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New Biology towards Socio-economic Progress

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ABSTRACT

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Prof. Birbal Sahni, the founder Director of the Birbal Sahni Institute of Palaeobotany paved the way for systematic developments in this field from botanical and geological aspects. Palaeobotany is the study of ancient life. The Indian sub-continent is bestowed with enormous biodiversity and richness of biological resources. The grave consequence of loss of biological diversity has to be understood on scientific basis. The global biological heritage, both for the present and for the future will have a proven influence on the potential of constructing a sustainable agriculture and forestry system which will produce useful products for the sustenance of human life. The work in new biology and the advent of biotechnology and genetic engineering have given a large number of fundamentals, innovations, tools and techniques. The scientists can produce crops with desired traits, enhance the food productivity and nutritional status of the crops, produce new vaccines and diagnostics, develop packages for environmental restoration and protection of biodiversity. The future advances in new biology offer enormous potential both for economic and societal development.

Key-words—Biology, Technology, Genome, Biodiversity, Protein.

सामाजिक-आर्थिक प्रगति में नवजीवविज्ञान का योगदान

मंजु शर्मा

सारांश

बीरबल साहनी पुरावनस्पतिविज्ञान संस्थान के संस्थापक निदेशक प्रो. बीरबल साहनी ने वानस्पतिक तथा भूगर्भीय परिप्रेक्ष्य से इस क्षेत्र में सुव्यवस्थित विकास के मार्ग का सूत्रपात किया। पुरावनस्पतिविज्ञान मूलतः 'प्राचीन जीवन का अध्ययन' है। भारतीय उपमहाद्वीप में जैवविविधता तथा जैविक संसाधनों का प्रचुर भण्डार उपलब्ध है। जैव विविधता के ह्रास के दुष्परिणामों को वैज्ञानिक दृष्टिकोण से समझा जाना चाहिए। भूमण्डलीय जैव सम्पदा वर्तमान तथा भविष्य दोनों ही के लिए दीर्घकालिक कृषि एवं वानिकी तंत्र को निर्मित करने हेतु आवश्यक है, जो मानव जीवन के पोषण हेतु उपयोगी उत्पाद निर्मित करती है। नव जीवविज्ञान तथा जैव प्रौद्योगिकी के आगमन से अनेक नए सूत्र, अनुसन्धान, उपकरण तथा प्रविधियाँ प्रकाश में आयी हैं। आज वैज्ञानिक इच्छित फसल उगा सकते हैं, खाद्य उत्पादन क्षमता बढ़ा सकते हैं, नए वैक्सीन तथा निदान खोज सकते हैं, पर्यावरण एवं जैवविविधता के संरक्षण हेतु पैकेज विकसित कर सकते हैं। नव जीवविज्ञान में भावी अनुसन्धानों से आर्थिक एवं सामाजिक विकास में अत्यधिक सम्भावनाएँ निर्मित होंगी।

संकेत शब्द—जीवविज्ञान, प्रौद्योगिकी, जीनोम, जैवविविधता, प्रोटीन.

31st Prof. Birbal Sahni Memorial Lecture delivered by Dr (Mrs) Manju Sharma, Secretary, Department of Biotechnology, on 16th November, 2001 at Birbal Sahni Institute of Palaeobotany, Lucknow.

INTRODUCTION

"My own interest in Palaeobotany raises the hope that I may help to bring this fascinating subject more prominently to the notice of my countrymen; and perhaps even succeed in inducing a larger number of them to turn their attention to the rich field that it offers for original investigation".

Prof. Birbal Sahni spoke in one of the sessions of Indian Science Congress in 1920. These words spoken nearly a century ago reflect the genius, the vision and concern about the country of the architect of the field of Palaeobotany in this country and the founder Director of the Birbal Sahni Institute.

Let me share with this audience—an emotion, very precious and personal to me. I received the first real academic distinction in my life in the name of Birbal Sahni Memorial Gold Medal for being the best student of Botany in M.Sc. from the Lucknow University, in 1961. All other previous prizes in school and colleges became second to this prestigious medal which gave me the inspiration, a desire to pursue science as a career. It was my good fortune that Prof. A.R. Rao, my Ph.D. guide, another leading Palaeobotanist had worked under the overall guidance of Prof. Birbal Sahni. Thus you can realize the sentimental value of this lecture for me. I am really grateful to the Director for giving me this opportunity to deliver the Prof. Birbal Sahni Memorial Lecture. I dedicate this lecture to the fond memory of my Guru, Late Prof. A.R. Rao and pay my most respectful tribute to the two great scientists—Prof. Sahni and Prof. Rao.

We have assembled here to commemorate the memory of Prof. Birbal Sahni, a dedicated Scientist and a great philosopher.

His untiring efforts to elucidate the importance of fossil plants both in Botany and in Geology lead to path breaking discoveries. It was due to his selfless, rigorous pursuit that this institute of Palaeobotany came up as a seat of excellence. Since its inception it has tried to live up to his expectations.

Before I proceed to the main topic of my lecture, let me also mention about another great scientist Sir C.V. Raman, who was very close to Prof. Birbal Sahni. The Two were superb communicators of science and certainly Raman had great influence on him.

The Foundation Stone of the new building of this prestigious Institute was laid by nobody less than Pandit Jawaharlal Nehru, on 3rd April 1949, a contemporary of Prof. Birbal Sahni at Cambridge. Let us recall the words of our first Prime Minister emphasizing the importance of science and values while addressing the Indian Science Congress in 1963:

"Without science there is no future for any society; but even with science, unless it is controlled by some spiritual impulses, there is also no future".

Systematic developments in Palaeopalynology from botanical and geological aspects and constantly updating the data for interaction with other allied disciplines have been the hallmarks. It is Palaeobotany which bridges Botany and Geology in order to peep into the evolutionary history of plants which directly or indirectly have a bearing on various aspects of plant life and their geographical distribution with reference to time and space.

Palaeobotany is a major branch of Paleontology – the study of ancient life. The most ancient fossils are those of Archean Era – which are possibly 2.5 billion to 3 billion years old. It involves the study of the origins and development of all plants and plant like organisms from yeast and bacteria to redwoods and orchids. Paleontology, so to say has a great value in Palaeobotany as it levels itself to quantification, age determinations of geologic strata and the correlation of strata from different locations.

The most outstanding and lasting contribution to 19th Century Palaeobotany was made by Dr W.C. Williamson in his studies of British Coal Balls from the precoal stages of peat layers of the lower coal measures. The advent of Precambrian Palaeobotany is one of the most significant developments. Studies on fossil algae have revealed results which have far reaching biological implications about the antiquity of life on earth and the origin of nucleated organisms from which sexual diversification originated.

OUR BIODIVERSITY AND BIOLOGICAL RESOURCES

Today we are in the midst of a revolution of biotechnology and information networking. Before we think of research in New Biology, we must understand the magnitude of our precious Biodiversity. The Indian Sub-continent by virtue of its varied topography, climate and habitat is rich in traditional knowledge of properties and uses of its resources. Biodiversity is a vast variety of living organisms and their products of utility including both flora and fauna with genetic variability not only in animals and plants but also in other organisms like viruses, bacteria, fungi and other microbial populations. It is now recognized as a source of prosperity and livelihood security of millions. The diversity is both in number of different species and at intraspecific levels in the form of races and varieties.

A record of India's plant wealth indicates that there are nearly 17,500 species of angiosperms, 48 species of gymnosperms, 1,200 species of ferns, 6,500 species of algae, 14,500 species of fungi, 2,500 species of lichens, 845 species of liverworts and 1,980 species of mosses. This great diversity of plant wealth thus has a direct bearing on the very existence of humankind and for the ecological security of our Planet. It is here that the great significance of New Biology innovations, biotechniques and discoveries have to be recognized.

In spite of phenomenal advances in discovering new species of flora and fauna on the planet earth, there are 3-27 undiscovered species and yet hundreds of species are discovered and classified by the Biologists every day.

Due to geographic topography there is a decline in diversity from equator to poles. So the losses are even more severe in tropical countries like ours, where human population is expanding at a much alarming rate. One really has to look into a so-called war of humans verses animals and plants. The need for expanding populations and an unequal distribution of wealth has invariably resulted in the unsustainable, exploitative use of naturally existing resources.

One of the grave consequences of this is the loss of biological diversity. A quarter of the earth's total biological diversity amounting nearly to more than a million species is at the brink of extinction in next few decades. Currently nearly more than 35% of the total land of the planet is threatened by desertification. The area of polluted soils and water is expanding exponentially. The green house effect has a direct bearing on world's climate. Both aquatic and terrestrial fauna are rapidly being wiped out and the Mother Earth is threatened of erosion. Hence our concerns about the loss of productivity of agriculture are genuine.

The global biological heritage – the living foundation of existence both for the present and future will certainly have a profound influence on the potential of constructing a sustainable agriculture and forestry system, producing useful products for the sustenance of the human life. India is one of the megacenters of biological diversity, Botanical Survey of India (BSI) has identified more than 45,000 plant species of which nearly 15,000 represent flowering plants, 37% is being endemic and 1,500 species being threatened. Out of 5,000 species studied at length, only 30 are useful in producing 95% of human nutrition. Three main crop species doing this job are maize, rice and wheat. In view of this diversity between and within few plant species it becomes imperative to develop program's of different crop genetic resources both at the National and International levels.

25 hotspots have been identified world over which cover nearly 0.746 million sq km and houses 0.45 million species. India has 2.4% of the world's area has 8.1% of the world's total biodiversity with a species count of about 0.130 million. Two of the world's hot spots are found in India, namely, the Eastern Himalayas and the Western Ghats; the former being the hottest of the hot spots. In addition, India has 26 recognized endemic centers.

To be agriculturally secure with maximum crop production, the best use of available land, has to be made and latest methods of crop improvement have to be brought into practice. A wide range of plant species have been selected over a period of time for their use in agriculture and horticulture. I do not want to elaborate on conventional plant breeding. We all are aware that with just the conventional approaches, it is not possible to improve a specific variety directly either from the viewpoint of productivity or quality. Thus a blending of old and new research techniques is called for.

NEW BIOLOGY

The advent of information technology has given a new dimension; there is a paradigm shift in the areas and strategies for new biology research. Genome technology, today, is an integral part of the new informatics. The latest throughput systems to the bioinformatics set up, high performance computer, DNA amplification and sequencing, genome assembly and gene prediction, proteomics and mass spectroscopy, development of different biochips, gene expression and so on starting with cell biology to modular biology, these are scientific and technological revolutions taking place with a spectacular speed. The scientists have come a long way; there is a thinking in United States, Switzerland and many advanced countries that scientists would be able to make simple "artificial cells from scratch". These can metabolise, replicate and evolve, i.e., fulfill the basic criteria for the living entities while they will be only synthetic. According to Szostak and his colleagues, this would mark, "the beginning of the field of synthetic biology".

There are various modes now available for the new biology studies starting from the genomics study to microbial, proteomics, etc. After all, the world has witnessed, based on the deep knowledge of the fundamentals of new biology and by harnessing the new biotechnological breakthroughs, the genetic profile of the human kind, the information on the blue print of life. The tools generated by the human genome project are applicable and have produced a whole genome catalogues, microbes, plants like *Arabidopsis*, fruit fly *Drosophila melanogaster*, round worm, *Caenorhabditis elegans*, etc. It is stated by the scientific community that the complete genome sequences serve as a foundation for the biology of the 21st century. The statement is : "Achieved a fundamental, comprehensive and systematic understanding of health.

The advent of biotechnology and genetic engineering has made it possible to overcome many problems. Biotechnology basically involves the translation of biological theory into engineering. It proclaims attempts to control biological processes for purposes, which are useful and render services for the good of humanity. To design crops with desired traits, molecular biology and genetic engineering as a tool have become handy. It is the conglomeration of various molecular techniques that has led to the development of such plants.

OUTCOME AND APPLICATIONS

It is interesting to note that between basic research and its application there is a thin line. Many times, the research concepts and research results are immediately applicable. New biology and biotechnology have been used safely for many years to develop new and useful products in a variety of industries. A large number of products have already been approved for marketing and many more are being developed.

These products include dozens of therapeutics including human insulin for diabetes, growth factors used in bone marrow transplants, products for treating heart attacks, scores of diagnostic kits for AIDS, Hepatitis and other infective agents, enzymes used in food production, etc. The first life saving drug Humulin was produced by recombinant DNA technology and this was followed by a plethora of drugs including Betaseron for treating multiple sclerosis, pulmozyme for cystic fibrosis, activase, a clot dissolving tissue plasminogen activator used for treating heat diseases. It is also possible to produce these biopharmaceuticals in a form identical to the normally occurring ones in the human body but also to design meaningful improvement in activity, stability or bio-availability. Such products are also free from contamination.

Cloning of the exact duplication of specific genes has been an essential tool in biotechnology for more than 20 years. Cloning of human cells, organs and other tissues can produce replacement skin, cartilage and bone tissue for burn and accident victims. This could prove useful for developing internal organs for human transplantation.

The cloning of Dolly and Polly demonstrated that nuclear transfer technology could be used effectively. The breakthrough in developing stem cells holds the potential to control cancer, regenerate spinal cord and brain tissue, and successfully treat many diseases associated with aging. Stem cell Biology has a great potential in saving many lives.

Vaccines are one of the greatest developments of modern biology. They have helped in eradicating diseases like, small pox, pushed polio to the brink of extinction and spared countless people from numerous diseases like, typhus, tetanus, measles, hepatitis A, hepatitis B, rotavirus and other dangerous infections.

But still many other diseases like, malaria, AIDS, herpes, hepatitis C have yet to find a successful vaccine. This gap exists due to the fact that standard immunization methods work poorly or pose unacceptable risks when targeted against a particular illness. Certainly alternate strategies are to be explored. One of the most promising ways is to develop vaccines out of the genetic material either the DNA or RNA. DNA based vaccines will preserve all the positive aspects of the existing vaccines while avoiding the risks. They are easy to design and generate in large quantities using recombinant DNA technology.

Biotechnology offers new opportunities and is the only hope for producing enough food for a growing world population. Malnutrition has been one of the main concerns of the developing world as it results in nearly 12 million deaths every year of the third world children under five. Growing enough staple crops such as corn, rice, wheat, potatoes without further extending the amount of land to be cultivated will require sustained increase in yields per acre. Biotechnological innovations will play a key role in fighting against malnutrition worldwide. Deficiencies of Vitamin-A and iron, for instance are very serious health issues in many regions of developing world, causing childhood blindness and maternal anemia in millions of people whose dietary staple food is rice. Biotechnology has been used to produce a new variety of rice "The Golden Rice" – that contains Vitamin A precursor-carotene and iron. This modified rice is expected to provide nutritional benefits to people suffering from Vitamin-A deficiency related diseases. Adequate Vitamin A intake can also reduce the mortality associated with infectious diseases like, diarrhea and childhood measles by enhancing the activity of human immune system. Genetically modified rice, which boosts yields by nearly 35% has been developed.

Tools of advanced biology to endow plants with genes that help them to resist pests have proved very fruitful. For instance cotton, potato and corn containing the Bt gene from a soil bacterium producing delta-toxin proteins that are selectively toxic to certain kinds of insects are harmless to other insects, humans and animals. Bt cotton has been launched for field trials in India with promising results.

Recently a protein, the first of its kind, that switches in a plant a natural defence against diseases and insects has been approved in US in April 2000 giving farmers an alternative to chemical pesticides. The protein, named Messenger is produced from genetically engineered bacteria. When transformed to a plant, it has shown to increase yields in tomatoes and peppers by 22% besides, making plants more tolerant to drought. This Messenger protein is the first natural product that can turn on the immune systems of crops.

The merging of medical and agricultural biotechnology has opened up new vistas to develop plant varieties with characteristics to improve health. Understanding of how natural plant substances, known as phyto-chemicals, confer protection against cancer and other diseases is amazing. Work is underway that will deliver medicines and vaccines through common foods, which could be used to immunize individuals against a wide variety of enteric and other infectious diseases. This has given birth to Neutraceutical foods. These developments will have far-reaching implications for improving human health worldwide, potentially saving million of lives in the poorest areas of the world.

New Biology has paved the way for conservation and sustainable use of biodiversity. Powerful tools for the conservation, evaluation and the use of genetic structure of species are available. Bioremediation employs biological agents to render hazardous wastes into non-hazardous wastes. Even plants have been used for phytoremediation successfully.

The generation of Biofuel cells by making use of catalytic properties of organisms and enzymes for energy conversion holds a great potential. Biofuel cells convert chemical energy into electrical energy. These biocells would be used as specific sensing devices for energy conservation.

Advent of computers has added a new dimension to biological research. With the rapidly evolving superfast

computers, improved accuracy in ligand screening, improved combinatorial chemistry designs, virtual explosion in the availability of three dimensional structural information and genome sequence database and the computational techniques will continue to take a center stage in many different aspects of drug design and development process.

Of late biological materials in the form of biochips are going to have a tremendous impact on computer development per se. The biochips would replace the conventional silicon chips used in the computer. The development of biomolecular computers promise to be ten to thousand times smaller than the best super computers with much faster switching times and extremely low power dissipation. Researchers at Advanced Center for Biochemical Engineering College, London have succeeded in obtaining a tiny semiconductor structure from yeast *Schizosaccharomyces pombe*.

Computational tools for mining the genomic data, identifying the potential new drug targets, elucidating and / or predicting the three dimensional structure of targets from the primary structure are at the core of the present day bioinformatics technology. Computational approaches will continue to be essential part of the ongoing and future drug design and development process.

Molecular biology is a technology driven process and numerous new techniques have come up during the last decade. This has totally changed the concept of cloning and studying a single gene at a time. Now one can study a number of genes simultaneously using Microarray or the DNA chip technology. Here one can process thousands of DNA segments for detecting differences in the pattern of DNA sequences or expression pattern of mRNA. Even one can study the over all picture of now genes in all organisms (total genome) function, including the expression profiles at mRNA (Transcriptome) and protein (Proteome). Maps can be made which could eventually help in identifying the defects as well as the positive aspects of concerned gene or a protein. Such are the advantages of using these modern biology tools.

CONCLUSION

Future advances in New biology offer the promise of an impressive array of new and useful products that will improve crop yield and quality, provide better nutrition, deliver needed vaccines and medicines produce more desirable fats and oil, extend the shelf life of fruits and vegetables, lower the food costs and create renewable non-food products. These research efforts, innovations and technologies will open up *new* markets, leading to rapid industrial development and more employment opportunities.

Let me conclude by once again reminding all of you the great potential of the field of new biology and biotechnology which must be to be harnessed for the welfare of humanity and economic progress of the nation. This certainly would depend on the dedicated and concerted efforts of the scientific community, specially the young scientists. We have to recognize that doing the highest quality of science and applying it to generate new products, processes, technologies and systems would form the basis of the socio-economic development of this country in the 21st century. Knowledge in biology can be converted into economic wealth with biotechnological innovations. On this assumption, let us move forward and do the best science.

विज्ञानं ब्रह्मेति व्यजानात्। विज्ञानाद्धयेव खल्विमानि भूतानि जायन्ते।
विज्ञानेन जातानि जीवन्ति। विज्ञानं प्रयन्त्यभिसंविशन्तीति।

तैत्तिरीयोपनिषद-3/6

"Science is Brahma, the almighty. All the living beings are born or are produced through science and at the end while practicing science, they get absorbed into it." (Upanishad)