseases	35.1	17.5

(Source WHO 1999)

The Nobel Prize for 1995-96 in Physiology and Medicine was given to three scientists in the area of Developmental Biology and this year it has gone to the work in Immunology showing the great importance of these two fields for health care.

The field of immunology both as protection against infection and also invasion of the foreign substances into the body has assumed enormous significance from the view point of fundamental and applied research. With the studies in immunology, it has been possible to also understand about hypersensitivity diseases. Allergy, autoimmune diseases such as rheumatoid arthritis or multiple sclerosis are all expressions of hypersensitivity. As far as reproductive immunology is concerned, the scope is tremendous not only for basic understanding of the subject but in terms of its clinical application.

The Seventeenth International Congress on Genetics in 1993 held in UK focussed the attention in a major way on the whole question of medical genetics and use of genetic technology as health care systems. Today, we know that there are about 6,000 genetic disorders.

The human genome project, an international research effort was started in 1990 with the objective of generating maps of human genome and producing complete sequence of human DNA by the year 2005. It was launched with the advice of a large scientific community which had emphasised that : "Will facilitate research in biochemistry, physiology and medicine, have a major impact on health care and disease prevention and provide enormous scientific technological advances ..... having both basic and commercial applications". The size of the human genome is 3 million base pairs of DNA. It is expected that by 2003, the sequencing will be completed. The driving force behind this research is to apply the basic principles of genetics to medicine by identifying the genes and studying the gene function and developing new technologies. In India we have started a programme on Indian Genome Initiative with very similar objectives to develop the technology base, specially keeping in view the understanding of the disease loci. The area of pharmacogenomics is critical for developing new medical products.

Gene therapy research has emerged as a major hope for a number of diseases and more than 100 clinical trials are undergoing, 70 for cancer alone in different countries. The first clinical trial on HIV in USA using gene therapy has been permitted. We know that somatic gene therapy is a very important field and would help in having cheaper methods of treatment than the protein vaccine. Therefore, in the field of medical biotechnology, there are enormous challenges in terms of the development of new molecular medicines, genome mapping, identification of novel genes, diagnostic applications, structure and function of the new genes, site specific drug delivery systems etc. Development of new drug and rationale drugs design is a challenge.

A rather recent development relates to the work on the transgenic plants that express foreign proteins with industrial or pharmaceutical value. Specific vaccines have been produced in plants as a result of the transient or stable expression of foreign genes. It has recently been shown that genes encoding antigens of bacterial and viral pathogens can be expressed in plants in a form in which they retain native immunogenic properties. These results provide 'proof of concept' for the use of plants as a vehicle to produce vaccines. [Hugh S. Mason and Charles J. Arntzen - TIBTECH September 1995 (Vol 13)]. Work on transgenic potato, tomato, banana has already been initiated. This would require sustained efforts to ultimately genetically engineer plants which particularly can be used by children for control of some of the important killer diseases. The concept of vaccine production in transgenic plants was introduced in 1992. Considering that the plants can be a useful system, this work is being pursued in a number of laboratories outside India and in some laboratories in India too.

With the type of advances that have taken place in the recombinant DNA technology, genome mapping and sequencing Walter Gilbert has predicted :

> ".....that 10 years after, genetic profiles will display between 2000-5000 potential disease genes, and by 2020 or 2030, you will be able to

go to a drug store and get your DNA sequence on a CD which you can then analyse at home on your Macintosh".

Recombinant vaccines, new drug delivery systems, new methods of administering the vaccines are all in advanced stages of development in many developed countries. The yeast genome has been identified in a collaborative effort of about 100 European laboratories. It is extremely important for the food and pharmaceutical industry. This work will also pave the way for new research on human illness such as cancer.

We have also to remember that the South East Asian region carries a major share of the world's disease burden accompanied with poverty, unemployment and unhealthy environment. There is financial crisis too.

We must have a better understanding of aging and disease processes, the whole area of brain research, cardio-vascular diseases, hypertension, diabetes and so on. We still have to work hard to control polio in this country. India is considered the reservoir for Type II polio virus. According to the DG, WHO in a recent statement on 5th January 2000, India is accounting for as many as 4320 cases of the 6449 polio cases registered in 1998.

It is in the light of this disease scenario that we have to look at the new biomedical research agenda for the next millennium. So what do we visualise for the 21st Century –

- The enhanced life expectancy of the children
- Freedom from diseases like poliomyelitis, measles, neo-natal tetanus
- Elimination of many parasitic diseases and the children overall to be protected from the vaccine preventable diseases
- Low-cost, affordable health care regimes in the form of drugs, vaccines, diagnostics to be available.

Environment:

According to the Chief of UNEP, Mr. Klaus Topfer The population is the main determinant of environmental problems of countries and poverty is the most toxic element. He said :

> "India with its dense networking of non-governmental organisations needs to empower the grassroots people more for dissemination of proper information, in order to secure informed decision making."

He further said that the five major issues for the country would be land degradation, biodiversity, air pollution, freshwater resources and hazardous waste management. It is in all these areas where biotechnology has had tremendous impact world over and in India, therefore, we have to relate the problem of poverty, environmental pollution and need for biotechnological inputs to alleviate the same.

The Stockholm Conference in 1972, the UNCED Conference in Rio in 1992, both focussed the world attention to the areas of pollution, biodiversity conservation and sustainable development. Plants and microbes are becoming lead players in pollution control. The World Bank estimates show that pollution in India is costing almost US$ 80 billion in terms of sickness and death and in the world, there are already 13 million environmental refugees. The new developments such as bioindicators, phytoremediation methods, bioleaching, development of biosensors, identification and isolation of microbial consortia, etc. are the priority research areas. Significant work has been done in the country but developing more and more a plant oriented approach towards pollution control would be truly important. Cleaning up the large river systems, ensuring the destruction of pesticide residue in large slums in the city are the priorities in which a biotechnological approach would be environmentally safe.

Phytoremediation to remove the high level of the explosives found in the soil has become a reality. Although it was known that some microbes can denitrify the nitrate explosives in the laboratory

but, they could not thrive on the site. Bruce and his colleagues (NATURE Biotechnology May 1999) have transferred this degradive ability from the microbe to the tobacco plants and these have produced a microbial enzyme capable of removing the nitrates.

Biodiversity:

The global biosphere can survive only if the biosphere resource utilisation is just about 1% and not 10%. The global environment is regulated by climate changes and biosphere dynamics. Knowledge about biodiversity accumulated in the last 250 years is being used by the scientists world over. We have many gene banks, botanical gardens and herbaria for conservation purposes. There are the molecular approaches including DNA fingerprinting for plant conservation. The totality of gene species and ecosystems have become exceedingly important not only to understand the world environment on this planet earth but from the view point of enormous commercial significance of the biodiversity.

Biotechnology is becoming a major tool in conservation biology. According to Pimm (1996)

"The present era has been described as an era of extinction".

12% vascular plants are threatened according to the Walter and Gillet (1998) "The number of threatened animal species is 5025 world wide which includes 563 Indian species. India has about 2000 species of vascular plants which are threatened."

According to the Species Survival Commission of IUCN **"Species are the continuing basis of life. They contain the genetic element evolved over millions of years that hold the key to future adaptations and survival."**

We have realised that the biodiversity is under threat and understanding of the scale of this destruction and extinction is essential. The scientists more than anybody else must appreciate that it is the greatest gift of nature to the planet Earth. Certainly questions such as who owns the biodiversity, who should benefit

from it and what is the role of the society and the common man are pertinent. There is a Kashmiri proverb :

> **"We have not inherited the world from our forefathers, we have borrowed it from our children."**

The forests, marine resources, bioremediation methods, restoration ecology, large scale tree plantation which has almost doubled from 90 million ha to 180 million ha may even increase manifold by 2010 are the areas related to environment which will continue to be researched upon.

I would like to make a special mention also of marine resources which are providing many goods and services to the human beings in the form of bioactive materials, drugs, food items, etc. The marine biodiversity, their documentation and characterisation are extremely important.

Industrial Biotechnology:

Research leads in Biotechnology can be converted into products processes and technologies by bringing together an interdisciplinary team. The pharmaceutical sector has had a major impact of this field as rare therapeutic molecules in the pure form could be made available. Diagnostics have mushroomed and over six hundred biotechnology based diagnostics are now available in clinical practice with a value of about US $20 billion. The PCR based diagnostics are the most common. Indian effort in the diagnostic area has been commendable and it is expected that the sale would rise from Rs.1 billion to 2 billion during this century. Industrial enzymes have also emerged as a major vehicle for improving the product quality. In India a number of units are coming up for production of industrial enzymes like alpha-amylose, proteases, lipases etc. This sector is expected to have a three fold increase by the end of the century which will match or surpass the computer industry in size, importance and growth. As in other countries the consumption of biotechnology products would increase from Rs.27.13 billion to about Rs.55.00 billion by 2000. We are producing 13 antibiotics by fermentation. Capacities exist to produce important

vaccines like DPT, BCG, JE, Cholera, Typhoid etc. The cell culture vaccines like MMR and rabies, hepatitis-B have also been introduced. Globally, we have about 35 – 40 biotechnology derived therapeutics and vaccines in use and more than 500 drugs and vaccines are in different phases of clinical trials.

Bioremediation has become another money earner.

The Ethical and Biosafety Issues:

The bioethics committee of UNESCO established in 1993 has evolved a large number of guidelines. In the words of Andrew Joscelyne:

> "Just as modern ecology aims for sustainable development, bioethics should ensure that biotechnological progress is directed towards sustaining those features of our common biological heritage worth preserving".

Biosafety issues for genetically modified organisms need to be strictly adhered to prevent any possible harm to environment. The three tier mechanism of Institutional Biosafety Committees: the Review Committee on Genetic Manipulation, the Genetic Engineering Approval Committee and the state level coordination committees have all been instituted. It is important to give a clear perception of the new biotechnologies to the public to allay their fears.

We must address the risks and the magnitude of the consequences on the environment. By establishing close linkages among research scientists, extension workers, industry and the farming community, one has to evolve new models of cooperation and partnership. It is possible to introduce large number of desired economical characters resistance to biotic and abiotic stresses. These can be combined with hybridization into a single super transgenic crop. A classical example of rice is well known as done by Dr. Khush in 1996.

Our Expectations

It is expected that the global agro-science market by 2010 will have a very different scenario. From the present turn over of US $29 billion, with conventional route, based on biotechnology it will be US $39 billion. The biotechnology based products and the markets will rise from US $2 billion to US $34 billion. The downstream processing for products in biotechnology will be from US $200 billion to US $350 billion. World over, we are conducting more than 25,000 field trials. The benefits certainly are: in terms of better planting material, saving on the inputs, genes of different varieties from biodiversity can be introduced in the gene pool of crop species for their improvement.

Certainly, one can hope for a large number of transgenic plant varieties in India. At least, cotton, rice, brassica, pigeonpea, moongbean, improved varieties of wheat, etc. tissue culture regeneration protocols for important species like mango, saffron, citrus, neem, would be available and it will be a major commercial activity. The micropropagation technology would provide the high quality planting material to the farming community. The environment friendly biological software namely, the biocontrol agents and biofertilizer packages would be made available to the farmers. In fact, the technologies would be transferred to them so that they can produce these on their own fields. The country would be in a position to fully utilise on a sustainable basis, the bioresources particularly the medicinal and aromatic plants. The molecular biology route for development of new diagnostic kits and vaccines for major diseases, emerging and re-emerging infections would make the health care system much more efficient and low-cost. The genetic counselling clinics, the molecular probes, the fingerprinting technique would all be used for tackling the genetic disorders. Ex situ gene banks to conserve the valuable germplasm and diversity and a large number of repositories, referral centres for animals, plants and microorganisms would be necessary. Detailed genetic read outs of individuals would be available. The information technology and biotechnology together would become a major economic force. It is expected that the plants as bioreactors would be able to produce

large number of proteins of therapeutic value and many other important items. The recent discovery of the gene for recalcitrant species is a landmark event. The mass propagation *in vitro* can be carried out on any desired species with non random programming. Certainly, the 21st Century would witness a major upsurge of new bioproducts generated through enormous biological wealth by utilising the tools of modern biology, on a sustainable basis.

In order to achieve our goal of self-reliance, we would require a strong educational and scientific base, clear public perception of new biotechnologies and involvement of society in many of these biological ventures.

With the large infrastructure in the form of 29 agriculture universities, 204 central and state universities, more than 500 national laboratories and research institutions, it would be possible to develop capabilities and programmes so that these universities act as the regional hub for the farming community, for poor people where they can get a direct feed back about the new technological interventions.

I must emphasise that girl students and women scientists need very special encouragement. They alone would be able to speed up the development process. Large number of girls are taking up biology as a career. We must nurture and encourage them.

It will be equally important to establish strong partnerships and linkages with the industry where they will have to be partners from the time a research lead has emerged till the packaging of technology and commercialisation is achieved.

To Conclude

Let me conclude this Convocation Address by quoting one of the greatest personalities of this country, the most respected and loved, Guru Rabindra Nath Tagore. In pursuit of scientific research and particularly its application to alleviate sufferings of humanity, his thoughts and words are most relevant and inspiring, truth symbolises the scientific innovations and the very spirit of science, knowledge to serve the country in various forms, retaining the value system, having love and affection for the people, concern for the

and scientifically developed India where the poorest of the poor are technologically empowered.

I quote from Gitanjali :

"Where the mind is without fear and the head is held high;
Where knowledge is free;
Where the world has not been broken up into fragments by narrow domestic walls;
Where words come out from the depth of truth;
Where tireless striving stretches its arms towards perfection;
Where the clear stream or reason has not lost its way into