EVERYMAN'S SCIENCE

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COVER PHOTOGRAPHS

Past General Presidents of ISCA

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2. **Prof. (Mrs.) Asima Chatterjee (1975)**
3. **Dr. M. S. Swaminathan (1976)**
4. **Dr. H. N. Sethna (1977)**
5. **Dr. S. M. Sircar (1978)**
6. **Prof. R. C. Mehrotra (1979)**

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EDITORIAL

ENGINEERING SCIENCES, EDUCATION AND ROLE OF SCIENCE HISTORY

In last few decades, globally, we have seen incredible and rapid technological advancement and information and communication boom has brought about a revolution. Advances in computational capabilities have provided unprecedented possibilities. Engineering Sciences have played an important role in the development of technology based on the recent scientific discoveries, understanding of the fundamental principles of science and engineering, available analytical and numerical tools as well as the constraints such as those of societal, economic and political nature. As a consequence, in recent times we have seen great engineering achievements which have contributed in improving our lives in several ways. With the advancements in technology, continuous developments in transport, infrastructure, communication, devices of various kinds, health care, safe food, safe drinking water, production of various gadgets, development of sophisticated machines, more efficient processes of production, advances in materials and understanding of their behaviour under various applications, and safety in unintended natural or man made disasters, and so on, have become so commonplace that at times we take them mostly for granted.

With increasing efficiency and availability of Scientific tools, like experimental devices, measuring instruments and characterization devices, available mathematical and computational tools, the pace in scientific researches is continuously increasing. International co-operations in major important areas in science and engineering are becoming important and are steadily increasing. In fact, the boundaries between science and engineering in several areas seem to be vanishing. With such rapid developments in science and engineering, development of technology is becoming a continuous process, and the role of engineering sciences in societal and economical development is continuously becoming more and more challenging.

Challenges for the Engineering Scientists stem from defining the engineering task, which when achieved should meet the desired objective effectively. For finding most efficient ways of meeting such actual or perceived "NEED", it is important for the Engineering Scientist to be well acquainted with the available scientific knowledge, recently developed existing technology, and tools of analysis, as well as social, economic and political constraints. The extent of his imagination and creativity adds to the quality of the solution. The pace of new discoveries and development of new technologies seems to be quite high. In global context, it becomes necessary for the engineers to be involved in developing new technologies, get abreast with the available new technologies and methodologies and use them in best way soon after these become available. Their own experience and researches are important component. However, the researches need to be motivated for getting the results faster and engineers need to employ these results in developing new technologies at a pace relatively faster than elsewhere.

EDUCATION OF FUTURE ENGINEERS

The rapid pace of technological development and discoveries makes the Job and education of the future Engineering Scientists very exciting, and has been subject of serious thought and discussions internationally. It is of course necessary for the Universities and Engineering Institutes to impart to the students a thorough grounding in fundamentals necessary for the profession and in several interdisciplinary and basic subjects. In addition, it is important that engineering students be provided with an environment conducive not only for continuous learning habits, hard work and perseverance, but also for developing vision, imagination, well founded objectives, curiosity, dedication and incentive for creative adventures.

ROLE OF THE HISTORY OF SCIENCE

To my mind, it also necessary that the history of great scientists be the part of education process of the engineering students. A familiarity with the scientists, and to know how the human beings like themselves worked, to achieve great scientific success with their dedication and passion, is certainly motivating in several ways.

Over the last five decades my interests in the area of "Impact Mechanics" (which finds application in design for crash worthiness of road and air vehicles and other sensitive structures and safety in defense), I have been fascinated by the simplicity of approach and dedication of several scientists, who have been able to make significant and far reaching scientific contributions in basic and applied aspects of mechanics. There are several names like Archimedes, Newton and Euler, who are known to the engineering students perhaps because of the theorems, principles and laws named after them. However, knowing about their background, circumstances, training, motivation, and the manner in which they devoted themselves to the scientific findings does open up vistas useful in motivating creative work.

15th April 2013 marked the 306th birth anniversary of the most prolific writer and one of the most creative mathematician of all times Leonard Euler. Euler's contributions are enormous, and his dedication exemplary. All engineering scientists/ students must have come across one of the Euler theorems or Euler equations in diverse applications. His publications number is phenomenal. It is indeed fascinating to know about his initial training, his interest in mathematics and association with Bernoullis. His life in St. Petersburg and Berlin, and his contributing so much even after his problems of loosing one eye at the age of 28, and the other in his later years speaks volumes of his dedication and motivation. Some of the equations like that of the buckling formula, are so simple and elegant examples of modeling a given phenomenon.

BENJAMIN ROBINS (1707–1751) AND LEONARD EULER (1707–1785)

In text books on engineering mechanics and physics, students are introduced to Ballistic Pendulum as an example of the application of the principles of momentum. Robins developed the ballistic pendulum in 1742 for measuring musket – ball speed. This device was quickly adopted internationally and remained in use for a century. I really wonder if the students of engineering and those working in impact mechanics would be familiar with the name of Benjamin Robins, known as father of "Gunnery", who is credited with the discovery of the Ballistic Pendulum (Fig. 1), and known as founder of experimental aerodynamics. By firing musket balls on the heavy pendulum metal backed wooden block and recording its swing, and using equations of momentum, velocity of the ball was determined. Generally the results obtained were within 2%.

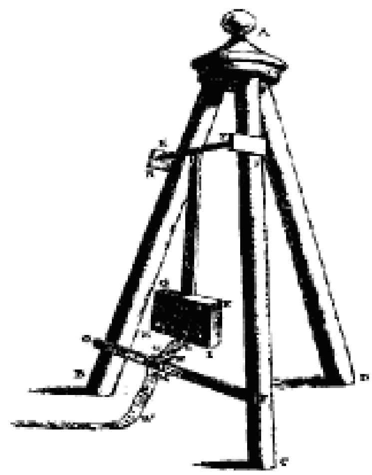

Fig. 1 Robins' Ballistic Pendulum as sketched in "The New principles of Gunnery"

He was born in Bath (UK) and received very little early formal education. His genius brought him to work in London. Known also for his work on Newton's Treatise on Quadratures, he was elected as Fellow of the Royal Society when he was 20 years of age. His book "the New Principles of Gunnery" was in two respects epoch-making in that (1) for the first time the magnitude and great importance of air resistance on swift moving bodies was recognized, and (ii) by the introduction of his ballistic pendulum the accurate measurement of projectile speed was also for the first time made possible. It is a great contribution to impact mechanics and design of guns. The quality of work and its importance in those times stimulated Leonard Euler to reproduce Robins' book in German language, and adding such a vast amount of commentary that its length turned out to be several times that of Robins' original monograph. This magnified the importance of Robins' book, as Euler was much celebrated scientist himself.

My aim in referring to this great discovery of Benjamin Robins and his encounters with Leonard Euler is to motivate engineering students to look at the simple solutions achieved through mostly experiments (by Robins) and get acquainted with the comments (of Leonard Euler) which were mostly based on mathematical considerations. This of course is an experience of great value in the learning processes in motivation for discovery, modeling, analysis and creativity.

TO CONCLUDE :

In last few decades there have been unprecedented advancements in technologies and discoveries in science. The demands on the engineering scientists are becoming more challenging with time. The education contents and methodologies need to change and adopt to the needs of the present state of the profession. Apart from providing the students opportunity to learn basics and fundamentals, environment to develop vision, creativity, problem formulation and solving abilities, including the history of science in their curriculum will expose them to the real life examples of the human beings, like themselves, in motivation and dedication in pursuing the chosen scientific activity.

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Science does not know its debt to imagination.
—Ralph Waldo Emerson

PRESIDENTIAL ADDRESS

SCIENCE EDUCATION AND RURAL DEVELOPMENT

Dr. S. M. Sircar

I express my deep gratitude to the scientists of India for the unique honour they have conferred on me by electing me as the General President of the Indian Science Congress. This year the congress with the intent of taking Science to the village is holding the Session in this historic state of Gujrat from where the messages of Mahatma Gandhi on Civil Disobedience, Non-cooperation and Non-violence led the country to attain independence. Gandhiji's conception of *purna swaraj* was basically from the appalling poverty and sufferings of the millions of the people living in rural India, "their economic and social resuscitation was a *sine qua non* for freedom from foreign rule". Exploitation of the village in the interest of the town was considered by Gandhiji as a species of violence. The growing disparity in economic standard and social amenities between the village and the town was to be bridged. This he suggested could be done by volunteers from town to help in the revival of dying rural industries, improved standard of nutrition, education and sanitation. He insisted on *Swadeshi* Cult and the use of articles made in villages. With this idea the All India Village Industries Association was formed in 1934 to work for the revival and encouragement of the village industries and the moral and physical advancement of the village. What Gandhiji could do in his own way against heavy odds without any state help was very impressive. Today after 30 years of independence what progress we have been able to put Gandhiji's idea in action is a big question. Rural economics and the sufferings of the villagers are still the same, if not worse. Whether Gandhiji's action, participation and guidance in the village uplift work have been rigidly followed, if so what is the net result? To what extent the basic education and its relation with rural economy have improved?

It is a great privilege that the Prime Minister, Shri Morarji Desai has been pleased to grace and inaugurate the congress session. The Prime Minister, in his broadcast to the nation after assuming the office of the new Janata Government, reiterated the Gandhian philosophy and principles for rural economy and development based on household and small industry which could generate wealth and harness the productive capacity of millions. He has pledged to the nation the way his Government is to shape the progress of the nation in which rural economy and prosperity will have equal partnership with progress in urban areas. In integrated approach to bridge the gap of social culture and economic inequalities of town and village, rich and poor, he has appealed to all people for a helping hand in achieving all round progress on a countrywide scale. I can assure him that the scientists in India will assist in all possible ways for attaining this objective.

The Indian Science Congress Association has been taking a great deal of interest in current

* General President, 65th Indian Science Congress held during January, 1978 at Ahmedabad.

Science problems by having inter-disciplinary discussions of academic and practical importance. In fulfilling its objective the association has made a significant impact which has its repercussions in the welfare of people in direct or indirect way, Since 1975 the congress initiated a programme of multi-disciplinary discussion on problems that have bearing to our attitude to rural development. The session in 1976 initiated the first theme "Science and Integrated Rural Development" followed by "Survey, Conservation and Utilisation of Resources" in 1977. In view of the declared policy and action of the new Government the focal theme for this year on "Science Education and Rural Development" will be appropriate for the scientists at the Congress session to express their views and recommendations based on scientific knowledge and technology.

India has been the spear head of the changed political situation in the world. In her transition from colonial and imperialistic domination to progress for independent development on socialistic ideology she is flanked by social and scientific industrial revolutions. These have led to growing awakening among the masses who are demanding education, equality of opportunity and higher standard of living. The demand for education is now an integral part of political movement and working class is very much concerned for the right kind of education that will fit the children in the skill and Science of agriculture and industry. If we as a democratic nation want to function effectively, our basis of democracy is to be elevated by mass education, S. Radhakrishnan in defining the aim of education remarked that "Democracy depends for its very life on a high standard of general, vocational and professional education". We are talking of total revolution which will imply uplift of rural people and make them conscious of their rights and privileges and democratic methods of solving national problems. This is feasible through universal education; every individual should have a scientific background in understanding life and environment.

SCIENCE EDUCATION AND DEVELOPMENT IN SOCIALIST COUNTRIES

During the three quarters of this century India has made significant contributions in Science and Technology the impact of which on benefits in the life and economic condition of the people have been large. We are living in the twentieth century scientific and industrial revolutions which have been followed by unprecedented socialist revolution. The world based on economic and political consideration is now divided into capitalist and socialist states. In between, the third sector of politically neutral countries exists, which before the evolution of socialism was free world for the exploitation of raw materials for the monopoly industrialists and capitalists with open market for the industrial production. India and many other under-developed countries belong to this sector which have not yet developed their independent economy without foreign aid and are trying hard to be socialist states. The sharp distinction between capitalist system which was established more than three centuries ago and the socialist system was noticeable only after the great October Russian revolution in 1917 and further intensified after Chinese revolution in 1949. The progress of Science and the scientific achievements have been tagged to the political and economic power of a country. Scientific research in capitalist countries has made very remarkable progress mainly due to industry investing large sums of money for utilizing manpower and talent in Science and Technology. To this was added the fund and scope for expansion of military research during the two great wars, to lead to very outstanding achievements in Science and Technology — one speaks of the dawn of space age as man began to walk on the moon. There was however class discrimination of higher science education and scientific research which appeared to be confined to heriditary educated class, so called intelligensia with a few brilliant exceptions who were mostly employed as scientists, engineers and administrators (J.D. Bernal, *Science in History*, 1969).

Whereas Science development in the socialist countries has been different. In the Soviet Union science education before revolution was stifled and limited to those who were well off and could get higher education. This is apparent from the fact that up to the first two decades of this century Science and Technology have not made so much spectacular headway as in the capitalist countries. Since the establishment of the Soviet Republic there has been deliberate and conscious drive for the most fruitful intrinsic growth of Science education, Science and Technology and the maximum of help that can be given to the full utilization of natural and human resources. It has now been recognised all over the world that the Soviet Russia from a very poor beginning with inadequate education and scientific manpower became in the course of thirty years the second industrial country in the world. In heavy industry Soviet Russia made greatest contribution the planning for which necessitated the reform in agricultural methods from the primitive wooden plough system in the isolated fragmentary landholding in the Czarist time to the setting up of collective mechanised farming. The remarkable feature is the rapid industrialisation in a widespread manner in order to raise the standard of industrial production equally in all areas and to develop agriculture in industrial sectors and industries in agricultural areas. This involved the active and planned use of Science and Technology in both industry and agriculture at the same time to provide enough food for all the population engaged in nation-building projects. The cities were rebuilt, factories equipped with modern implements, health services increased and the most remarkable of all was that education system was extended and thrown open to all. The Soviet Russia ushered in the era of space research by launching the world's first artificial satellite in October 1957 within 4 decades after liberation. This was followed by first spaceflight by a Soviet citizen in 1961 and lately in July 1975 further advance in space research and technology was announced when joint test project involving the docking in orbit of the Soviet spaceship Soyez 19 and the U.S. Appollo Space Craft and mutual crew transfer which was high precision point in the history of international cooperation in space research.

The impressive spectacular achievements in agriculture, industry, space programme and social science that have been made in the socialist country during the short period of 3 to 4 decades are mainly due to enormous drive for universal education, particularly Science education. The Soviet Union felt that in view of increasing demand for trained scientists scientific education had to be increased several fold for use in agriculture, industry and health services. There was also a need for much greater balance of interest between the Sciences notably Geology, Biology and Medicine. A very remarkable event in the education system is the entry of large number of women in Science. It is said that instead of one woman to six men in British Science there are more women than men entering Science in the socialist education. The Czarist Government gave people little chance to develop their abilities and there had been definite impediment by the military officials of the government for keeping the people of Central Russia with less than 1 percent literacy subdued forever as shepherds and nomads and never to allow them to learn how to take to farming or acquire any knowledge of Science. Prior to 1917 about 75 percent of the population of Russia could neither write nor read, only 20 percent of the children received elementary education and 1 percent received higher education which were confined to boys of upper class. Within 10 years after liberation education was free and open to all 90 percent villagers were studying in local schools in their regional language. The campaign of universal education was at its height within 15 years after liberation when the main aim was to provide schooling for the entire adult population. In order to assist the campaign for removal of illiteracy among the adult population it was necessary to introduce universal primary education which was followed by seven years of compulsory schooling for the entire population. Higher education was for every occupational group without any class distinction. After the adoption of the policy of universal higher education and a comprehensive programme of science education from primary school stage to secondary school Soviet Russia has reached a very high standard of scientific and technical education and the whole population knows enough about Science to cooperate actively among themselves. J.D. Bernal writes that "Already, both in the United States and Britain, the recognition that the Soviet Union is turning out from twice to four times the number of scientists per head of population is causing alarm and belated efforts to emulate it".

People's Republic of China, an enormous country with largest population in the world had a very low standard of living comparable to that of India and a typical under-developed country; but in course of five years after liberation in 1949 started well with plan of development. China has shown remarkable success in solving two basic economic problems of food and employment. Rise in food production during the last two decades has been 1-7 percent per annum which has kept pace with the growth rate of population of 1-8 percent. Scientists in a short time became self reliant in building powerful hydroelectric power schemes and fabricating their own sophisticated scientific equipments; very seldom they use imported ones for research and advance technology. The birth of new China could show the transformation of oil poor China to be very rich in oil resources. The rapid building of road and railways are ending the curse of poor transport and communication, great water works and completed irrigation projects are putting an end to the danger of drought and flood. The miracles of reconstruction of china within a short time have been achieved on the basis of utilisation of large human as well as natural resources of mineral ores, coal and oil. She has also been able to absorb the entire labour force in the productive work in the rural areas. The changes that have taken place since liberation are far greater than that have occurred elsewhere in the world. The first requirement for this was considered literacy which has been tackled with such great strides that more than 80 percent illiteracy in the preliberation years has been removed and within a few years 90 percent of Chinese population have learned to read and write and within a generation the majority have secondary education.

The object of presenting in this address a brief narration of achievements in Socialist countries irrespective of any political or personal bias is to focus our attention on performance in Science and Technology in India which has been enshrined as a democratic republic of socialism after independence in 1947. It would show our weakness, deficiency, negligence and lack of proper perspective planning in fostering Science and technology and creation of effective manpower for which the basis is Science education. Very recently it was stated in the Parliament by the Union Home Minister "About 40 to 60 percent people in India are still illiterate and on the economic front she had plunged from no 51 to 105 in the list; even extremely backward countries in Africa which won freedom after India, have gone ahead of us — all in the name of socialism". After 30 years of freedom we have achieved and progressed very much less in comparison to what the USSR did in less than 4 decades after liberation from the Czarist rule. During these years improvement of the living condition of the people of India and progress to prosperity compare very unfavourably with that of People's Republic of China which was liberated later than us in 1949. The thesis is that the world history at the present time will very precisely indicate that wealth and prosperity of a nation no longer lies in the machines or raw materials or uneducated labour force but in having educated and technological manpower; education has been the real wealth of the new age of scientific industrial revolution.

SCIENCE EDUCATION

Science is the determining factor in our economic and cultural life. Every phase in the productive processes in agriculture and industry and practical aspects of our household affair needs intelligent approach in experimentation, improvement and innovation. Science education is the principal means of conveying scientific literacy to our population as well as for creating the scientific and technical manpower indispensable for economic and social advancement. It should be viewed as an integral part of the national education development policy. In a developing country like India with increasing population the problem of Science education needs a massive approach for the very fact that quite a large proportion, more than 40 percent of population, is illiterate and teaching Science will be a formidable task whereas at the same time there is no other way for rural development without giving them working knowledge in science so that they can find solutions to their day-to-day problems and also become meaningful participants in the execution of the developmental plans.

The Government of India for universal free compulsory elementary education have initiated a programme for reorganisation and expansion of Science teaching at the school stage from the Fourth Plan period with UNICEF assistance. The emphasis has been given on primary school stage and application of Science to the children's living condition. The National Council of Education and Research Training (NCERT) with the expertise advice from different educational institutions has framed exhaustive curriculum for general education with Mathematics and Sciences as the integral part of school education up to class X. In the primary school stage up to class VIII broad principles in proper understanding of the main facts, concepts, principles and processes in the physical and biological environment, some generalisations in Physics, Chemistry, Biology, Earth sciences and Astronomy are also visualised as useful and interesting to students to the secondary school stage. There has also been a tendency in some states to teach Sciences as composite courses like Physical Science including Physics, Chemistry, Life Science with Botany, Zoology and Physiology and Earth Science as Geology and Geography. With the increasing knowledge in science it is felt that our curriculum should be periodically reviewed and modified in order to give students modern knowledge which will infuse their curiosity and develop their method of enquiry how the additional knowledge could be of use to living condition and general welfare of the people. The emphasis should be given for developing scientific outlook rather than memorisation of facts. It should be broad-based and centred on direct experience of the pupils and related to their environment, particular attention being given to those related to conservation of natural resources, nutrition and health. The students are to be trained in such a way that they can make their own discoveries. The laboratories should be kept in such way that the students can learn the fundamentals of scientific approach and develop the qualities of self-reliance in the application of Science and Technology for national development. While emphasizing the new approach in Science education we are also to recognise the fact that too rapid and 169 frequent changes in the syllabi or methods of experimentation may carry the risk of confusing the students or diverting them from the career of a scientific worker. In addition the changes also involve cost which may be often prohibitive unless low cost materials and equipments are made available for the school. One of the most urgent needs is publication of Science books including textbooks in regional languages which will create interest in Science amongst the students.

While considering all these basic requirements our efforts should be directed to improve the quality of Science education. We should know to what extent new devices for learning and teaching adopted in developed countries could be fitted in the existing system of imparting education to our student population. In adopting a new approach which envisages changes in Science education emphasis is to be placed on solving varied problems that challenge the students. There has been criticism against the syllabi for Science teaching in our secondary courses being very heavy and not appropriate for the children of the age group. It seems specialists in different disciplines have tried to emphasise the importance of the discovery in the respective disciplines without taking into consideration the capacity of the young students to assimilate and retain the basic facts of the scientific knowledge which is increasing at a very fast rate. It should be our aim not to confuse and confront the students with so much of sciences accumulated for years together. Modern Science Teaching in developed countries aims to drop the rigidities of traditional disciplines like Physics, Chemistry and Biology and make a unified integrated and multi-disciplinary curriculum which is oriented toward solving the problems of living and studying man and his response to different problems of environment and society known as Human Sciences Our approach towards Science teaching in India should be oriented to understand not only the value of Science but its uses in improving the human relations and quality of life. Mere imparting knowledge of tight scientific facts and high sounding terminology irrelevant to students understanding the facts of life and his culture will fail to fulfill the objective for creation of scientific literacy amongst the Indian people.

After 10 years of school education, a programme for higher secondary with diversification in several vocational studies has been laid down. The objective has been to provide the students after general education opportunities to choose courses and programme of studies in a wider field of education keeping in view their fitness for the type of training that will provide them suitable employment. The other feature of the secondary education is to provide flexible facilities for the students to go on academic studies according to aptitude, interest and ability. This category of students can go for higher education provided a minimum standard of performance is maintained. At the higher secondary stage for 2 years flexibility in the choosing of course has been laid down with the basic idea of transferring from academic to vocational courses or vice versa as needed according to the aptitude of the students and social needs. This will avoid the unnecessary crowding of students to higher education with restricted scope of employment. The curriculum courses have been prepared in accordance with the need and future set up in the education plan of the country. The question arises whether this system of education particularly in the rural areas will be in conformity with the social implication of the people in relation to material welfare, tradition and cultural value.

Thus the present system of a 12 year study up to higher secondary courses plus 4 to 5 years in the university for completion of higher education has now been open to reconsideration when we are to increase the technical manpower and to increase the efficiency and speed of our developmental plans. One would feel to consider the possibility of reducing the total period of education by four to five years in schooling from primary school through university as in the new China experiments have been made to complete the primary school course in five years, middle school in four to five years and the university course in two to three years. In this period the students are given more practical and theoretical knowledge than in the past, superflous subjects and redundant or useless teaching materials are being discarded. More important is that the ideological education of students is strengthened and book learning closely integrated with practical production. School education is no longer confined to the class room as primary and secondary middle schools in town and country have established close links with nearby factories and People's communes. The university education system has also been altered. Universities no longer take senior middle school students in their graduation year but instead select them from among outstanding young workers, peasants and soldiers with two or more years of practical work behind them on the recommendation by the masses and approval by the leadership of the locality. This system does away with the book knowledge, first criterion which uniformly barred the labouring people and their sons and daughters from higher education in the universities.

The teaching of Science in a vast majority of schools in India is rather of very poor quality and fails to create any scientific attitude in the mind of the young student. For implementation of Science education shortage of Science teachers and inadequate laboratory accommodation and equipments are serious problems in India. It has been estimated that we have 90 million students studying under 2.5 million not qualified Science teachers in 0.5 million poorly equipped schools. This would work out a teacher to student ratio at 1 to 36, while in the USSR it is 1 to 18. It has not yet been properly spelled out how we are going to meet this challenge or shortcomings in our Science education. Teachers training colleges spread over different regions will not meet the rising demand of education in Science which needs a special scientific attitude and constant review of appropriate methods of teaching by prominent scientists and specialists.

The situation of shortages of Science teachers and equipments was felt quite early in the fifties in most of the western countries. The British Association for the Advancement of Science, well-known for deliberation of the progress of Science to the notice of a wide public was convinced that in Great Britain more attention should be focussed on the condition of Science teaching in schools; accordingly it sponsored in April, 1958 a conference of industrialists, scientists and educationists to discuss the need of scientists in industry and shortage of Science teachers and inadequate equipments. It was established that since the school population after high birth rate rose by one million in 10 years the corresponding rise would be to provide 30,000 extra teachers to cope with the rise in population. On this assumption the requirement in India, a country much larger than Great Britain and having higher population growth will be several fold for which an estimation is to be made. The salient features of the trend of discussion and recommendations in the conference are that as output of scientists and technologists should be increased, to meet this increasing demand the proportionate increase in science teachers at different school levels are to be maintained. This would enlarge the scope of teaching Science in graduate level in the university as minimum qualification for teachers is considered Science graduate. The question then arises how to attract the students before they could finish their final degree examination. Regular visit of the people from the industry is to contact the promising students with inducement for joining the service in the industry. One of the important suggestions is the earlier entry in the university after finishing school education at 17 instead 18 years. This has raised some controversy as to its effect on the standard of Science education which may not be beneficial for improving the quality of Science teaching and outturn of scientist in the competitive field for development of sophisticated industry in the country, but at the same time a group of experts think this will hasten the output of Science teachers badly needed for the nation. The salary of teachers before the war was comparable with that paid by other professions open to them such as universities, scientific civil services and industries etc. But later after the war the scale in industry rose very high, and thereby a large proportion of good quality Science graduates joined the industry. In order to attract the science graduates to teaching measures suggested were to increase salary from prewar £500 to £1400/£1600 a year, and raise the age of retirement from 65 to 70 thus enabling Science teachers to continue for five years more. The first and second class honours degree holders in science going to teach Science were also deferred from compulsory national service. It was tentatively estimated that to increase the annual output of scientists and technologists from 10,300 in 1955 to 19,700 in 1970 in U.K. there will be required about 1000 more Science teachers who will be able to teach the necessary number of students to enter graduate courses in university and technical colleges. In order to meet acute shortage of Science teachers neighbouring schools have been encouraged to share Science teaching. This is particularly desirable in a vast country like India when we are to meet the increasing demand of scientists and technologists in the rural area where the scope for full-time teachers is largely limited due to paucity of qualified teachers and adequate funds. A large number of graduates from agricultural universities are expected to join the development work in the villages. They may be induced to take part in teaching Science to the school students. It may be noted that in U.K. a system of hiring Science teachers from the industries has been followed with good success. Sometimes army and navy officers after retirement before 50 are inducted to teaching Science and Mathematics in U.K.

It is relevant here to consider the situation of Science teachers in Russia. Since cultural revolution teachers became the special concern of the Soviet Government because of the reorganisation of the school system and process of education depend on them. The idea has been that the school teacher should be raised to a standard he has never achieved and can not achieve in a bourgeois society. In 1976 there are 2.74 million teachers for 50 million school children in the Soviet Union. The teachers are provided with additional incentives like paid annual extended vacation with extra pay and allowances and rural area teachers could enjoy rent free apartments with heating and electricity. In order to improve the quality of education and to raise the scientific level of teaching the educational institutions carry out their work of profession in teaching in close cooperation with prominent scientists and specialists. Soviet educationists and teachers are seeking more effective teaching methods and ways of making teaching process more rational. Russian schools have now established 10 years schooling for every child within the Union; for this there is no teacher problem throughout the whole Union. This claim was made at a conference of the International Bureau of Education conference at Geneva in 1956. The planning was made according to the need coming for such teachers. The result of the planning was that in 1955, 80 percent of the graduates from the universities in the Soviet Union were directed into teaching. The question is whether the Russian policy of directing people into teaching and other professions could be adopted in India which is facing acute shortage of qualified teachers for our forthcoming Science education in the village along with rural industries. This may be a simple solution but not favoured in many western countries because of the fact that if an unwilling person is directed to take the profession of teaching the whole spirit of teaching within the school may be ruined.

In addition to qualified teachers there is great need of laboratory accommodation and equipments for the programme of Science teaching. A Science teacher will live in an atmosphere of frustration if he is not provided with facilities for equipment and technical assistance, in absence of these teaching becomes entirely theoretical. Scientists cannot be produced by mere theoretical knowledge or theory alone but it needs the practical work for solving problems or use of correct technique. When a boy enters the Science stream with overwhelming interest and inquisitiveness it becomes a challenge to the teacher to meet his queries and accentuate his interest by actual experimentation of the theoretical principles and also giving scope to the boy to do experiments by himself, to make use of his skills and brains in formulating results. This will lead to a systematic approach for future guidance in the formulation of new principles of scientific value. The technical assistants for laboratory are essential for the maintenance of the laboratory and for the best possible use of the Science teachers. The school authorities often assign these duties to Science teachers. It will be rather uneconomic in the sense if the teacher is given dual responsibility of teaching as well as the proper upkeep of the laboratory and instruments. Provision of laboratory technicians would be great step forward in raising the status of science teachers as well as the students will be in a position to spend more time in the workshops with the technicians to devise or fabricate instruments. An example may be cited that in the Imperial College, London, it was possible for me to device and fabricate a new precision instrument for research work only with the help of the experienced laboratory technician of the workshop.

It has not been worked out separately what additional cost would be involved for the introduction of Science education at all stages of schooling in India. The expenditures that will be needed for Science teaching particularly in rural areas are to be ascertained so as to enable the planners of rural projects to a portion a suitable fund for initiating science teaching in schools. The estimated cost of education according to Kothari report for the period up to 1985 is Rs. 54/- per head of population on the basis of 6 percent G.N.P. invested in education. This evidently includes the cost of proposed science teaching at all stages of education which is inadequate in view of the most of the developed countries spending atleast 10-12 percent of G.N.P. for education. This comes to Rs. 515 per head in U.K., Rs. 378 in USSR; Rs. 244 in Japan Rs. 119 in France and Rs. 1175 in U.S.A. This large difference is due to highly industrialised countries spending a large fund directly or indirectly on education and scientific researches. The cost of laboratory expenses for Science education in U.K in fifties was found varying between £3 to 28s per year for each pupil with a total capital of £4000/- per Science unit of a school. These figures are quite inadequate in the present rising cost of materials. The estimated figures are likely to be useful in our planning for extending Science education to rural areas. Industries in U.K. have come forward by establishing the Industrial Fund for Advancement of Scientific Education in Schools with a view to extending help in teaching Science as the output of scientists and technologists for the competitive sophisticated industry will depend on proper and adequate Science teaching the students receive in the schools. This step of the industrialists has helped to impart good quality of Science education in U.K. The schools receiving such help are known as independent and direct grant schools. While the maintained schools are run by the Government, the Industrial Fund Association has been helping the schools by way of capital grants for building, expansion, modernising and equipping Science laboratories. These schools do not receive any grant from the Government or local educational authorities. The total amount of grant provided by the fund to 187 schools in fifties in about £3.5 million for the purchase of apparatus etc., This example should be emulated by the industrialists in lndia. It would be realised that the scientists and technicians the industries need will come from the Science training we can give them on the basis of which the proper technology of industries in India could be built up. I believe the industrialists while setting up new industries in rural areas will give due consideration to this work of national importance as well as for their own industrial gain. While speaking at the British Association on the financial implication of science education the reputed scientist Dame Kathleen Lonsdale suggested that the large sum of money needed for it could be found by cutting the expenditure in defence and military research. Her estimate is that out of every £ 1 spent on research 15s comes out of the tax payer's pocket but out of this 15s, 12s is spent on so-called defence research. This rather causes two fold obsessions in the minds of the people; firstly many parents and young men look at modern Science as very powerful but essentially devilish, they are repelled by it. Secondly, Science for peaceful constructive purpose is hampered and starved of support. She went further to mention that the most important role of the universities of all nations is to produce thinking men and women who will no longer tolerate their anachronistic and suicidal prostitution of world wealth and scientific talent. It is heartening to note the press report that the Prime Minister, Sri Morarji Dessai has reduced the defence budget of the first Janata Government and provided additional Rs. 40/- crores for education. This will no doubt be good incentive to follow in future years to gear up the deficiency in the budget for our educational plan.

HIGHER SCIENCE EDUCATION

I have discussed at length the position and problem of Science education for students before joining the University or technical course. Since the publication of the reports of the university education by Radhakrishnan in 1948–49 and Kothari Commission on education, 1964–66 attempts have been made to extend and intensify higher education; several universities and technological institutes have been established in states so as to make available advance learning in Science & technology to a large cross-section of people. A perusal of the figures of the Government of India, Ministry of Education and Social Welfare and Kothari report will indicate that higher education in the last 10 years rose from 10.94 lakhs (1965–66) to 24.26 lakhs (1975–76) and this is projected to rise further to 41.60 lakhs (1985-86). On this assumption the percentage of total enrolment to population in the age group for higher education (18–23) was estimated to rise from 1.2 (1950–51) to 2.1 (1965–66). These figures indicate that higher education in general has been making satisfactory progress; but the question has arisen as to the employment potentials of the graduates from arts and commerce courses. The commission report suggests the need for reducing the rate of expansion at the undergraduate stage in the courses of arts and commerce. In regard to the situation in Science the figures available from 1950 to 1963 show that the total number of degrees awarded rose from 13600 in 1950 to 51602 in 1963 with an average of compounded rate of growth per year of 9.6 p.c. in B.Sc to 16.6 p.c. in M.Sc and in bachelors degree in technology 14.1 p.c. and in agriculture veterinary sciences 12.1 p.c. The doctorate degree in Science and technology is about 14 p.c. These achievements in higher education in Science is not altogether unsatisfactory but is to be considerably improved as our output in comparison to USA or USSR is rather small. It has been estimated that in USA the number of Science doctorates is doubled every twelve years with a current output of graduates in Science and technology of about 4 percent of the relevant age group and is equally divided between the engineers and scientists; in USSR the percentage is about the same but the proportion of engineers is far more than scientists, Kothari Commission envisaged the expansion of science education to meet the demand rapidly increasing for scientists and technologists due to developing research activities and industries. An estimate of annual rate of increase of about 10-15 per cent was visualised which at the end of two decades would be about 10 times the enrolment early in sixties. Presumably on this basis we are now told that India has been placed in third position in scientific and technological manpower in the world; but this large manpower is not commensurate with the achievements in Science and technology in the context of the developed countries. It would possibly lead one to conclude that such large scientific and technological personnel has failed to make any significant impact on the scientific and technological achievements for the country. Is it we are having quantity in place of quality? What might be the reasons for this discrepancy; the answer presumably would have to be sought from the unrestricted higher education in Science that has been made available to the students after secondary education. Our higher education should accordingly be very precise and restrictive to those who will be suitably qualified and benefited by the system of advance study. The question was not often very seriously thought of in the past presumably due to the absence of opening to young students to any vocational training or suitable employment; this state of affairs should be removed, Higher Science education should be given to the rural people who will be profitably employed in the industries of the village or neighbouring areas.

AGRICULTURAL EDUCATION

The pattern of agricultural education and research should be the greatest concern in India which is basically an agricultural country. Agricultural production and rural economy play the major role in our social and cultural life, employ a large population and contribute a large part of national income and earn foreign exchange, a major portion of which is used for amenities in our civic life. The rural population are to be made aware of the implication of Science and technology for the development of agricultural productivity. The executive officers and technicians who administer the public services in villages should have knowledge in the technical and scientific basis of agricultural practices in order to be able to apply new methods and innovations discarding the techniques that became absolete and not remunerative in the changed conditions. For developing rural economy, continued progress and better employment potential, it is necessary to increase the specialised technical personnel with training in agro-industries. The objective behind this should be to establish a balance between the tendency on the one hand to impart education very closely to the practical training of farmers and on the other hand to relate to the technical and industrial training with emphasis on Science and Technology. The establishment of a close link between agriculture and industry will also lead to exchange of ideas and give chances to transfer from one type of education to another.

In India separate universities of agriculture and Science faculties have been established in which agricultural Sciences are divorced from pure basic Sciences. Most of the advanced and developed countries have an integration of Pure Sciences with agriculture faculties, both these are in the same university campus. It is to be seen to what extent the separate university of agriculture in India will benefit the basic research in plant sciences. Kothari Commission while recommending the establishment of separate agricultural universities discouraged the tendency in resisting the admission of students of other faculties to postgraduate study in agricultural faculty. Inspite of the definite recommendation of the commission and the ICAR objective for integrating the agricultural sciences the practice of admitting agricultural graduates only is understood to have been imposed on the university authority from outside influence with possibility of reduction in the general standard of education in agriculture as an integrated science more appropriately needed for tropical environment. This shortsighted policy is also likely to discourage the employment of Pure Science specialists in the agricultural universities which in the long run will hinder the prospect of original contribution in Agricultural Sciences in the country.

The personnel that will be needed for the rural development in the agriculture sector has not been properly estimated. We need three categories of trained manpower; firstly diploma holders or persons having short training course in appropriate agricultural operations; secondly agricultural graduates largely needed for developmental projects in the villages as well as for teaching in secondary schools; thirdly postgraduates for teaching and research. According to the estimation of Kothari commission the total number of agricultural graduates for a period of 15 years ending 1985-86 will be 3.05 lakhs including one lakh postgraduates with specialised training which will be distributed as 10000 for research; 35000 for education; and 55000 for agricultural and agro-industrial development work. The total number of the graduates will be about one-third of the number of estimated requirements of graduate engineers for the same period or in other words 5 percent agricultural graduates to total output of all graduates is not excessive in view of the rising need of development in the rural areas. There are about 6 lakh villages in India for which on average one agricultural graduate and one diploma holder in agricultural training per village will have to be provided for all developmental work in the rural sectors. In addition agricultural graduates will also be needed for teaching in the secondary schools. When we are to take all these into consideration our requirement of trained agricultural personnel will be fairly large. This is to be provided in future plan periods. The question will be whether we have got the required facilities and equipments to give training to such large personnel without sacrificing the quality of teaching. It has been brought to notice that some of the existing institutes in India do not have proper facilities and staff for teaching in graduate or postgraduate levels. The Indian Council Agricultural Research (ICAR) has taken the responsibility for having uniformly high standard of training in agricultural universities so that the graduates coming out can take up advanced level of teaching and research in the country. The need for agricultural polytechnics can not be over emphasised in rural development projects when several agrobase industries are to be set up in the villages; these technicians will be essential as farm mechanics, farm managers, craftsmen, technicians in agro-industries, assistants in extension services, field representatives of fertiliser and pesticide industries. These polytechnics could be fitted in with the vocational institutions in the general higher secondary educational set up of the states.

AGRICULTURAL RESEARCH

India where more than 75 per cent people live on agricultural occupation should develop export trade on cereals and other farm products in addition to her normal requirements. Instead she was importing more than Rs. 143/- million worth of food grains alone prior to independence. After freedom it was expected that the situation should improve and the country would be self-sufficient in food; unfortunately she continued to be dependent on supplies of essential food grains from abroad. It was stated recently that more than Rs. 600/- million worth of wheat alone was imported with U.S. PL 480 loan. The Planning Commission from the begining of the first plan wanted to boost industrial production to increase the wealth of the nation. The industrial wealth thus created would increase the credit in the world market to pay for all the imports for national development including food. Apparently this would only enhance the prospect of about one-fourth non-agricultural population depending on industry. This proposition unfortunately did not work satisfactorily and the country was plunged into debts for supplies of essential food grains which resulted in scarcity, rising prices and inflation. The policy for industrial production was pursued with greater emphasis and agricultural improvement was not seriously thought of assuming that allocation of more funds in the plan budgets would boom agricultural productivity. The net outcome of the policy adopted was only marginal increase in production but not commensurate with the need of the country. This is evident from the estimates made in the ICAR Agricultural year book . Taking the base production of 90 million tonnes of total food grains at the begining of the fourth plan the production with intensive cultivation and use of traditional varieties would be additional 19 million tonnes making a total of 109 million tonnes by the end of the fourth plan period. As against this the estimated demand by the end of the fourth plan according to planning commission would be 120 million tonnes. This would mean that with the existing technology such an increase was not possible. The average yield of rice rose by 20 per cent and wheat 13 percent from the first plan to the end of the third plan, while population rose by 37 per cent during the period. Thus our strategy for agricultural productivity was not adequate enough to cope with the rising demand for food grains and other products. Research programme in the initial plan periods after independence did not create much enthusiasm as there was no innovation in the application of scientific technology. Breeding of varieties was continued without new Science and lacked coordination with other disciplines; as a result there were large number of varieties but seldom reaching the desired goal of higher yield potential or resistance against pest and adverse environments. It may be mentioned that rice research is in progress in this country for more than 5 decades; but suitable high-yielding varieties were evolved after 1960 when different disciplines of Agricultural Sciences collaborated at the International Rice Research Institute, Philippines. The major contributing factors for high yield potentials are optimum utilisation of solar energy, high photosynthetic efficiency ensured from the position and shape of leaf, leaf age, dwarf habit resisting lodging and deep penetrating root system, This gave the Indian rice breeding the guideline to evolve high-yielding varieties which are now being bred in the country. One would expect that this lead should have come from India which is traditionally a rice-growing region with a strong research organisation.

Since the introduction of high-yielding varieties from 1960 onward wheat production has considerably increased; the country is in the way of self-sufficiency and the scope for export is visualised; this is all due to supply of irrigation, essential inputs including pesticides and application of modern farm technology. In the productivity of rice we are still far from attaining self-sufficiency. According to the estimation of National Commission of Agriculture average yield of rice is 1.8 tonnes while in Japan and Taiwan it is 5 to 6 tonnes per hectare. We are to take the effective steps; what scientific knowledge is needed to improve the productivity? Assuming that proper land managements, adequate fertilisers, pesticides, timely water resources are available how we can act on the relation of climatic factors that greatly affect the yield potentials of the crop. Because of peculiar situations rice growing regions in India face very diverse climate from abundance of rain and low temperature to periodic drought and high temperature prevailing during grain formation. Depending on the climatic influence photosynthetic process, flowering and filling of grains are crucial in the yield of rice. The analysis of climatic factors indicates greater yields are obtained not due to use of fertilisers alone or varieties but in warm temperate regions having temperature below 15°C and longer days with bright sunlight. Rice growing *kharif* season in most parts of India generally lacks the ideal conditions; higher temperature and absence of bright sunlight due to cloudy sky affect photosynthesis; consequently yield is reduced inspite of monsoon rains.

The approach for the utilisation of solar energy for the productivity of crop plants in India is very meagre. The survey in the photosynthetic productivity in different parts of Japan have adduced evidence for the marked effects of climatic variations on growth and economic yield. The regional differences in productivity have been made clear by prevailing temperature and solar radiation specific to each locality. The variations in the grain yield with years and regions could be explained by a regression equation composed of two factors; one, the total dry weight at ear emergence which in turn is determined by the summation of mean temperature and solar radiation from transplanting to ear emergence and the other, the average radiation during the grain filling period. This was also indicated from the fact that the net utilisation of solar energy is variable between different growth stages, years as well as varieties. The maximum value of solar energy utilisation is noticed with maximum leaf area index at the vegetative growth stages while with net assimilation rate in reproductive stage. In general the dry matter production in the vegetative phase is mostly affected by the summation of maximum temperature and the period of grain filling by solar radiation. Thus the crux of Japanese rice production programme has centered around the climatic influence at different locations with varietal reactions with optimum agronomic techniques.

Informations on the lines of the survey carried out by the Japanese International Biological Programme are lacking for rice cultivations in India; yet some significant results have been reported by the speaker and his associates from a comprehensive study on the photosynthetic process of different varieties under varying levels of fertilisers and climatic conditions and their implications on grain yield. The problem was approached by studying the photosynthetic efficiency of several varieties in wet (*Kharif*) and dry (*Rabi*) seasons and its impact on the components of yield potentials of different varieties. The difference in the wet and dry seasons is characterised by solar energy incident on the leaf surface at various growth phases resulting variations in the production of dry matter. The incidence of sunlight on the leaf surface of the dwarf type of the plant is larger because of the erect leaf which receives directly more light than tall varieties having spreading longer and broader leaves shading the lower ones. Such differences in the light interruption varied between the different growth phases. The most active photosynthetic period is when the plant produces tillering and initiates flowering. In dwarf varieties such differences between the dry and wet seasons vary from 16 to 36 per cent in the wet season. This results lower assimilation rate with reduced grain yield in monsoon.

In order to increase the productivity it is essential to enlarge the availability and more effective use of solar energy after flowering. This can be achieved by adjusting the flowering time so that grain formation takes place within the period of optimum solar radiation. The significance of photosensitivity of winter rice flowering twice a year according to available day length is largely felt on the productivity and higher yield potentials of rice. In addition to higher photosynthetic efficiency rice cultivation in *Rabi* or dry season is more conducive to greater yield prospect, because the photosensitive winter rice has a shorter growth duration with flowering in the first week of April making the land available for double cropping while the photosynthetic dwarf varieties are thermo-sensitive and take longer time for harvesting in the *Rabi* season. Another aspect of photosynthetic productivity that is recently brought out is the utilisation of photosynthate in the formations and filling of grains. The yield potentials depend on the dry matter production during 30 days after flowering and transport of the matter to the ripening grains. The higher-yielding dwarf varieties transport more than 67 to 83 per cent photosynthate while tall local varieties translocate 31 to 54 per cent dry matter to the ripening grains. An important physiological peculiarity of rice is noticed in the loss of storage carbohydrate in light by photorespiration which takes place in addition to normal respiration. In this process total dry matter is lost which otherwise could have been added to increase the grain yield. The presence of light of different wavelengths induced respiratory loss of dry matter more than 200 per cent from the rice seedlings in comparison to normal respiration in dark, Claims have been made that by controlling or reducing photorespiration the grain yield could be increased more than 50 per cent in cereals. This requires further investigation into the problem to reduce photorespiration by breeding or use of suitable chemicals.

Indian population suffers to a great extent from malnutrition due to shortage of proteins. Estimations by Food and Agriculture Organisation (FAO) show one out of every two takes inadequate quantities of proteins, fats and vitamins. Unlike the developed countries were most of the protein supply is met from animal products It will not be feasible to feed the entire Indian people with required amount of proteins from animal sources. For the supply of milk protein alone 10 million hectares of land will be needed for fodder cultivation with improved varieties and balanced fertilisers; such large tracts of land will not be available to add for fodder cultivation. This brings in the question how we can increase the protein quality and quantity from plant sources which can be grown throughout the year having enough sunshine and equitable temperature. It has also been highlighted by FAO that in future with increasing population and restricted supply of protein from animal sources cereals will continue to be the larger source of proteins for human consumption. Estimates by various experts show that the yields per acre of plant protein for direct human consumption are 5 to 10 times more than those of animal protein. Yields of plant proteins from pulses, nuts and leafy vegetables are 300 to 1000 Ibs per acre against 40 to 55 Ibs per acre of meat protein. Protein yield from vegetables on a given piece of land can be 11 to 28 times as high as for meat raised on the same piece of land. This would show that animal protein is more expensive and the conversion of plant protein to meat production is wasteful, time-consuming to produce and involves loss of vitamins.

There is one difficulty in plant proteins lacking in essential amino acids of high biological value like lysine and methionine etc. In recent breeding and genetical studies the possibility of increasing the contents of these amino acids have been explored. Rice protein is of good quality but the average protein value is only 7 to 8 percent. At the Rice Research Institutes in India and elsewhere the scope for a suitable strain having 10 to 13.5 percent protein have been indicated. A wide survey in North Eastern India has shown suitable varieties having 15 to 17 percent but with low yield potentials. This would mean that proper mutation breeding may be of particular value of having a desirable combination of high protein content and good milling quality with high yield potentials. Both these desirable characters are largely controlled by environmental factors and their influence on photosynthetic efficiency and nitrogen metabolism will have to be studied in close cooperation between different disciplines of plant science.

Our protein is mainly obtained from pulses, cereals and nuts; there is enough scope to increase protein supply from pulses by researches in plant sciences. We are very much in short supply of pulse crops, no serious efforts were made to increase productivity of pulse crops in India. Our production in around 23 million acres has been lying stagnant between 10-13 million tones during the last 4/5 plan periods, not adequate enough to provide enough protein to our poor people whose main supply of protein is from pulses. It is to be admitted that efforts similar to wheat revolution have not been made with impoved varieties although we know that unlike other food grains pulses can not be imported in large quantities from other countries. The cultivation of pulse crop has an additional advantage of enriching the soil nitrogen by symbiotic fixation of atmospheric nitrogen. There is enough scope to enlarge our research programme in both these aspects. Biological fixation of atmospheric nitrogen by legumes and other non-symbiotic processes have been the main source of nitrogen economy of many countries. This has the advantage that the input of nitrogen into the plant system by biological fixation causes less pollution problem than industrial fertilisers which increases nitrate nitrogen in drainage water. Many developed countries are now thinking in terms of having a proper balance of biological nitrogen fixation and industrial sources of fixed nitrogen.

One of the basic problems we should undertake in our legume research programme is sorting out different rhizobial strains and selecting those which appear to fix nitrogen most effectively in local environmental conditions. The basic biochemistry of nitrogen fixation under tropical conditions should be studied to gain knowledge for the control mechanism of fixation which can be explored for practical purpose. Research programme should also be directed to find out suitable plant type of legumes combining high efficiency of nitrogen fixation and protein synthesis using photosynthesis of the leaves. Since the legumes are generally grown in *Rabi* season with availability of bright sunlight the problem will be to study mobilisation of large photosynthates from leaves to the pods. What are the factors associated with the speedy transport to the ripening pods? One interesting feature will be to investigate the possibility of increasing the size of pods and number of seeds per pod so as to facilitate the movement of proteins and other dry matters to the developing pods and increase productivity. Another feature to investigate is whether it is feasible to induce formation of more flower buds at the axils of the branches which will finally produce more seeds loaded with protein.

An exciting field in Biology for research and development is the control system; we envisage two such systems in plant life; one mediated through genes and nucleic acids and the other is the hormonal level in different organs controlling growth and reproduction. In the former a large number of our scientists have crowded to manipulate control and expression of plant characters for major achievements in agriculture through genetics and breeding by mutagens but the most promising line is genetic engineering which involves the transfer of genes from one species to another. Some of the important objectives of genetic engineering will be to eliminate malnutrition by building more proteins into plants which typically do not have, and in transferring the nitrogen fixing capacity of blue-green algal cells or bacteria to the chloroplast of cereals like rice, wheat etc to eliminate or reduce the use of nitrogen fertilisers. This will involve a large exploratory work in the culture of cells and cell free structures in suitable media.

The hormonal control system in plant life processes have been extensively studied during the last 50 years or so and the science of plant endocrinology has been visualised with the fundamental difference from animal hormone in the formation of plant hormone not from a specific gland but from any living cell. Evidences have been presented showing exogenous applications of chemicals similar in structure to endogenous hormonal compounds result large stimulation of growth and development. There are many practical applications of these phenomena, most rewarding is the large number of herbicides developed on the selective basis of hormonal effect on growth. Control of physiological processes by hormones opens a vast field of study enabling us to regulate growth and productivity of plants by chemicals. By such manipulation whether we can control or induce early flowering and fruiting to avoid adverse weather conditions, accelerate and increase production. Evidences are there to show useful practical application of hormone research in horticulture and agriculture particularly seedless large grapes, double cropping or biennial bearing in mangoes and increased output of fibre and rubber. Most of the hormones are synthesised in the laboratory but gibbrellins are yet to be synthesised. While naturally-occurring gibbrellins particularly from water hyacinth have been found promising for the increased production of fibre of jute and growth of leafy shoots. A promising field or research lies ahead in the rural sector on the naturally-occurring hormones and their implication for growth and productivity of tropical plants. The synthetic chemicals used for regulating plant growth cause soil pollution and are hazardous for human health tiom the edible parts. Accordingly use of naturally-occurring growth substances has been advocated for agricultural operations in the developed countries.

RURAL DEVELOPMENT

Agriculture is the mainstay for our villagers; increase in agricultural productivity is essential for rural economy for which research in the new perspective is all that we visualise towards self-sufficiency in food, export, of farm products and agriculture-oriented jobs for the rural people. Some of the research problems have been discussed before. One may also feel that our agricultural research is generally urban-oriented in the sense researchers are confined to laboratories located in the urban areas and seldom have contact with the rural people, their problems and the peculiarities of the plants that need attention. Survey of the useful plants for fodder, timber, indigenous medicinal products and industrial raw materials and their preservation from wanton destruction should be the job of the scientists in cooperation with the villagers. By keeping contact with the rural people and living in the villages our agricultural scientists will be in a better position to advise and improve farming and village uplift work. Our farmers have long practical experience for their research and development work. An important event for my research career may be traced to the rural life I spent for completing high school. While walking along the paddy field to attend the school 3 miles away I used to notice a few of the ears of rice remaining sterile empty and others being full of ripe grains. This led me to think why this discrepancy; similarly very rapid multiplication of water hyacinth without flowers and seeds in ponds or shallow water beds made us thinking how this growth is possible. These observations in the village life somehow involved me in future research programme on the physiology of the rice plant and growth hormones for about four decades.

Since independence the Government have been taking steps to ameliorate the sufferings of the rural people by small-scale cottage industry; but not very significant improvement of the situation has been made. This is presumably due to the fact that the village people were allured for urban industrialisation with employment of large labour on better wages. The big capital made available for industries adversely affected agriculture and ancillary rural industries by exodus of trained labour from villages. In addition the people educated in cities did not return to villages for jobs or initiating any new enterprise or business for the prosperity of the rural area. The result was continued depletion of the educated intelligensia and neglect of the village prospect. This has been made more so after independence. The Prime Minister in his broadcast to the nation stressed that "we must reverse the process of villagers coming to cities in search of labour and employment. Instead, it is the town folk who must go to the village for an open life, combining it with service to the people and making their contribution to economic build up and prosperity of rural areas, and through it, that of the country."

The village economy does not depend on agricultural productivity alone. According to National Commission on Agriculture at least 30 percent of the village labour will need jobs in rural industries. The agro-base industries in the village have not been given sufficient impetus to progress along with agriculture. Handloom and small-scale cottage industries have languished for lack of modern techniques for improving the productive capacity and marketing facilities. The greatest drawback in the development of rural industries are absence of infrastructure in the village. It is rather unfortunate that even after 30 years of independence we have not been able to provide good drinking water to all our villages; absence of required irrigation in more than 50 percent cropped area leads to gambling by farmers for rains for assured productivity; lack of good roads makes communication difficult for taking effective measures in the uplift of villages; more than 70 percent people live in mud houses which are liable to be damaged by fire and rains. The source of energy is very limited from the local fuel supply of cowdung and firewood which are inadequate, Not more than 25 per cent villages are provided with electricity which is essential in modern times to run the machines. The scheme for rural health centres has not been functioning satisfactorily due to absence of these infrastructures. The Government have now given special attention to remove these lacuna in the villages and in improve on the living condition of the people. Big industrial concerns have been requested by the Government to start industries in rural areas to relieve exodus of villagers to towns for which necessary provision of funds for infrastructures have been made by the Planning Commission. It is now for the industrialists to come forward with their plans for the villagers so that both agriculture and rural industry can develop side by side.

In order to meet the technical personnel for the industries that will be set up in the villages it is expected that the new orientation of secondary and vocational education will equip the rural people with adequate training for employment in the industries, I have discussed at length the need for basic Science education for our students in the secondary school stage so that they are qualified for appropriate training in Industries and agriculture. It is to be emphasised that with our efforts to remove illiteracy in the rural areas Science education up to the secondary school should be the essential part of our objective for formal or non-formal education. The distinction is focussed on the basis of which the pupil of the former category will follow the usual path of higher education through different grades of examinations at the universities and institutes while in the latter we include those who are not for any regular course of schooling but have their own training from traditional experience handed over from generation to generation. The skill and training thus acquired in the village life is a great assel for development. This sort of non-formal education essential for rural development will do well if in their profession of rural industries they are initially given Science education at least up to class VIII standard as the Govt. has assured the prospect of universal free education to all citizens of the country.

Amongst several agro-base industries silk industry is an important one which can provide employment to both men in the field and women in the house. It is estimated by Central Silk Board to provide livelihood is additional 7 lakh people of scheduled and backward classes and tribes which could hardly be covered by any other medium-or large-size industry. Economic footing of this industry is much more firm than other rural industries. The comparative statements made by the Central Silk Board and the Government of India show that with improvement of cultivation of mulberry and silk rearing practices, the net profit will lie around Rs. 8300/- per hectare of cultivation and this combined with silk worm rearing will reach a figure of Rs. 18750/- against Rs. 6795/- per hectare for cultivation of wheat, rice and jute. In addition the employment potentials show more than twice the number of persons who could find jobs for the cultivation of the crop. If we are to take the full advantage of the scope of this industry our efforts should be to increasing the productivity of silk which can be done in two ways; firstly by increasing the productivity per unit area; secondly by putting more area under mulberry cultivation. It is not possible to release more area for the cultivation; hence the only alternative is to increase the production of silk per unit area for which there are several methods of improving the cultivation of plant and rearing of the silkworm free from pests and diseases. Japan produces 125 kg of silk through 2 crops a year while in India through 4 crops only 25 kg per hectare are produced. It is desirable that we should aim at improving our silk technology on the lines obtaining in Japan since we have enough labour to intensify our efforts to reach a dominant position in silk production which has now declined from third to fifth in the world. We should practice intensive farming, breeding better varieties, improved cultivation methods, proper management of soil and fertiliser, economic feeding of the silkworm with good supply of nutritious diet, marketing facilities, and rearing methods. These are some of the important considerations for increasing the production of silk in the country; it is expected that in course of time the efforts spent on this will increase the employment potential of the rural people as well as earn large foreign exchange as Indian Silk has a traditionally good world market.

In 1974 the Department of Science & Technology, Government of India established a separate set-up for rural development which is expected to deal with different problems of village industry, health, family welfare and also coordinate the progress made in the village uplift work in 20 districts in different parts of the country. It will also collaborate with the similar nature of work in other organisations like ICAR, CSIR, ICMR etc. Rural industry projects have also been started in 41 backward districts. The main objective of this is to train the agricultural labourers, village artisans in carpentry, black smithy, use of tractors, pump sets and diesel engines etc. This will enable the village labour to gain efficiency in modern technology for agriculture and small-scale cottage industry. These projects have been started late; it is expected that in course of time they will considerably add to the welfare of the rural people. The Indian Council of Agricultural Research through Krishi Vigyan Kendra (Farm Science Centres) and Agro-Industries Corporation have been taking active part in rural development by giving training to villagers in the use of manures, implements and good qualities of seed. The training is for skill and craft-oriented mainly for self-employment under the auspices of the rural artisans programme.

Several other organisations like Gujrat Vidyapith, Gandhigram Rural Institutes and Lok Bharati have been taking active interest in rural development. The University of Bombay has recently decided to introduce courses on this in the new 3 years degree in arts, Science or commerce faculties as a set of optional papers in lieu of usual discipline-wise based papers. There has also been National Service Scheme in the university which enables the students to have experience in living in the village and participation in some rural activities. Similar other approaches for introducing graduate courses in relation to environmental Biology, Chemistry or Physics have been planned in the universities of Bombay as well as in South Gujrat and Madras. All these would indicate our rethinking in organising the courses of study that will be useful for rural development programme.

THE DEADLY METALS : SOME REMOVAL TECHNOLOGIES FROM DRINKING WATER

Amrita Singh

The presence of heavy metals in water has become a worldwide problem in the past decades. Many of the heavy metals are known to be poisonous even at low concentrations. Toxic heavy metals such as cadmium, chromium, lead, manganese, arsenic etc. are among the major contaminants in drinking water. Safe drinking water is the most sensitive issue for survival of a living habitat. This article concerns the application of different technologies for heavy metals removal from drinking water.

INTRODUCTION

Among the basic needs of human beings, water is required for drinking, bathing, washing, cooking, gardening, irrigation, industries and navigation and for body contact sports as swimming, water skating and fishing. Among all these needs, drinking gets the first priority. Normally if water is fit for drinking, it will be suitable for all other purposes. An adult human body holds about 35 to 50 liters of water, out of which 2.5 to 2.8 liters is lost in the form of urine as well as sweating. The human blood consists of 83 percent of water, muscles contain 75 percent of water and bones contain 22 percent of water. Almost three-quarters of the earth's surface are covered with water, of which 97.2% is sea or brackish water unsuitable for human use, 2.8% is fresh water. The greatest part of the fresh water is contained in ice caps or glaciers (2%), deep inside the earth as groundwater (0.6%), on ground as rivers and lakes (0.017%) and in atmosphere as ice and water vapour (0.001%). In India more than 225 million people have no access to safe drinking water. Water pollution is a serious problem in India as almost 70% of its surface water resources and a growing numbers of its groundwater reserves are already contaminated by biological, organic and inorganic pollutants. In many cases, these sources have been rendered unsafe for human consumption. The supply of safe potable water has a significant impact on the prevention of water-transmissible diseases. The abundance of organic compounds, toxic metals, radio-nuclides, nitrites and nitrates in potable water may cause adverse effects on human health. Heavy metals are a key component of modern civilization. They play an important role in all branches of our life, agriculture, engineering, science, architecture, and medicine. The bioaccumulation of toxic heavy metals in the food chain can be highly dangerous to human health due to their persistent nature and potential toxicity. They can neither be created or destroyed nor can one heavy metal be transformed into another i.e. they are immutable. Heavy metals are those whose density is greater than $5 g/cm^3$. They are normally regarded as ones having an atomic number of 22 to 92, In excessive quantities they are poisonous and cause death of living organisms.

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TOXIC METALS AND HUMAN HEALTH

Viewed from the standpoint of environmental pollution, metals may be classified according to three criteria (a) noncritical i.e. Na, K, Mg, Ca, F, Al, Si etc. (b) toxic but very insoluble or very rare i.e. Ti, Re, Ga, Os, Ba etc. and (c) very toxic and relatively accessible i.e. Be, Co, Zn, Sn, As, Pd, Ag, Cd, Hg, Pb, Bi etc. Some of the heavy metals such as cobalt, chromium, copper, iron, manganese, selenium, molybdenum and zinc are believed to be essential for human health. However, all are probably toxic if ingested in sufficient amount. Non-essential metals, particularly mercury, cadmium and lead are extremely toxic at relatively low concentrations.

Mercury is strictly a poison, having a serious neurophysiological effect when present in the methyl mercury form. Many salts of mercury such as mercuric chloride and organic compounds of mercury are acutely toxic and can even cause death. The "Minamata disease" was caused by the consumption of mercury-contaminated fish taken by fishermen and their families from Minamata Bay in Japan. The patients who had consumed fish and shellfish progressively suffered from a weakening of muscles, loss of vision, impairment of cerebral functions and eventual paralysis which in numerous cases resulted in coma and death[1]. Cadmium can cause damage to the kidneys, lungs and bones. In acute exposure, death may occur. During 1947 an unusual and painful disease of a "rheumatic nature" (itai-itai disease meaning "ouch-ouch") was recorded on the banks of the Jintsu River from Japan caused by chronic cadmium poisoning. The toxicity of lead has been known to man from Biblical times. Plumbism, a disease caused by acute lead poisoning, has been known for centuries. Lead can cause brain damage, disorders of central nervous system, anemia and serious behavioural problems. Lead plumbing may become a major source of lead uptake by people living in soft water areas (low in calcium concentration). Young children who live in dilapidated buildings are exposed to acute lead poisoning because of the habit of eating nonfood substances such as lead containing peeling paint, putty, and plaster. The word arsenic is virtually synonymous with poison. All compounds of arsenic are toxic, Trivalent arsenic is 60 times more toxic to human beings than pentavalent forms. There is sufficient evidence from human epidemiologic studies linking increased mortality from liver, kidney, bladder and lung cancers to drinking arsenic-contaminated water[2]. Manganese is a known mutagen. The accumulation of Mn may cause hepatic encephalopathy. Moreover, the chronic ingestion of Mn in drinking water is associated with neurologic damages[3]. The occupational risks due to chromium salts are well known. Hexavalent chromium is 100 times more toxic than trivalent forms. WHO states that 0.05mg/l drinking water guideline for total Cr is unlikely to cause significant health risk.

CONVENTIONAL METHODS OF HEAVY METALS REMOVAL FROM DRINKING WATER

Coagulation, Flocculation and Filtration

Coagulation is the destabilization of colloids by neutralizing the forces that keep them apart, Cationic coagulants provide positive electric charges to reduce the negative charge of the colloids. As a result, the particles collide to form larger particles. Flocculation is the action of polymers to form bridges between the larger mass particles and bind the particles into large clumps. The conventional removal of inorganic Hg, Ba(II), Se(IV) Se(VI), As(III) and As(V) from drinking water has been reported by Fe coagulation, Al coagulation, lime softening, and high lime treatment. Iron flocculation reduces the arsenic, copper and lead levels in drinking water. Aluminum flocculation reduces the zinc, lead and manganese concentration in drinking water. For the arsenic removal, ferric chloride and ferric sulphate are used as coagulants which remove most successfully arsenic from drinking water. Filtration through a bed of granular media such as sand or coal is employed for removal of precipitated compounds from lime softened water and precipitated iron or magnesium in drinking water. However, the problems with this technique are the safe separation, filtration, and the handling and disposal of the contaminated sludge.

Activated Carbon Adsorption

Activated carbon was formerly used for dechlorination purposes and removal of organic colour, taste and odour. Now it plays a large role in the elimination of the dissolved organic substances. It is a crude form of graphite with a random or amorphous highly porous structure with a broad range of pore sizes, from visible cracks and crevices, to crevices of molecular dimensions. Activated carbons have been prepared from coconut shells, wood char, rice hulls, wheat straw, jute stick, tea leaves, graphite etc. Physical adsorption is caused by Van der Waals forces and electrostatic forces between adsorbate molecules and the atoms which compose the adsorbent surface. Adsorption capacity depends on activated carbon properties, adsorbate chemical properties (polarity, functional groups and solubility), temperature, pH, ionic strength etc. The carbon contains noncarbon impurities as oxygen and sulfur. The oxygen and sulfur content of the carbon depend upon the temperature, impurities in the base material and upon the method of activation. Oxygen forms surface oxides and sulfur leads to the formation of sulfide groups at the carbon surface. Both attract heavy metals from the solution. The carbon surface also provides nucleation sites for the precipitation of metals from solution. However, the high prices and regeneration cost of activated carbon limits their large scale use for the removal of inorganic and organic pollutants.

Ion Exchange

Ion exchange is a physical or chemical process in which ions are held electrostatically on the surface of a solid phase. It is a reversible interchange where there is no permanent change in the structure of the solid. The solid phase can be a natural zeolite or a synthetic resin consisting of a cross-linked polymeric network with charged functional groups. At present, there are more than 30 natural zeolites known. They attract oppositely charged ionic species and retain them by electrostatic forces. The relative affinity of resin for opposite charged ionic species depends upon the specific ionic charge, the hydrated ionic radius, the concentration in solution, the degree of resin cross-linking and the nature of the functional group(i.e. sulfonic, phosphonic or carbonic acid groups) on the resin. The cation exchange resins remove divalent Ca(II) and Mg(II) ions and Cd(II), Zn(II), Ag(I) etc. while, anion exchange resins exhibit an affinity for the common hydrogencarbonate, sulfate, chloride as well as hydrogenarsenate, selenite, hydrogenchromate. Copper, lead, mercury and nickel have also been successfully treated by cation exchange. In arsenic removal from drinking water sulphate, selenium, fluoride and nitrate compete with arsenic and can affect the removal process. So the low selectivity in the presence of other competing anions has made this process less attractive. Due to its higher treatment cost compared to conventional treatment technologies, ion exchange application is limited primarily to small-to-medium-scale.

Bioadsorbents

Bioadsorption is a passive immobilization of metals by biomass. Bioadsorption is capable of removing traces of heavy metals from water. Algae, fungi and bacteria are examples of biomass-derived sorbents for several metals. The cell wall of microorganism mainly consists of polysaccharides, lipids and proteins, which have many binding sites for metals. This process is independent of cell metabolism. They are based upon physicochemical interactions between metals and functional groups of the cell wall. The fungus *Penicillium purpurogenum* used as bioadsorbents for cadmium, lead, mercury and arsenic ion in water[4]. Heavy metal loading capacity increased with increasing pH under acidic conditions. The tea fungus, a waste produced during black tea fermentation, has capacity to sequester the metal ions from water. *Lessonia nigrescens,* an alga is utilized for arsenic (V) removal from water[5]. Dried plants are natural materials widely available and used as an alternative adsorbent for different heavy metals. The proposed plant leaves efficient in removing metal ions from water are reed for cadmium, poplar for lead and copper, cinchona for copper and lead, pine for cadmium and nickel. Jute stick and leaf powder, lily leaf powder and water hyacinth powder also mitigate the arsenic from drinking water[6]. Chitosan is produced from chitin used as bioadsorbent for heavy metal. It is found in the exoskeleton of Crustacea shellfish, shrimp, crabs, insects etc[7]. It is most widely occurring natural carbohydrate polymer next to cellulose. Chitosan is an excellent natural adsorbent for all heavy metals.

Low-cost Adsorbents

Numerous low-cost adsorbents have so far been studied for the removal of heavy metals from water. Clay minerals are hydrous aluminum, silicates, sometimes with minor amounts of iron, magnesium and other cations. The typical clay minerals are kaolinite, illite and montmorillionite. They adsorb the cationic, anionic and neutral metal species. They can also take part in the cation and anion exchange processes. Maple wood ash without any chemical treatment is utilized to remediate arsenite and arsenate from contaminated water. A low-cost ferruginous manganese ore can remove both As (III) and As (V) from groundwater without any pretreatment in the pH range of 2-8. Biochar by-products from fast wood and bark (oak and pine) pyrolysis are used to remove the As (III), Cd (II) and Pb (II) from water. Red mud is a ferric hydroxide material used to develop effective adsorbents to remove arsenic from water. It is pH dependent adsorption. Arsenate removal at pH 4 was reported higher than that at pH 7 or 10 by using fly ash collected from coal power stations[8].

CONCLUSION

During the last decades, treatment of metal contaminated water has become more and more important and today, sophisticated technology can bring new advances in this field. Water can have many type of contaminants and the quality of water varies from place to place. Therefore, there is no universal water treatment technology or process which is the best and can take care of all metal removal from water. The solution depends upon the quality of the water available which tends to vary from location to location. The low-cost adsorbents and at the same time natural adsorbents can be viable alternatives for the removal of heavy metals from drinking water.

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CO_2 SEQUESTRATION AND EARTH PROCESSES

Malti Goel

This article deals with the emerging topic of CO_2 Sequestration, which is among the advanced energy technologies. CO_2 Sequestration is being discussed in national and international forum and is of particular importance to coal based economies. Various earth processes for permanent fixation of CO_2 away from atmosphere are discussed in details.

1. INTRODUCTION

Capturing carbon dioxide is an end-of-pipe solution for pollution mitigation in fossil fuel based energy systems. Significant strides are being made in understanding carbon capture and storage CO_2 Sequestration in fossil fuel based economies. The CO_2 Sequestration involves capture of excess CO_2 from its point sources and its permanent fixation away from the atmosphere. The various techniques of CO_2 capture are derived from gas separation techniques, which include chemical absorption, membrane separation, physical adsorption, and cryogenic separation at source[1]. Captured CO_2 is then sequestrated by means of surface processes, by sub surface storage and/or by recovery of energy fuels & minerals. If the source and the underground fixation sites are not near to each other, transport of CO_2 in liquid form over longer distances is required. To achieve a carbon balance in the atmosphere in an enhanced CO_2 scenario, Science & Technology gaps exist in CO_2 capture processes and materials as well as site specific models for its fixation[2,3].

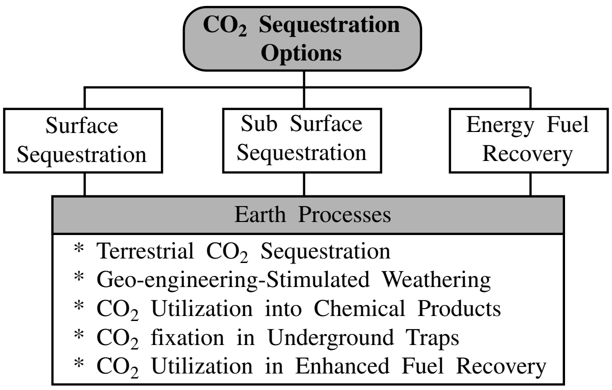

Fig. 1. The CO_2 Sequestration options

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2. EARTH PROCESSES

Development of technologies for quantifying carbon stored in a given ecosystem and manipulation of ecosystem to increase the carbon sequestration rate beyond current conditions requires modeling research[4]. Whereas, earth processes in surface and subsurface for CO_2 Sequestration can be understood as follows :

2.1 CO_2 Fixation in Terrestrial Ecosystems

The terrestrial sequestration approach is having significant potential for terrestrial sequestration i.e., plant & soil sequestration, microbial and micro-algae fixation to stabilize atmospheric concentration of CO_2.

2.1.1 Plants and Soil

The terrestrial biosphere is capable of sequestering large amount of carbon dioxide. Plants absorb CO_2 in the photosynthesis process. Carbon assimilation occurs in forests, trees, crops and soil and these are CO_2 sinks. Terrestrial CO_2 storage can lead to afforestation in forest areas and can enhance crop productivity in rural areas. Advanced crop species and cultivation practices could be designed to increase the uptake of CO_2 through an enhanced photosynthesis rate.

The primary ways that carbon is stored in plants or in the soil as soil organic matter (SOM), which is a complex mixture of carbon compounds, consisting of decomposing plant and animal tissue, microbes (protozoa, nematodes, fungi, and bacteria) and carbon associated with soil minerals. Soils contain three times more carbon than the amount stored in living plants and animals.

It is estimated that increasing the soil organic carbon (SOC) by 0.01 per cent could nullify the annual increase in atmospheric carbon due to anthropogenic CO_2 emissions. The soil carbon pool and emissions of CO_2 are also influenced by vegetation types and local environmental factors[5, 6]. Enhanced CO_2 absorption rate in vegetation and cropland can lead to active storage whereas in wetlands, mined or un-mined forest sites and highway construction sites it can be a form of passive storage. Development of techniques for enhanced absorption of CO_2 while using least forest area and to understand the feedback mechanisms with a view to undertake agro-forestry modeling are needed.

2.1.2 Bio Sequestration

A further biological route can be to capture CO_2 from the flue gas using an algae pond in the vicinity of a thermal power plant. Development of algal strains with high productivity appears to be the most cost-effective solution with value addition. But the greatest challenge is to isolate algae and genetically improve algal strain for both higher oil content and overall productivity. Marine algae forms a possible solution for thermal power plants situated along the sea coast. Enhanced biological CO_2 capture has become possible by designing photo-bio reactors. Controlled micro organism activation methods using photo bio reactors are under development as biofixation option of CO_2. Solar bioreactors have been proposed for warm and sunny climatic regions. Bio-mimetic approaches using immobilized carbonic anhydrase are being studied in bioreactors for assessing CO_2 sequestration potential.

Further studies of carbon concentrating mechanisms in photoautotrophic organisms and non-photosynthetic organisms, standardization and creation of data bank can potentially lead to the development of cost-effective large scale operation of CO_2 sequestration[7].

2.2 Geo-engineering - Stimulated Weathering

Mafic and Ultramafic rock minerals, olivine, pyroxene and anorthite are present in large quantities in the subsurface environment. These minerals play an important role in the natural *carbon cycle.* Natural weathering occurs over geological time scales. Accelerating the natural process of CO_2 absorption by enhanced mineralization of olivine/ silicate rocks offers another potentially low cost solution for CO_2 sequestration[8]. The effects of CO_2 fugacity and salinity on the kinetics of diffusion of CO_2 into olivine have been investigated. Several studies have been made to study mineral reactivity, energy balance, intense grinding in presence of gaseous CO_2 and dynamics of CO_2 in pores. Accelerated rate of precipitation of mineral carbonate with industrial wastewater as a cation source has been demonstrated[9] in presence of a catalyst.

Silicates and compounds of magnesium and iron are present in small quantities in mineral industry waste. By using the geo-engineering approach for stimulated weathering of mining and industrial wastes, it is possible to sequester excess CO_2 from the atmosphere. Large scale sequestration by such means requires further and more detailed modeling research and understanding of field processes.

2.3 CO_2 Utilization and Value Added Products

The CO_2 has low chemical activity but it is possible to activate it towards chemical reactions by application of temperature or pressure or by use of catalysts. A variety of chemicals can be produced from CO_2. These can be subdivided into a number of important areas; (i) Synthetic fuel products from CO_2 could be regarded as energy vectors or energy stores, utilizing renewable energy sources at off-peak hours with temporarily stored local CO_2. (ii) By hydrogenation of CO_2 over a wide range of catalysts, synthetic hydrocarbons as transportation fuel can be produced. Hydrogen is required in considerable quantity and selectively to produce a single fraction of commercially vehicular fuels. (iii) Synthesis gas can be produced by reforming reactions, sometimes in multiple steps. One of the benefits of reforming reactions is the simplicity of the catalysts used, including nickel and cobalt catalysts. (iv) The synthesis gas produced can then be used in the transition metal catalyzed Fischer-Tropsch (F-T) synthesis.

Challenge exists to develop not only the F-T process conditions, but also to design new effective and selective catalysts. Use of enzyme carbonic anhydrase has been suggested as most efficient catalyst in CO_2 reaction with water. A pilot plant for multi-fuel generation has been designed and fabricated at Rajiv Gandhi Prodiyiki Vidyalaya, Bhopal[10].

2.4 CO_2 Fixation in Underground Traps

Permanence of storage and no risk from leakage are main safety criteria for sub-surface storage. As a CO_2 plume migrates, some of it may react with formation minerals to precipitate carbonates. When CO_2 reacts with *in-situ* fluids and gels dissolved geo chemical trapping occurs. The CO_2 laden water becomes denser and sinks to bottom. Chemical reactions with rock minerals can lead to formation of solid carbonates minerals. Mineral trapping is more permanent as Silicate minerals are converted to secondary Carbonates. Under suitable conditions of pressure and temperatures, minerals trapping capacity is high. Sequestration potential is high. On the whole, the nature of dissolution, mixing and segregation of CO_2 is dependent on reservoir characteristics and required scientific understanding of local geology[11].

The US Department of Energy has classified eleven major types of reservoirs for knowledge development pathways for CO_2 Sequestration. Each has unique characteristics and requires considerable research on their performance analysis[12]. In the sub-surface CO_2 is normally stored in the supercritical phase, which is attained at the temperature of 304.1K and pressure 73.8 bars. Injection of CO_2 into deep saline aquifers, depleted oil & gas reservoirs, un-mineable coal seams and in basalts has been conceptualized. Physical trapping is expected to occur where there is a good cap rock with a low permeability. Engineered geological traps are also expected to provide a permanent storage for CO_2. Both active and passive underground trapping mechanisms have been studied extensively.

2.4.1 Underground Solution Trapping

CO_2 fixation in deep saline aquifers, both on shore and offshore and are expected to provide the largest storage capacity at below 800m depth. At this depth, CO_2 is in liquid or supercritical state and has density less than water. The buoyant forces tend to drive upwards and therefore good cap rock is essential, in a manner similar to a soda water bottle where CO_2 occupies the space by partially displacing the fluid. In Saline formations, estimates of potential storage volume are low up to 30% of the total rock volume. The storage efficiency would depend on its structure as well as storage strategies and purity of captured CO_2.

2.4.2 Large Scale Stratigraphic Trapping

Upward migration of CO_2 is blocked by the Stratigraphic structure of clay rocks above the storage formation. Lateral migration of CO_2 can also take place beneath the cap rock isolated within anticline structures bound by the shale cap and capillary forces may also retain CO_2 in the pore spaces of the formation.

2.4.3 Mineralogical Trapping

Basalt formations are attractive storage media as ancient hot lava sites. Pacific Northwest National Laboratory (PNNL), USA has identified carbon dioxide sequestration research priorities in flood basalts in the Columbia River region[13]. Field research carried out in these formations suggests that lateral dispersions and vertical transport of CO_2 to overlaying basalt flows are expected to be important limiting factors controlling *in-situ* processes.

Will clay and calcium carbonate precipitation clog the available pore space at the injection site? Considerable further research is needed to understand the kinetics of rapid mineralization reaction rates that may occur in different basalts across the world. The area of Deccan flood basalts in India is estimated to be 0.5 million km^2. Consisting of the thick Mesozoic sediments, its thickness varies from a few hundred m to 1.5 km, it could show accelerated reaction with CO_2 and its conversion into mineral carbonates possibly below sediments. It comprises of reactive Fe-Mg-Ca and Na rich silicon minerals. A preliminary feasibly study in Deccan Volcanic Province has been conducted at National Geophysical Research Laboratory, Hyderabad to study nature of secondary carbonation that takes place upon reaction with CO_2 in supercritical conditions[14].

2.4.4 Residual Gas trapping

Residual gas trapping can occur in a sub-surface reservoir. When free-phase CO_2 migrates, it forms a plume, the CO_2 concentration towards the tail of the plume can get trapped by capillary pressure from the water in the pore spaces between the rocks. Similar to solution trapping CO_2 either forms residual - droplets in the pore or gets dissolved in the formation water. This is how oil was held for millions of years.

2.5 CO_2 Utilization in Recovery of Energy Fuels

An important aspect of carbon sequestration is recovery of value added products. Active underground storage of CO_2 in oil, gas or coal fields for enhanced fuel recovery can provide an economic synergy to CO_2 sequestration process.

2.5.1 Enhanced Oil Recovery (EOR)

The CO_2 has been injected in depleting oil fields for enhanced recovery of oil. Scientific research for testing of storage of anthropogenic CO_2 in EOR has also been carried out depending on the pressure of injection gas into the reservoir. The CO_2 in an oil well can either be in miscible or in immiscible phase. In the miscible phase, injected CO_2 mixes with the viscous crude causing it to swell. It reduces its viscosity in the reservoir causing a flow to produce more oil. In the immiscible phase CO_2 does not dissolve in the crude. It raises the pressure and helps to sweep the oil towards the production well. A combination of both miscible and immiscible phases normally occurs. How much oil is displaced depends on various parameters such as; oil swelling, viscosity reduction, miscibility generation and reduction in residual oil saturation. Relative contribution of various parameters depends on the reservoir conditions as well as crude oil quantity. Dynamic modeling tools are needed to study migration, flow / behavior of stored CO_2 and actual performance prediction for enhanced oil recovery.

2.5.2 Enhanced Coal Bed Methane Recovery (ECBM)

Coal beds have absorption capacity for CO_2 which is two to three times that of methane. Like oil fields, an un-mineable coal seam can also prove to be a potential reservoir for enhanced coal bed methane recovery (ECBM). Physical adsorption of

CO_2 occurs on the internal surface and micro pores in coal beds and replacing methane. The CO_2 remains trapped as long as pressure and temperature remain stable. The absorption isotherms for CO_2 are important. Sorption capacity of coal decreases significantly with increasing temperature. Normally temperature in the range of 12° to 26°C is preferred. High moisture content in coal also decreases sorption capacity. Model predictions suggest that injection of CO_2 can achieve 70-90 percent recovery of CBM as against 40 percent without it. CO_2 storage in coal beds takes place at shallower depth than in Saline and oil reservoirs.

The key parameters which need to be monitored are moisture, ash content of coal, Vitrinite reflectance, temperature and pressure[15]. Mineral matter acts an inert diluting agent in the coal and contributes to gas desorption, therefore the areas of coal having relative low ash yield are more favorable to CO_2 sequestration. Presence of large-scale faults can be harmful as the gas may escape or remain trapped. Further studies are needed for assessing CO_2 Sequestration potential in coal beds are : (i) Coal quality, (ii) Sorption capacity, (iii) Intra-molecular structure of coal, (iv) Hydrodynamics (v) dynamics of CO_2 flow.

3. IMPORTANT LARGE SCALE SEQUESTRATION INITIATIVES

Global field experimentation is being pursued to determine benchmarks. Among the large scale demonstration noteworthy is Weyburn oil fields in Southern Saskatchewan, Canada for enhanced oil recovery. By injecting about 6000 tons of CO_2 per day, a total of 20Mt of CO_2 is expected to be sequestered[16]. During its life, such an operation could produce 122 million barrels of incremental oil, which is about 30 percent enhancement over the recoveries so far. The emphasis is on measuring and monitoring of leakage, risks, etc, to develop a best practice manual for CO_2-EOR.

In Salah in Algeria is another international project of CO_2 Sequestration in depleted gas fields. It is expected that 17Mt of CO_2 could be injected in the gas leg of the reservoir till the project completion in 2020. Since 2004 about 1 Mt of CO_2 has been sequestered per year at a depth of 1800 m in the Krechba reservoir, a geological formation with low permeability sandstone. Scientific monitoring of CO_2 plume inside the well has been developed. Using satellite based Interferometric Synthetic Aperture Radar (InSAR) remote sensing imagery techniques. CO_2 ground movement is being tracked.

The earliest CO_2 storage project has been Sleipner West in Norway, began in 1996 in Norway. The Sleipner reservoir is situated in the Utsira formation comprises a 200-250m thick fluid saturated sandstone formation at a depth of 1,000 metres beneath the seabed. More than 15 million of CO_2 has been injected and images of the CO_2 plume at Sleipner from the time-lapse 3D seismic data have been obtained[16]. The changes in seismic impedance have been monitored from new seismic data produced at regular intervals.

The CO_2 sequestration project at Reykjavik, Iceland aims to study feasibility of permanent storage of CO_2 captured from geothermal waters into basaltic rocks. Located in the vicinity of a geothermal power plant, geochemical modeling of the CO_2 in waters as a natural analogue in CarbFix pilot is expected to throw some light on its feasibility despite limited pores that are present in basalts.

Medium to large-scale field tests for enhanced coal bed methane recovery have been reported in San Juan field of USA, Yubari Iskari coal fields in Japan, Silesian basin in Poland and Fenn Big Valley, Canada. A dual porosity model based on idealization of fracture media is adopted and two phase flow of gas and water has been proposed.

It is worth mentioning the CO_2 Sequestration Initiative, a unique multi-national programme at Pacific Northwest National Laboratory, USA aims to integrate geo-modeling and monitoring studies'[18] for study of sequestration. Having two main components; (i) *in-situ* Supercritical suite IS^3 and (ii) Geological Sequestration Software suit GS^3, IS^3 is an investigative approach to probe geochemical reactions under supercritical pressures and temperatures to study CO_2 geochemistry of the cap rock and injection trapping mechanisms. GS^3 has been designed for modeling of geological sites for sequestration using advanced scientific programming and benchmarking of scientific simulators for different geo-environments.

4. CONCLUSIONS

The CO_2 sequestration is a large-scale infrastructure intensive emerging energy technology for mitigation of climate change. Advancements made in CO_2 sequestration in the surface or subsurface – be it terrestrial plantation or algae or a coal mine or oil reservoir or mineral rocks -are a scientific necessity in developing the knowledge base about its disposal. CO_2 sequestration in the long run can offer an opportunity to recover clean energy fuels only when technology is proven. The studies so far are site specific and need to be evaluated on case to case basis. Considerable additional geological investigation and modeling research would be needed to create a comprehensive data base for effective mapping of various reservoirs and test the efficacy in the long run. Further Geological studies and geo-modeling research is needed to explore and prove technological sustainability.

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AN UNDERSTANDING OF PAIN & FUNCTIONAL IMPAIRMENT AND MANAGEMENT ISSUES IN KNEE OSTEOARTHRITIS

Meenakshi Batra

Knee Osteoarthritis is a degenerative & disabling condition characterized by pain, muscle dysfunction, proprioceptive impairments, neuromuscular incoordination & sensorimotor dysfunctions. It is important to understand the underlying neurophysiological & biomechanical mechanisms contributing to the disease process in order to formulate specific intervention strategy.

INTRODUCTION

Osteoarthritis is a slowly evolving disorder of synovial joints in which a complex combination of degradative and reparative processes alters the anatomy and matrix composition of the articular cartilage and subchondral bone. It affects the hands, feet, spine, and large weight-bearing joints, such as the hips and knees. But the knees joints are most commonly affected.

Osteoarthritis of the knee can affect the main surfaces of knee joint and the cartilage under kneecap (patella). It is characterized by muscle dysfunction [8], proprioceptive impairments, impaired ability to generate force quickly during voluntary muscle contraction, neuromuscular incoordination and reduced functional performance which adversely affects the quality of life. Signs & symptoms range from acute pain to chronic pain typically worse with weight-bearing, swelling, spasm, stiffness, diminished knee range of motion, decreased muscle strength & endurance. In response to pain and stiffness, patients tend to become more sedentary, which further induces muscle atrophy and functional performance limitations [6, 7]. It mainly affects the elderly population but may appear as early as 35 years of age affecting approximately 4 % of the world's current population. As per World Health Organization (WHO) estimates approximately 70 million Indians are its victims.

Knee pain is the most frequently reported peripheral joint complaint in community-based studies worldwide and has been found to be present in 5–13% of adult populations in Asia conducted under the 'Community Oriented Programme for the Control of Rheumatic Diseases' (COPCORD). Its estimated prevalence in India, Thailand, Malaysia is approximately 13.2%, 12.5%, and 9.3%, respectively. The male to female ratio is 8.5%: 12.3%, 2.7%: 6%, and 9.4%: 10.9% for the Indians, Chinese and Malaysia [9].

PATHOPHYSIOLOGICAL CHANGES

The pathophysiology involves a combination of mechanical, cellular, and biochemical changes. These changes can interfere with continued internal remodeling, maintenance of the tissue, and loss of cartilage. This finally results in roughening of the bony surface and osteophytes formation interfering with normal joint movement [4]. These degenerative changes ultimately culminate into abnormal stress loading, altered weight bearing pattern, and gait deviations.

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NEUROPHYSIOLOGY OF KNEE PAIN IN OSTEOARTHRITIS

The Knee pain is a major symptom of knee osteoarthritis and its presence & severity are important determinants of disability. Osteoarthritic pain may originate in several articular or para-articular tissues supplied by sensory nerves [9]. The mechanism for pain production may be irritation of articular nerve endings by chemical substances (such as inflammatory mediators) or mechanical irritation (mechanical overload / abnormal stress loading), neurogenic inflammation or raised intraosseous pressure. This pain sensation is carried via partially Myelinated A delta (d) and Unmyelinated C fibres to the cerebral cortex. In addition, psychological stress, depression & sleep deprivation may amplify pain attributable to local joint condition.

PATHOMECHANICS OF IMPAIRED PROPRIOCEPTIVE ACUITY & ITS FUNCTIONAL CORRELATES

Proprioception plays an integral role in neuromotor control of the knee joint. It relies on accurate sensory input & requires the integration of sensory information from peripheral proprioceptors (i.e. muscle spindles), vision and the vestibular apparatus thereby promoting central integration [1, 4] Therefore factors which adversely affect muscle spindle sensitivity results in impaired proprioceptive acuity & muscle dysfunction [6, 7].

FUNCTIONAL IMPAIRMENTS IN KNEE OSTEOARTHRITIS

Muscle dysfunction in context to knee Osteoarthritis : It has been observed that neuromuscular joint protection requires proprioceptive input and motor output. The quadriceps muscle group weakness or atrophy reduces the amount of protective force generated at the knee joint. In addition, however, if the speed of muscle contraction is also affected and slower, then it will also take longer for protective and stabilizing muscle contraction to occur. The ability to generate force quickly during voluntary muscle contraction is affected in the quadriceps. This knowledge about muscle dysfunction may be useful in understanding the etiology of knee osteoarthritis and clinical decision making process[7].

Postural instability and equilibrium : Severe pain, articular damage, and quadriceps muscle weakness associated with knee osteoarthritis contribute to postural instability, gait deviations and impaired proprioceptive acuity, and decreased capacity to maintain equilibrium under static or dynamic conditions.

MANAGEMENT OF KNEE OSTEO-ARTHRITIS

Management in osteoarthritis can be Nonpharmacological, pharmacological and surgical. The primary goals of treatment are to improve joint function and quality of life. Treatment should be individualized based upon severity of OA and the patient's needs. Education regarding the natural progression of OA is critical to establish realistic patient expectations regarding current treatment modalities.

Non-pharmacologic interventions : It includes exercise, occupational therapy, physical agent modalities, dietary modification, weight reduction and ambulatory assistive devices.

Pharmacological interventions : It begins with analgesics (such as acetaminophen, topical creams and non-steroidal anti-inflammatory drugs (such as ibuprofen, ketoprofen & naproxen) etc.

Surgical interventions : The Patients with osteoarthritis may develop symptoms refractory to nonsurgical management. For these patients there are several options available including arthroscopic joint lavage and debridement, realignment procedures (osteotomy), joint fusion (arthrodesis) and joint replacement (arthroplasty). Current researches has focused heavily on cartilage repair with important advances noted in stimulation of intrinsic repair mechanisms (microfracture), regeneration (autologous chondrocyte implantation), and substitution techniques (osteochondral allograft or autograft plugs). The objectives of these treatments are to obtain pain relief, reduce joint inflammation, restore function and reduce disability.

The management of knee osteoarthritis is quite challenging in order to provide relief to the patients. Presently, available intervention strategies works on relief of pain, spasm, improving joint range of motion, muscle strength and endurance *via* knee immobilization, stretching, knee strengthening, therapeutic massage, physical agent modalities such as moist-heat packs, ultrasound, diathermy (thermotherapy) and electrical stimulation etc. There are different opinions regarding the best option available for managing functional impairments in knee osteoarthritis [2, 10]. The relationship between weight bearing exercise and osteoarthritis is complex. Many experts claim that exercise provides some protection against the development of osteoarthritis by reducing body weight, improving muscle strength, and increasing flexibility. In addition, exercise stimulates the secretion of synovial fluid which lubricates and nourishes the joints. Non-weight-bearing exercise, especially swimming, is often promoted as treatment for mild forms of osteoarthritis.

The available literature emphasizes on the need for specially designed and individually tailored[5] intervention strategy such as Neuromusculoskeletal Multijoint Coupling Dynamics (NMJCD) Strategy which incorporates neurophysiological and biomechanical principles within functional context for patients with knee osteoarthritis.

The understanding of these underlying pathophysiological & neurophysiological mechanisms may serve as guiding tool while formulating specific intervention strategy for patients with knee osteoarthritis.

Table 1 Management of Osteoarthritis

Nonpharmacological	Pharmacological	Surgical
Patient education, Exercise, Occupational Therapy, Physical agent modalities, Dietary modification, Weight reduction Ambulatory assistive devices, Neuromusculoskeletal Multijoint Coupling Dynamics (NMJCD) approach,	Non-opiod analgesics, topical ointments, Anti-inflammatory, drugs, Intraarticular injections of hyaluronic acid products.	Arthroscopic debridement, Osteotomy, Autologous chondrocyte implantation, Osteochondral allograft plugs, Partial or total joint replacement.

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LACCASES : THE BLUE OXIDASES WITH IMMENSE SCOPE FOR BIOTECHNOLOGICAL EXPLOITATION

Vidya Pradeep* & Manpal Sridhar

Laccases, the blue oxidases, have received much attention from researchers in last decades due to their ability to oxidize both phenolic and nonphenolic lignin related compounds as well as highly recalcitrant environmental pollutants, which makes them very useful for their application to several biotechnological processes. Laccases have wide applications which include detoxification of industrial effluents, mostly from the paper and pulp, textile and petrochemical industries, use as a tool for medical diagnostics and as a bioremediation agent to clean up herbicides, pesticides and certain explosives in soil. Laccases are also used as cleaning agents for certain water purification systems, as catalysts for the manufacture of anti-cancer drugs and even as ingredients in cosmetics. In addition, their capacity to remove xenobiotic substances and produce polymeric products makes them a useful tool for bioremediation purposes.

INTRODUCTION

Laccases are enzymes belonging to the blue oxidases[1], which also include ascorbate oxidases and ceruloplasmins. Laccases: Benzenediol : oxygen oxidoreductases, EC 1.10.3.2 are thus known as blue multicopper oxidases that catalyse the oxidation of an array of aromatic substrates concomitantly with the reduction of molecular oxygen to water. Their characteristic blue colour is caused by a copper atom that is thought to be the primary electron acceptor. Laccase was first discovered in the sap of Japanese Lacquer tree, *Rhus vernicifera*[2]. Majority of fungal laccases are extracellular, monomeric, globular proteins of approximately 60-70 kDa with an acidic isoelectric point around pH 4.0[3]. Laccase catalyze the direct oxidation of ortho and para biphenols, aminophenols, polyphenols, polyamines and aryl diamines as well as some inorganic ions. Amongst more than 200 kinds of oxidases and oxygenases, only six classes of enzymes are capable of catalyzing this type of oxygen reaction. They are cytochrome-C-oxidase, laccases, L-ascorbate oxidase, ceruloplasmin, bilirubin oxidase and phenoxazinone synthase.

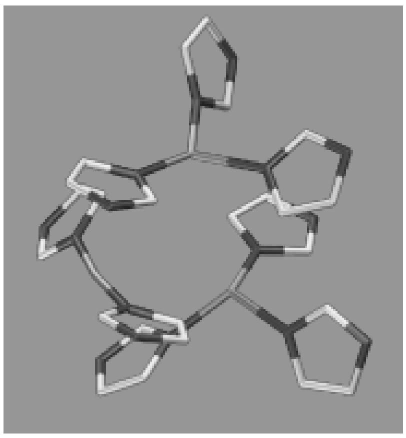

Fig 1 : The tricopper site found in laccases with each copper centre being bound to imidazole adapted from smoke foot, Wikipedia Commons, 2008)

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Laccases are enzymes able to oxidize polyphenols with oxygen as final electron acceptor. The active site is constructed by four copper atoms. The four copper ions essential for catalytic activity are buried within the protein. Type 1- which drives phenol oxidation and which gives the protein is characteristic greenish-blue color. Type 2 (one) and Type 3 (two) [Total three Cu atoms], organized in cluster driving the di oxygen activation (Fig 1). Fungal laccases have higher reduction potentials for the copper sites compared with those from other organisms. Halides, pseudohalides, sulphides, carbonates and heavy metals decrease the catalytic efficiency of laccases. Laccases usually contain four Cu atoms and show a UV absorption peak at around 600 nm. Some laccases lacking the Cu^1 characteristic absorption spectrum are called Yellow or White laccases. Yellow laccases are formed as a result of binding of aromatic products of lignin degradation to the blue laccase during fungal growth in solid-state conditions. The first purification of white laccase was obtained from the basidiomycete *P. ostreatus.*

SOURCES

Laccases are ubiquitous enzymes as they are found in nearly all wood rotting fungi. Laccase activity is found in higher plants (wood and cellular walls of herbaceous species in the process of lignin biosynthesis), bovine rumen microflora, fungi (ascomycetes, basidiomycetes), bacteria, arthropods, insects, yeasts and molds.

PRODUCTION OF LACCASES IN FUNGI

Laccases are secreted out in the medium extra cellularly by several fungi during the secondary metabolism and not all fungal species produce laccase such as zygomycetes and chytridiomycetes. Laccase is also produced by soil as well as some fresh water ascomycetes species. Though laccase production from *Gaeumannomyces graminis*, *Magnaporthe grisea*, *Ophiostoma novoulmi*, *Marginella*, *Melanocarpus albomyces*, *Monocillium indicum*, *Neurospora crassa*, and *Podospora anserina* has been reported, Basidiomycetes and saprotrophic fungi are the most widely known species that produce substantial amount of laccase[4]. *Trametes versicolor*, *Chaetomium thermophilum* and *Pleurotus eryngii* are well known producers of laccase. Laccase has also been produced by many edible mushrooms including the oyster mushroom *Pleurotus ostreatus*, the rice mushroom *Lentinula edodes* and *Champignon agaricus bisporus*. Other laccase producers of wood-rotting fungi include *Trametes hirsuta* (*C. hirsutus*), *Trametes villosa*, *Trametes gallica*, *Cerrena maxima*, *Lentinus tigrinus*, *Trametes ochracea*, *Pleurotus eryngii*, *Trametes* (*Coriolus*) *versicolor*, *Coriolopsis polyzona*, etc. Several factors influence laccase production such as type of cultivation (submerged or solid state), carbon limitation, and nitrogen source. Effect of several inducers on the production of laccase showed copper sulphate had the greatest tendency to enhance the produce of laccase with production increasing 3.5 fold in the presence of copper sulfate.

PRODUCTION OF LACCASE IN BACTERIA

Laccase in bacteria is present intracellularly and as periplasmic protoplast. The first bacterial laccase was found in the plant root associated bacterium, *Azospirillum lipoferum* where it was shown to be involved in melanin formation. Laccase has been discovered in a number of bacteria including *Bacillus subtilis*, *Bordetella compestris*, *Caulobacter crescentus*, *Escherichia coli*, *Mycobacterium tuberculosum*, *Pseudomonas syringae*, *Pseudomonas aeruginosa*, and *Yersinia pestis*. *Stenotrophomonas maltophilia* strain was found to be laccase producing, which was used to degrade synthetic dyes[5]. Incubation temperature, incubation period, agitation rate, concentrations of yeast extract, $MgSO_4$. $7H_2O$, and trace elements were found to influence laccase production significantly.

PRODUCTION OF LACCASE IN PLANTS

The plants in which the laccase enzyme has been detected include lacquer, mango, mung bean, peach, pine, prune, and sycamore[5]. Techniques have also been developed to express laccase in the crop plants. Laccase has been expressed in the embryo of maize (*Zea mays*) seeds.

PRODUCTION OF LACCASE IN INSECTS

Laccase enzyme has also been characterized in different insects e.g., *Bombyx*, *Calliphora*, *Diploptera*, *Drosophila*, *Lucilia*, *Manduca*, *Musca*, *Orycetes*, *Papilio*, *Phormia*, *Rhodnius*, *Sarcophaga*, *Schistocerca*, and *Tenebrio*[5]. In insects, laccases have been suggested to be active in cuticle sclerotization.

Submerged and Solid State modes of fermentation are used intensively for the production of laccases. Submerged fermentation involves the nurturing of microorganisms in high oxygen concentrated liquid nutrient medium. Solid State Fermentation is suitable for the production of enzymes by using natural substrates such as agricultural residues because they mimic the conditions under which the fungi grow naturally. Furthermore, agro-wastes have been shown to produce higher laccase activities than inert supports for the same fungal strain and culture conditions.

PHYSIOLOGICAL ROLES

Laccases play diverse roles in nature. Fungal laccases have been associated with lignification, delignification, fruiting body formation, pigment formation during asexual development, pathogenesis, competitor interactions, soil organic matter cycling, oxidative plant stress management, fungal morphogenesis and virulence, depolymerization of lignin/coal and humic acids, polymerization and coupling two different molecules. In bacteria, laccases appear to have a role in morphogenesis, in the biosynthesis of the brown spore pigment and in the protection afforded by the spore coat against UV light and hydrogen peroxide and in copper homeostasis and in insects, sclerotization of the cuticle in the epidermis. Collectively, laccases exploit a disparate range of natural substrates. Individually, substrate usage varies between species, as do their constituent laccases. Synthesis and secretion of laccases are strictly influenced by nutritional levels, cultural conditions and developmental strategies as well as the addition of different inducers in culture media.

MECHANISM OF ACTION

The catalysis of laccase occurs with the reduction of one molecule of oxygen to water along with one electron oxidation of a range of aromatic compounds like aromatic amines, polyphenols and methoxy substituted monophenols. In this oxidation Type 1 Cu extracts one electron from the substrate. The electron is then transferred to the T2/T3 centre at a distant of about 12.5A. After complete reduction of the trinuclear center, the molecular oxygen reduction occurs. Laccase mediated catalysis can be extended to nonphenolic substrates also by the help of mediators (Fig 2).

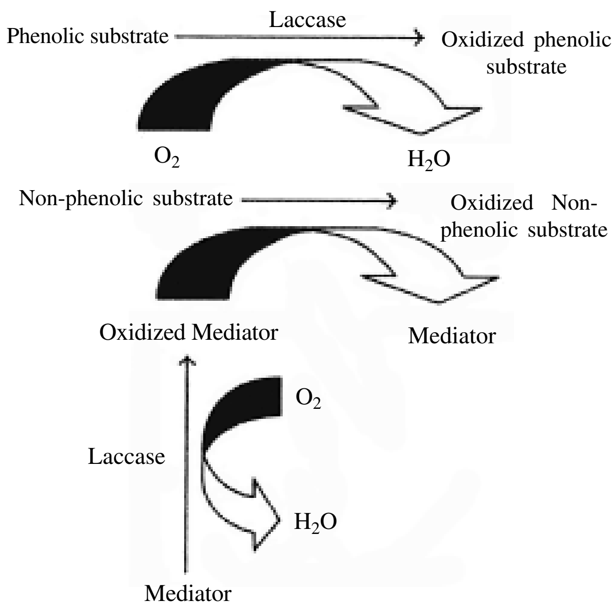

Fig 2 : Mechanism of laccase action for both phenolic and nonphenolic substrates[6].

STRUCTURAL FEATURES

A majority of the fungal laccases are extracellular monomeric globular proteins of approximately 60-70 kDa with an acidic isoelectric point around pH 4.0. They are generally glycosylated. There are four ungapped sequence regions which distinguish them from other multi copper oxidases. These 12 amino acid residues act as copper ligands. One substrate molecule transforms into several reactive products of oxidation. The structure of basidiomycete laccase is stabilized by two disulfide bridges. The reduction of Cu^1 is the rate limiting step in the catalytic process. The Cu^1 is the primary electron acceptor site in a laccase catalyzed reaction, where four single electron oxidation of a reducing substrate occur. The three Cu^2/Cu^3 ions are arranged in a triangular fashion, as consistently observed in MCO's and coordinated to a strongly conserved pattern of four His -X-His motifs.

SUBSTRATE RANGE

Laccase have very broad substrate specificity with respect to the electron donor. These enzymes catalyse the one electron oxidation of a wide variety of organic and inorganic substrates, including mono-, di-, and polyphenols, aminophenols, methoxyphenols (sinapinic acid, ferulic acid, guaiacol, hydroquinone, catechol, gallic acid, vanillic acid, syringic acid, hydroxylated biphenyls, 2,6 dimethoxy phenol, 4-OH TEMPO, tannic acid, ABTS), aromatic amines and ascorbate with the concomitant four-electron reduction of oxygen to water. These enzymes are being increasingly evaluated for a variety of biotechnological applications, due to their broad substrate range.

POTENTIAL INDUSTRIAL AND BIOTECHNOLOGICAL APPLICATIONS OF LACCASE ENZYME

Laccases find innumerable applications within the below discussed fields :

Food Industry

Many laccase substrates, such as carbohydrates, unsaturated fatty acids, phenols, and thiol-containing proteins, are important components of various foods and beverages. Their modification by laccase may lead to new functionality, quality improvement, or cost reduction. Laccases can be applied to certain processes that enhance or modify the color appearance of food or beverage. In this way, an interesting application of laccases involves the elimination of undesirable phenolics, responsible for the browning, haze formation and turbidity development in clear fruit juice, beer and wine. Laccases are currently of interest in baking due to their ability to cross-link biopolymers. The potential applications of laccase in different aspects of the food industry such as bioremediation, beverage processing, ascorbic acid determination, sugar beet pectin gelation, baking and as a biosensor has been described[7]. However, it has been suggested that more studies of laccase production and immobilization techniques at lower costs are needed to improve the industrial application of this enzyme.

Pulp and Paper Industry

In the industrial preparation of paper, the separation and degradation of lignin in wood pulp are conventionally obtained using chlorine- or oxygen-based chemical oxidants. Non-chlorine bleaching of pulp with laccase was first patented in 1994 using an enzyme treatment to obtain a brighter pulp with low lignin content. The capability of laccases to form reactive radicals in lignin can also be used in targeted modification of wood fibers. Laccases have been proposed to activate the fiber bound lignin during manufacturing of the composites, thus, resulting in boards with good mechanical properties without toxic synthetic adhesives. Another possibility is to functionalize lignocellulosic fibers by laccases in order to improve the chemical or physical properties of the fiber products. Preliminary results have shown that laccases are able to graft various phenolics acid derivatives onto kraft pulp fibers. This ability could be used in the future to attach chemically versatile compounds to the fiber surfaces, possibly resulting in fiber materials with completely novel properties such as hydrophobicity or charge.

Textile Industry

The textile industry accounts for two-thirds of the total dyestuff market and consumes large volumes of water and chemicals for wet processing of textiles. The chemical reagents used are very diverse in chemical composition, ranging from inorganic compounds to polymers and organic products. Several dyes are made from known carcinogens such as benzidine and other aromatic compounds. Most currently existing processes to treat dye wastewater are ineffective and not economical. Laccase is used in commercial textile applications to improve the whiteness in conventional bleaching of cotton and recently bio stoning by decolorizing textile effluents.

The development of processes based on laccases seem an attractive solution due to their potential in degrading dyes of diverse chemical structure, including synthetic dyes currently employed in the industry. The use of laccase in the textile industry is growing very fast, since besides decolorization of textile effluents laccase is used to bleach textiles and even to synthesize dyes[8].

Nanobiotechnology

During the past two decades, bioelectrochemistry has received increased attention. As laccases are able to catalyze electron transfer reactions without additional cofactors, their use has been studied in biosensors to detect various phenolic compounds, oxygen or azides. Immobilization has an important influence on the biosensor sensitivity. Micro patterning is an efficient method for the immobilization of laccases on a solid surface in order to develop a multi-functional biosensor. Cross-linked enzyme crystals (CLEC) of laccase from *Trametes versicolor* could be used in biosensor applications with great advantage over the soluble enzyme. Laccase from *Coriolus versicolor* on N-hydroxysuccinimide-terminated self-assembled monolayers on gold, a procedure useful for the further development of biosensors. In addition, an enzyme electrode based on the co-immobilization of an osmium redox polymer and a laccase from *T. versicolor* on glassy carbon electrodes was applied to ultrasensitive amperometric detection of the catecholamine, neurotransmitters, dopamine, epinephrine and nor epinephrine, attaining nanomolar detection limits.

Laccase can also be immobilized on the cathode of bio fuel cells that could provide power, for example, for small transmitter systems[10,11]. Biofuel cells are extremely attractive from an environmental point of view because electrical energy is generated without combusting fuel, thus, providing a cleaner source of energy.

DELIGNIFICATION OF LIGNOCELLULOSICS

Lignin is the most common aromatic natural material on earth and also one of the most resistant natural polymers. It is a complex, three-dimensional, non-stereo regular aromatic polymer composed of phenyl-propanoid units linked through several major types of carbon and ether bonds, encrusting the cellulosic micro fibril of plants which is chemically bounded to the hemicelluloses. In recent years, much interest has been evidence in new bio techniques to improve the nutritive value of lingo-cellulosics. Biologically delignifying crop residues to improve the utilization of lingo celluloses by ruminants appears to be positive insight into adding nutritive value. Lignocellulosics are mostly known in the form of wood and straw consisting of three main components, cellulose, hemicellulose and lignin. Lignocellulosic residues are not high value feeds. They are classified instead as low quality roughage, due to its high content of fiber, low protein, vitamins and minerals.

Delignification is an essential step in utilization of lignocellulosic materials by pulping or enzymatic hydrolysis. The biodegradation of lignin occupies a significant position in the global carbon cycle since lignin constitutes the second largest sink for fixed carbon after cellulose.

Separation of lignin from cellulose fibers is an important step in processing of wood for manufacturing of paper pulp. Conventional methods involve chlorine-, sulfite-, or oxygen based chemical oxidants which impose serious drawbacks of disposal of chlorinated and sulfide by-products or loss of cellulose fiber strength. To overcome these drawbacks, microbial or enzyme-based delignification systems can be used. Laccase is capable of degrading natural or synthetic lignin polymers. Oxidation by laccase results in breakage of aromatic and aliphatic C–C bonds and depolymerixalion of lignin. Fermentation of lignocellulosics to generate fuels such as ethanol or butanediol also requires delignification. Lignocellulosic hydrolysates such as furan derivatives and organic acids may inhibit the microbial fermentation of agricultural residues to desirable fuel products. Purified laccase from *Trametes versicolor* has also been used for such delignification, resulting in better productivity.

SIGNIFICANCE OF LACCASES IN ANIMAL FEED

A vast energy potential for animal feed is locked in the lingo-cellulosic materials (crop-residues and forages etc.) in the form of celluloses and hemi-cellulose. However this is not available on account of the lignin with which these are bound and to improve the access of hydrolytic enzymes to cellulose and hemicelluloses, it is necessary to disrupt the organization of the lingo-cellulosic or lingo-hemicellulosic bonds of plant cell walls. Bio-delignification of such agricultural lignocellulosics not only enhances the digestibility of the feed but also improves their nutritional value. The use of fungi and other organisms on straws has been used as an alternative to chemical and physical treatments to enhance straw quality for animal feed[5]. Lignolytic enzymes like laccase can be produced economically in bulk quantities from white rot fungi using immobilization on cheap inert matrices or even by recombination. Pretreatment of the crop residues with these laccases would aid in lignin degradation.

OTHER APPLICATIONS OF LACCASES

Bio remediation

Laccases have many possible applications in bioremediation and are used to degrade various substances such as undesirable contaminants, by-products, or discarded materials[7]. Polycyclic Aromatic Hydrocarbons (PAHs) together with other xenobiotics are a major source of contamination in soil, therefore, their degradation is of great importance for the environment. The catalytic properties of laccases can also be used to degrade such compounds. Thus, laccases were able to mediate the coupling of reduced 2,4,6-trinitrotoluene (TNT) metabolites to an organic soil matrix, which resulted in detoxification of the munitions residue. PAHs, which arise from natural oil deposits and utilization of fossil fuels, were also found to be degraded by laccases.

Pharmaceutical sector

Many products generated by laccases are antimicrobial, detoxifying, or active personal-care agents. Due to their specificity and bio-based nature, potential applications of laccases in the field are attracting active research efforts. Laccase can be used in the synthesis of complex medical compounds as anesthetics, anti-inflammatory, antibiotics, sedatives, etc., including triazolo (benzo) cycloalkyl thiadiazines, vinblastine, mitomycin, penicillin X dimer, cephalosporins, and dimerized vindoline.

Laccase based biocatalysts

The ability to use enzymes in non aqueous solvents greatly expands the potential scope and economic impact of biocatalysis. When biological catalysts are placed in this unnatural environment they exhibit a number of remarkable novel properties such as altered stereo-selectivity, enhanced stability and increased rigidity.

Synthetic chemistry

Laccases replace H_2O_2 as an oxidizing agent in the dye formulation. Laccases also find potential applications for analytical purposes, environmental friendly synthesis of fine chemicals, derivatization of biologically active compounds- antibiotics, amino acids, antioxidants, cytostatics; production of polymers with anti oxidative properties, co-polymerization of lignin components with low molecular mass compounds, coating of cellulosic cotton fibers or wool, coloring of hair and leathers, cross linking and oligomerization of peptides, juice and wine clarification, detoxification and decolouration of sewage, to create antimicrobial compositions, production of wood fiber plates, production of detergents, purification of colored waste waters etc. These applications stimulate new waves of fundamental research concerning this enzyme. In the future, laccases may also be of great interest in synthetic chemistry, where they have been proposed to be applicable for oxidative de protection and production of complex polymers and medical agents. Laccase provides an environmentally benign process of polymer production in air without the use of H_2O_2.

CONCLUSION

Laccases are ancient enzymes with a promising future. The most important obstacles to commercial application of laccases are the lack of sufficient enzyme stocks and the cost of redox mediators. Use of enzymes is considered a promising method to increase milk production, animal performance and feed digestion. Efforts have to be made in order to achieve cheap over production of this biocatalyst in heterologous hosts and also their modification by chemical means or protein engineering to obtain more robust and active enzymes.

For the potential of designer laccases to be realized, effective, low-cost, efficient and green production systems are required in which over expression of laccase can be induced. Filamentous fungi are best producers of recombinant laccases with protein yields ranging from 70-230 mg/1. The industrial and environmental application of laccases requires a large amount of low priced enzyme. Therefore, it is of great benefit to identify a high laccase output organism and to develop an efficient system for the heterologous expression of laccases.

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100TH INDIAN SCIENCE CONGRESS

LIST OF ISCA AWARDEES FOR 2012-2013

JAWAHARLAL NEHRU BIRTH CENTENARY AWARD

Shri Somnath Chatterjee,
Former Speaker, Lok Sabha
Kolkata

MILLENNIUM PLAQUES OF HONOUR

Dr. Devi Shetty
Chairman, Narayana,
Hrudayalaya, Bangalore

C. V. RAMAN BIRTH CENTENARY AWARD

Prof. S. Rajarajan
Dept. of Microbiology and Biotechnology
Presidency College, Chennai

BIRBAL SAHANI BIRTH CENTENARY AWARD

Dr. Ashok Kumar Singhvi
Outstanding Scientist, Physical Research Laboratory, Ahmedabad

M. K. SINGHAL MEMORIAL AWARD

Prof. Shrikrishna Gopalrao Dani
Distinguished Professor, Tata Institute of Fundamental Research, Mumbai

G. P. CHATTERJEE MEMORIAL AWARD

Prof. Amalendu Bandyopadhyay
Birla Planetarium, Kolkata

HIRA LAL CHAKRAVARTY AWARD

Dr. Sudesh Kumar Yadav
Senior Scientist, CSIR-Institute of Himalayan Bioresource Technology, Palampur

PRAN VOHRA AWARD

Dr. Gyan Prakash Mishra
Defence Institute of High Altitude Research
Leh, Ladakh, J & K

UMAKANT SINHA MEMORIAL AWARD

Dr. Durai Sundar
Department of Biochemical Engineering & Biotechnology, Indian Institute of Technology (IIT), New Delhi

DR. B.C. DEB MEMORIAL AWARD FOR SOIL/ PHYSICAL CHEMISTRY

Dr. Alok Krishna Sinha
Staff Scientist V, National Institute of Plant Genome Research, New Delhi

DR. B. C. DEB MEMORIAL AWARD FOR POPULARISATION OF SCIENCE

Dr. Debasish Mandal
Senior Scientist, Central Soil & Water Conservation Research & Training Institute, Dehradun

PROF. R. C. MEHROTRA COMMEMORATION LECTURE

Prof. Sandeep Verma
Shri Deva Raj Chair Professor,
Department of Chemistry, IIT Kanpur, Kanpur

PROF. (MRS.) ANIMA SEN MEMORIAL LECTURE

Prof. Giridhar Prasad Thakur
Chairman, Manjushree Mental Health Care & Cure Society, New Delhi

DR. (MRS.) GOURI GANGULY MEMORIAL AWARD

Dr. Rajnish Kumar Chaturvedi
Scientist, Indian Institute of Toxicology Research, Lucknow

PROF. S. S. KATIYAR ENDOWMENT LECTURE

Prof. Jitendra Paul Khurana
Department of Plant Molecular Biology, University of Delhi South Campus, New Delhi

PROF. R. C. SHAH MEMORIAL LECTURE

Dr. J. Mathiyarasu
Senior Scientist, CSIR-Central Electrochemical Research Institute, Karaikudi

PROF. ARCHANA SHARMA MEMORIAL AWARD

Prof. Awatar Kishen Koul
School of Biosciences & Biotechnology, BGSB University, Rajkot

DR. V. PURI MEMORIAL AWARD

Dr. R. Raghvendra Rao
INSA Honorary Scientist, Yelahanka, Bangalore

100TH INDIAN SCIENCE CONGRESS
YOUNG SCIENTIST AWARDEES FOR 2012-2013

Sl. No.	Name	Title of paper
1.	**Dr. K. Chakraborty,** Plant Physiology, Directorate of Groundnut Research (ICAR) Junagadh – 362 001	Differential Expression Genes Involved in Osmolyte Biosynthesis Play of Major Role in Salinity Tolerance of *Brassica* spp.
2.	**Mr. A. K. Verma,** Department of Zoology, Cell & Tumor Biology Lab., North-Eastern Hill University, Shillong – 793 022	Changes in Glutathione and Glutathione-related Enzymes Induces Mitochondrial Stress and Apoptosis in the Anticancer Activities of Cantharidin Isolated from Red-headed Blister Beetles, *Epicauta hirticornis* and its Mechanism of Action.
3.	**Ms. Madhumati Chatterjee,** Department of Anthropology, Univ. College of Science, Tech. and Agriculture, University of Calcutta, Kolkata – 700 074	On the Variation of Primate Hair : Approach to Evolutionary Biology.
4.	**Dr. Rubel Chakravarty,** Radiopharmaceuticals Division Bhabha Atomic Research Center, Trombay, Mumbai – 400 085	Combination of Nano-Ceria-Polyacrylonitrile Based $^{68}Ge/^{68}Ga$ Generator and NOTA as Bifunctional Chelator Makes ^{68}Ga-Radiopharmaceutical Chemistry more Practical.
5.	**Mr. Parijat Roy,** ICP-MS Lab., Geochemistry Division, National Geophysical Research Institute, Hyderabad – 700 005	PGE Geochemistry of Kimberlites from Anantapur Area, Southern India : Implicatons for Nature of Mantle below Dharwar and Diamond Potentiality.
6.	**Mr. Abhilash,** Waste Recycling and Utilisation Group, Metal Extraction and Forming Division, CSIR–National Metallurgical Laboratory, Jamshedpur – 831007	Bioreactor Processing of Low Grade Indian Uranium Ores : Improvisation in Leaching Kinetics Vis-à-vis Resource Utilisation

7.	**Dr. Divya Sharma,** Division of Agricultural Chemicals, Indian Agricultural Research Institute, New Delhi – 110012	Microbial Degradation of Bifenthrin by Consortium in Broth and Soil.
8.	**Ms. Mallamma V. Reddy,** Dept. of Computer Science and Applications, Bangalore University, Bangalore	Indic Language Machine Translation Tool for NLP.
9.	**Mr. Arvinder Singh,** Department of Physics and Meteorology, Indian Institute of Technology, Kharagpur – 721 302	Graphite Oxide Based Composites : Promising Candidates for Applications in Energy Storage Devices.
10.	**Mr. Pratibhamoy Das** Dept. of Mathematics, IIT, Guwahati, Guwahati	A Priori and a Posteriori Error Estimates for Singularly Perturbed General System of Reaction-Diffusion Boundary-Value Problems using Grid Adaptation.
11.	**Ms. Poulami Karmakar,** Division of Pathophysiology, National Instt. of Cholera and Enteric Diseases, Kolkata – 700 010	Involvement of EGFR Tyrosine Kinase in the Downregulation of Cell Proliferation on Colon Carcinoma Cell Line by Thermostable Direct Hemolysin Secreted by *Vibrio parahaemolyticus.*
12.	**Dr. Amit Kumar Mishra,** Cellular and Molecular Neuroscience Lab., MBM Engineering College Jodhpur – 342 011	Association of E6-AP Ubiquitin Ligase with SOD1 Aggresomes Promotes their Proteasomal Degradation and Suppresses Mutant SOD1-Mediated Toxicity.
13.	**Ms. Richa Srivastava,** Department of Physics, University of Lucknow, Locknow – 226 007	Experimental Investigation on Manufacturing of Excellent Moisture Sensor at Room Temperature.
14.	**Dr. Ranjan Singh** Department of Microbiology, Dr. Ram Manohar Lohia Avadh University, Faizabad–224 001	Optimization of Physico-chemical and Nutritional Parameters for Pullulan Production by a Thermotolerant Strain of *Aureobasidium pullulan* in Non-stirred Feb Batch Fermentation Process.

100TH INDIAN SCIENCE CONGRESS
BEST POSTER AWARDEES FOR 2012-2013

Sl. No	Section		Name	Title of paper
1.	*Agriculture and Forestry Sciences*	(a)	**Angira Das** University of Calcutta, Kolkata	Evaluation of Effect of Storage on *in-vitro* Anti oxidative Capacities of Honeys Collected from Sundarban.
		(b)	**Paromita Ghosh** G.B.P.I.H.E. & D, Garhwal	Spatial and Temporal Distribution of Nitrifying Bacteria and N Transformation Rates in Tropical Rain-fed Rice Soil.
2.	*Animal, Veterinary and Fishery Sciences*	(a)	**Swapan Kumar Maiti** IVRI, Bareilly	Canine Mammary Cancer : Incidence, Therapeutic Management and Prognostic Tumour Marker Study.
		(b)	**Seema Jain** RGPG College, Meerut	Application of Immunostimulants for Modulation of the Non-Specific Defense Mechanisms in Indian Snake Head *Channa punctatus* (Bloch.).
3.	*Anthropological and Behavioural Sciences (including Archaeology and Psychology & Educational Sciences and Military Sciences)*	(a)	**Prerna Bhasin** University of Delhi, Delhi	Filialties in Cardio-metabolic Risks Among Children at 9-11 years of Age.
		(b)	**Joydeep Chowdhury** Indian Statistical Institute, Kolkata	Markovian Combat and Duel Modeling on Stochastic Modeling of Combat, Duel and Fencing.
4.	*Chemical Sciences*	(a)	**Prabha Singh** DAV PG College, Muzaffarnagar	A New Method for Microgram Determination of 3, 5-dimethylaniline.
		(b)	**Ritu Yadav** H. S. Gour University, Sagar	Synthesis of S-(substituted arylidenes)-2-(substituted aryl)-3-(4-nitrophenoxy acetamido)-4-oxo-thiazolidines Derivatives and Investigation of their Biological Activity.
5.	*Earth System Sciences*	(a)	**Nahida Ali** University of Kashmir, Srinagar	Futuristic Land Cover Projections in Kashmir Valley Using CLUE Model.
		(b)	**Rimjhim Bhatnagar Singh** Space Application Centre, Ahmedabad	Albedo Based Characterization of Martian Features.

Sl. No	Section		Name	Title of paper
6.	*Engineering Sciences*	(a)	**Surashree Sengupta** University of Calcutta, Kolkata	Development of Nanocapsules of lipid Based Nutraceuticals.
7.	*Environmental Sciences*	(a)	**Sourav Bhattacharyya** Jain University, Bangalore	*Ex situ* Bioremediation of Congo Red Dye by Filamentous Fungi.
		(b)	**Priya Banerjee** CGCRI, Kolkata	Comparative Analysis of Toxicity and Antioxidant Responses in *Heteropneustes fossilis* (Bloch) Exposed to Untreated and Ultrafiltration Membrane Bioreactor Treated Textile Effluent.
8.	*Information and Communication Science & Technology (including Computer Sciences)*	(a)	**K. Jyotimani** NGM College, Tamilnadu	EDS-FI : Efficient Data Structure for Mining Frequent Item Sets.
		(b)	**Maumita Maiti** Bengal Engineering College, Howrah	Design of Reversible Circuits Using QCA for Low Power Nano-Scale computing : Challenges and Future.
9.	*Materials Science*	(a)	**Inderjeet Singh** IIT, Kharagpur	Application of Activated Carbon Supported MnO_2 Nanorods as a Cathode Material for Achieving High Power Densities in Microbial Fuel Cells.
		(b)	**K. K. Samanta** IIT, Delhi	Application of Plasma Technology in Textile Chemical Processing to Reduce Water Pollution.
10.	*Mathematical Sciences (including Statistics)*	(a)	**Kabita Sarkar** Salesian College, Siliguri	Identifying Space-time Metric of Distant Compact Objects.
		(b)	**Sumanta Kumar Das** ISSA, DRDO, Metcalfe House, Delhi	Statistical Estimation of Attrition Rate Coefficients for Fitting Lanchester Model.
11.	*Medical Sciences (including Physiology)*	(a)	**A. R. Goswami** Univ. College of Science, Kolkata	Effects of Vitamin C on the Neurotransmitter Levels of the Different Brain Areas in Male Rats Exposed to Simulated Hypobaric Hypoxia.
		(b)	**Anvitha Mikkilineni** GITAM University, Visakhapatnam	Detection of Presence or Absence of Bacterial Endotoxin by Lal Testing Method.

Sl. No	Section		Name	Title of paper
12.	*New Biology (including Biochemistry, Biophysics & Molecular Biology and Biotechnology)*	(a)	**Moitri Basu** IICB, Kolkata	A Novel Fibroblast Growth Factor, is Regulated Synergistically By Pitx2 Transcription Factor and Wnt Pathway in Ovarian Carcinoma Cells, SKOV-3
		(b)	**Parvathi M. V. S.** IIBT, Tamilnadu	Micro RNA mediated Regulation of BM11 Polycomb Gene expresssion and its Correlation with Hormone Receptor Status in Invasive Ductal Carcinomas of Breast.
13.	*Physical Sciences*	(a)	**Nishant T. Tayade** Institute of Science, Nagpur	Synthesis and Study of Iron Oxide Ultrafine Particles.
		(b)	**S. K. Biswas** University of Calcutta, Kolkata	Structure and Thermal Behavior of PET Granule and Fibers.
14.	*Plant Sciences*	(a)	**Arunava Mandal** Bose Institute, Kolkata	Transcriptional Regulation of a Cell Expansion Gene upon Tomato Leaf Curl Virus Infection.
		(b)	**Santosh Kumar Rai** CIMAP, Lucknow	DNA marker, ITS nrDNA Sequence and Karyomorphology Based Characterization of Oleferous and Non-oil Species of *Vetiveria* L.

THE INDIAN SCIENCE CONGRESS ASSOCIATION
14, DR. BIRESH GUHA STREET, KOLKATA–700 017

ISCA BEST POSTER AWARDS : 2013-2014

To encourage Scientists, The Indian Science Congress Association has instituted two Best Poster Awards in each Sections. These awards carry a sum of ₹ 5,000/- besides a Certificate of Merit.

1. Applications are invited from members (Life, Annual & Student) of the Association who have paid their subscription on or before **July 15, 2013**.
2. Four copies of full length paper along with four copies of the abstract (not exceeding 100 words) must reach the office of the General Secretary (Membership Affairs) not later than **September 15, 2013**. At the top of each copy of the paper and its abstract, the name of the Section under which the paper is to be considered should be indicated. For details of Sections see http://www.sciencecongress.nic.in
3. Along with the Four copies of paper, Four copies of the Application Form (to be downloaded from ISCA website http://www.sciencecongres.nic.in) with brief bio-data of the candidate (not exceeding 2 pages), full length paper, abstract in the form of a CD must also be sent simultaneously along with the hard copies.
4. The number of authors of each poster submitted for the award shall be limited to two only. The first author of the poster shall be presenting author.
5. The research work should have been carried out in India and this has to be certified by the Head of the Institution from where the candidate is applying.
6. The candidate should give an undertaking that the paper being submitted has not been published in any journal or presented in any other Conference/ Seminar/ Symposium or submitted for consideration of any award.
7. A scientist shall submit only one poster in any one Section (and not a second poster on the same or any other topic in any other Section) for consideration for poster presentation award.
8. A person who has already received ISCA Best Poster Award in any section once will not be eligible to apply for the above Award in the same or any other section.
9. Incomplete Application will not be considered.
10. Full length papers will be evaluated by experts and twenty posters in each section will be selected for presentation during 101st Indian Science Congress.
11. The final selection for the Awards will be made by a duly constituted committee and the awards will be given during the Valedictory Session of 101st Indian Science Congress session.
12. Applications submitted for the above award will not be returned.
13. The last date for receiving applications for the above award at ISCA Headquarters is **September 15, 2013.**

All correspondences should be made to : **The General Secretary (Membership Affairs), The Indian Science Congress Association, 14, Dr. Biresh Guha Street, Kolkata-700 017. Tel. Nos. (033) 2287-4530/2281-5323 Fax No. 91-33-2287-2551, E-mail : iscacal@vsnl.net, Website : http://www.sciencecongress.nic.in**

THE INDIAN SCIENCE CONGRESS ASSOCIATION

14, DR. BIRESH GUHA STREET, KOLKATA – 700 017

ANNOUNCEMENT FOR AWARDS : 2013–2014

Nominations/applications in prescribed forms are invited from Indian Scientists for following Awards :

- Professor Umakant Sinha Memorial Award—New Biology
- Dr. B. C. Deb Memorial Award for Soil/Physical Chemistry—Chemical Sciences
- Dr. B. C. Deb Memorial Award for Popularisation of Science
- Professor K. P. Rode Memorial Lecture—Earth System Sciences
- Dr. (Mrs.) Gouri Ganguly Memorial Award for Young Scientist—Animal, Veterinary and Fishery Sciences.
- Prof Sushil Kr. Mukherjee Commemoration Lecture—Agriculture and Forestry Sciences
- Prof. S. S. Katiyar Endowment Lecture—New Biology/Chemical Sciences
- Prof. R. C. Shah Memorial Lecture—Chemical Sciences
- Prof. Archana Sharma Memorial Award—Plant Sciences
- Dr. V. Puri Memorial Award—Plant Sciences
- Prof. G. K. Manna Memorial Award—Animal, Veterinary and Fishery Sciences.

Last date on submitting application is July 31, 2013

For proforma of application forms and necessary information, please write to the **General Secretary (Membership Affairs), The Indian Science Congress Association, 14, Dr. Biresh Guha Street, Kolkata – 700 017, E-mail :** es.sciencecongress.nic.in/iscacal@vsnl.net, Fax No. 91-33-2287 2551. The forms can also be downloaded from http://www.sciencecongress.nic.in

KNOW THY INSTITUTIONS

CENTRAL INSTITUTE FOR SUBTROPICAL HORTICULTURE, LUCKNOW

ABOUT THE INSTITUTE

- The Central Institute for Subtropical Horticulture (CISH) was started as Central Mango Research Station on September 4, 1972 under the aegis of the Indian Institute of Horticultural Research, Bangalore.
- The Research Station was upgraded to a full-fledged Institute and named as Central Institute of Horticulture for Northern Plains on June 1, 1984.
- Renamed as Central Institute for Subtropical Horticulture (CISH) on June 14, 1995, is serving the nation on different aspects of research on mandated subtropical fruits.
- Has two experimental farms, one at Rehmankhera (132.5 ha) approximately 25 km away from the city and the other (13.2 ha) at Rai Bareli (R.B.) Road, in the city of Lucknow
- Has scientific nursery facilities, well established orchards, fully equipped laboratories; trainees hostel-cum-guest house located at R.B. Road Campus
- Has in place MOU to facilitate capacity building with Allahabad Agricultural Institute (Deemed University), Allahabad, APS University, Rewa, Babasaheb Bhimrao Ambedkar University, Lucknow, Bundelkhand University, Jhansi, and Lucknow University, Lucknow; trains students for acquiring M.Sc and Ph.D degrees
- Recognized by IGNOU, New Delhi as one of the study centres for offering one year

Diploma Course on value added products from fruits and vegetables

- National Horticulture Mission has identified the Institute as nodal centre for imparting training on rejuvenation of old and senile mango orchards and meadow orcharding in guava
- A fully equipped pesticide residue analysis and bio-control laboratories are other features
- Modern facility to address issues of post-harvest management is available Transfer of Technology initiatives and Kisan Call Centre.

MANDATE

The institute is presently functioning with the following mandates :

- To undertake basic and applied research to enhance productivity and develop value chain for major and minor subtropical fruits
- To function as national repository of above fruit crops
- To act as a centre for human resource development and provide consultancy to the stake holders
- To develop linkage with national and international agencies to accomplish the above mandates

OBJECTIVES

The institute pursues its mandate through the following objectives:

- Management of genetic resources of mandated fruit crops and their conventional and molecular characterization
- Crop improvement through breeding and genetic engineering
- Enhancing productivity through improving quality and quantity of planting materials using modern propagation techniques and rootstocks, precision farming practices including mechanization and management of biotic and abiotic stresses
- Reduction in post-harvest losses through improved post-harvest management practices, value addition and diversification of products
- Human resource development, transfer of technology and evaluation of its socio-economic impact
- Data storage and retrieval on all aspects of mandated crops

DIVISIONS

Division of Crop Improvement

- Micropropagation technology using shoot bud culture has been developed in guava, aonla, bael and jamun.
- Somatic embryogenesis protocols have been developed in guava and papaya.
- Genetic transformation system has been developed in papaya and guava
- Five putative transgenic papaya plants containing Cp gene of PRSV have been developed and these are being evaluated in the transgenic glass house.
- Two hundred cultivars of mango from eastern and northern parts of India were characterized with 30 STMS primers and data is used for genotyping.
- In preliminary marker-association studies in mango, four markers have been found to be associated with traits, fruit length and fruit weight.
- Clones of Dashehari, Chausa and Himsagar were characterized with 8 STMS primers and variability was detected among clones of Dashehari and Himsagar. Chausa clones showed no variation.

- 19 cultivars/accessions of guava were characterized with 8 microsatellite primers, which were able to discriminate cultivars.
- 24 litchi cultivars have been characterized using 20 RAPD primers and 6 SSR primers.
- Laboratory is also providing hands-on training and facilities for projects to students (graduation and post graduation) of different universities in tissue culture, transgenics and molecular markers.

Crop Production

- Technologies to rejuvenate old and senile orchards have been standardized for mango, guava and aonla.
- High density planting for mango cv. Dashehari with 400 plants ha -1 spaced at 5.0 × 5.0 m and guava cv. Allahabad Safeda with 555 plants ha -1 spaced at 3.0 × 6.0m were standardized.
- Drip irrigation from September to second week of May followed by fertigation with P and K of 25 per cent of the recommended dose in split doses at flowering and fruit setting have given highest fruit yield (59.74 kg tree -1) in comparison to conventional (basin system 18.71 kg tree -1) irrigation and fertilizer use.
- Institute developed meadow orchard system for guava, which accommodates 5000 plants ha-1 (1.0m × 2.0m) coupled with regular topping and hedging. An average yield of 12.5 tonnes ha-1 was obtained after first year and it reached to 50 tonnes ha-1 after 3rd year.
- Institute developed a technique of rapid multiplication (Wedge grafting), which has a tremendous potential for multiplying guava plants rapidly throughout the year in greenhouse as well as in open conditions.
- Model nursery having a separate Nucleous scion bank, poly and net house facilities have been established for the multiplication of elite clones of mango, guava, aonla and bael.
- Cow dung pasting in rejuvenated mango trees is found most effective for the control of gummosis.
- Mango based cropping system has been developed and recommended by the Institute. Cowpea-potato system has been found to give high monetary returns up to 10 years of plantation.
- Soil application of 4g per tree of paclobutrazol (3.2 ml/metre of canopy diameter) has been found effective to induce regular flowering and fruiting and in controlling irregular bearing in mango cultivar Dashehari.
- Soil application of 1 kg N, 1 kg P_2O_5 and 1 kg K_2O per tree during July to 10 years old (grown-up) Dashehari mango tree increased the yield.
- 250g *Azospyrillum* with 40 kg FYM has been found effective in increasing yield of 15 years old mango cv. Dashehari.
- Farm waste utilization through NADEP, Vermi, micro mediated and Biodynamic (BD) compost have enhanced beneficial microorganisms in soil.

Crop Protection

- Bio-ecological studies of important insect pests of mango have been carried out and forecasting models for fruit fly and hopper of mango have been developed.
- Methyl eugenol wooden block traps were found highly efficient in trapping male mango fruit flies to reduce the population of this important pest.

- A forecasting model for the prediction of powdery mildew was developed. A temperature regime of 7.80–14.40 0 C (Min.) and 28.10–36.40 0 C (Max.) prevailed during February and March was found congenial for the appearance of powdery mildew.

- Five antagonists, isolated from mango phylloplane (*Bacillus coagulans*), fruit surface (LSF-8) and organic liquid pesticides (BDB-I, II & III) when applied against mango bacterial canker under field conditions (5.50-10.55 & 21.11- 26.34) was almost found comparable with antibiotic (9.98-18.70 & 20.0-21.33) in checking the disease incidence and intensity, respectively. These antagonists were identified as species *of Bacillus* , *Pseudomonas* and *Acenetobacter.*

- Four distinct bacterial isolates have been found to exhibit nemato-antagonistic potential. Out of four, two (*Flavobacterium sp. & Sphingomonas terrae*) appears to be new nematode antagonists.

- Chemical control measures of important insect pests and diseases of mango have been standardized and spray schedules have been developed for their commercial adoption.

- Integrated Pest Management (IPM) module for mango insect pests and diseases have been developed and standardized. The technology is being demonstrated in six districts of Uttar Pradesh.

- Efficient pollinators for mango, guava and aonla have been identified.

- A simple technique for control of postharvest diseases is developed which involves covering fruits on trees with paper bags one month prior harvest, which eliminates all postharvest diseases in eco-friendly manner.

- Inoculation technique (stem hole inoculation) for reproduction of wilt in guava has been standardized. *Gliocladium roseum* has been found most potent causal pathogen for guava wilt, as it produces symptoms in grown up plants in field within 2 months of inoculation.

- Papaya Ring Spot Virus (PRSV) has been identified as the most important viral disease of papaya, which causes considerable loss to the crop. Aphid vectors for the transmission of this virus have been identified.

- Major nematode pests of papaya have been identified and synergistic interaction of root-knot nematode with PRSV has been its established.

Postharvest Management

- To reduce cost of production, post harvest losses and increasing profitability through improved post harvest management practices.

- To develop protocols for value addition of fruits, waste utilization organic farming biosafety models against toxic pesticides.

- To evaluate the technologies for marketing and market intelligence studies.

LIBRARY

The CISH library is an integral part of the Institute, is well furnished and equipped with computers and internet facility. It has rich collection of publication on subtropical fruit crops and on other Institute's mandate crops. A large number of National and International journal fulfill the need of Scientist, Research Associates, Senior Research Fellows, Junior Research Fellows and students. The library has 3112 scientific and technical books and 7,458 back volumes of periodicals. It subscribes 111 National and International journals. Out of which 49 are foreign journals and 62 Indian. Besides this, there are 42 Masters and Ph. D. thesis on the subject related to Institute's mandate.

The library is also providing reprography services and internet surfing, exploring literature search through CD ROMs like Agris-CD ROM and Hort. CD ROM.

Contact
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Conferences / Meetings / Symposia / Seminars

Sixth International Conference on Contemporary Computing (IC3-2013), August 8-10, 2013. Noida, New Delhi.

Theme :

- Algorithms
- Systems (Hardware & Software)
- Applications
- Education

Contact : Dr. Divakar Yadav, Phone : 0120-2594141
E-mail : divakar.yadav@jiit.ac.in

National Seminar to Commemorate the Sesquicentennial Birth Anniversary of Sir Asutosh Mookerjee (1864-1924), September 6-8, 2013, Kolkata

Theme :

- Electromagnetic theory of light
- Elastic Vibration
- Green and Fresnel's Dynamical theory of reflection
- Airy and MacCullagh, Stokes' Dynamical theory of diffraction
- Theory of Electric oscillations
- Maxwell's dynamical theory of Electromagnetic field
- Hydrokinetics and the theory of Potential
- Green's theorem and its Applications
- Equations of motion
- Equations of Continuity; Vortex motion
- Cauchy's Integrals of Lagrange's equations
- Stokes' theorem
- Waves and wave motion in liquids
- Surface integrals
- Definite integrals
- Fourier's theorem and its applications in Physics
- Theories of elastic solids
- Astronomy, Relativity and Cosmology

- Statistics and Probability
- Analytical Geometry
- Boole's theorems on linear transformations
- General Cartesian equations of lines of the second order in relation to their foci, asymptotes and eccentricity
- Theorems on central conies and Non-Central conies and its applications
- Theory of analytic functions
- Integration of algebraic functions
- Hyperbolic functions
- Abel's theorem
- Dirichlet's theorem
- Gamma functions
- Differential geometry (surfaces and curves)
- Differential equation and its applications
- Education and Social Sciences

Contact : Dr. Balai Chaki, Convener, Calcutta Mathematical Society, Austosh Bhavan, AE-374 Sector-1, Salt Lake, Kolkata-700 064, West Bengal, India, Phone : +91-9830494816 E-mail : chakibalai@gmail.com, cmsonf@gmail.com

18th Annual cum International Conference of Gwalior Academy of Mathematical Science (GAMS), September 22-23, 2013, Bhopal.

Theme : Mathematical, computational and Intergrative Sciences.

Contact : Dr. Neeru Adlakha, Organizing Secretary, Department of Mathematics, Maulana Azad National Institute of Technology, Bhopal-462 051, Madhya Pradesh, INDIA. Mob : +91-8989110218, +91-8989110219 Phone : +91 - 755 - 4051000, 4052000 Fax : +91-755-2670562, E-mail : gamsint2013@gmail.com

7th International Symposium on Feedstock Recycling of Polymeric Materials, 23-26 October 2013, New Delhi.

Theme :

- Polymer waste management around the world - holistic view
- Polymeric waste availability and conversion methods - statistics and strategies
- Mechanical recycling of waste plastics
- Metal recovery from polymeric wastes
- E-waste treatment techniques
- Thermo-chemical routes (pyrolysis, gasification, combustion etc.) for industrial, municipal plastic wastes and biomass.

- Novel materials / catalysts for conversion process
- Energy from waste polymeric materials
- Biological routes for industrial, municipal plastic wastes and biomass
- Novel analytical techniques (separation and analysis)
- Sustainability - LCA studies
- Going global - Opportunities and challenges

Contact : Dr. Thallada Bhaskar, Senior Scientist & Head, Biomass Thermocatalytic Processes Area (TPA) Bio-Fuels Division (BFD), CSIR - Indian Institute of Petroleum (IIP), Council of Scientific and Industrial Research (CSIR), Dehradun - 248 005, Uttarakhand, India, Website : http://www.iip.res.in/thalladabhaskar.php, www.isfr2013.org

International Symposium on Role of Earth System Sciences & Human Prosperity, 23-25th October, 2013, Hyderabad.

Theme :

- Earth Hazards
- Geochemical Exploration of ferrous & non-ferrous minerals atomic minerals, PGE, Gold and Diamonds (Kimberlites)
- Petroleum & Coal Geochemistry and Exploration
- Climate changes in the Geological history : impact on Earth
- Sustainable development and renewable energy resources
- Environmental Pollution - remedial measures
- Analytical geochemistry & instrumental methods of analysis
- Hard Rock Geochemistry, Modelling and Petrogenesis

Contact : Prof. K. Surya Prakash Rao, Hon. Secretary, Indian Society of Applied Geochemists (ISAG), P. B. No. 706, Osmania University, 1-2-7/1, "Roja", Kakatiyanagar, Habsiguda, Hyderabad - 500 007, Andhra Pradesh, India, Telefax : 040-27176020 (O), 040-27170246 (R), Mobile : 9848880980, E-mail : isag1993@yahoo.co.in, ksprao1939@yahoo.co.in

Fourth Biopesticide International Conference (BIOCICON2013), November 28-30, 2013, Tamil Nadu.

Theme :

- Microbes-basic and applied aspects
- Botanicals-basic and applied aspects
- Natural enemies
- Other Arthropod management

- Bionano materials in Pest and Disease Management
- Other aspects of Biopesticides
- Biopesticides for forest pest and disease management

Contact : Dr. K. Sahayaraj, Organizing Secretary, BIOCICON 2013, Crop Protection Research Centre, Department of Zoology, St. Xavier's College (Autonomous), Palayamkottai 627 002, Tamil Nadu, India. Phone No. +91- 462-4264376 (Off.); +91-462-2542303 (Res.) Mobile : 09443497192; Fax : +91 - 462-2561765, E-mail : biocicon2013@gmail.com.

5th Asian Conference on Colloid and Interface Science (ACCIS 2013), November 20-23, 2013, Darjeeling.

Theme :

- Adsorption
- Colloids and Dispersions
- Surfaces and Interfaces
- Nanomaterials, Biomaterials
- Molecular Assemblies
- Gels
- Thin Flims, Membranes
- Devices and Applications

Contact : Dr. Amiya Kumar Panda, Working President, ACCIS 2013, Department of Chemistry, University of North Bengal, Darjeeling 734 013, West Bengal, INDIA, Phone : +919433347210, Fax : +913532699001, Web : www.nbu.ac.in/notice/circular, E-mail : akpanda1@yahoo.com

S & T ACROSS THE WORLD

BODY'S CLOCK LINKED TO DEPRESSION

The disruption of sleep and other bodily rhythms that often accompanies clinical depression may leave a mark on the brain. A study of gene activity in the brains of people who suffered from depression reveals that their daily clocks were probably out of whack. The results appear May 13 in the *Proceedings of the National Academy of Sciences*.

"This is really important work, amazing work," says Noga Kronfeld-Schor, a physiologist who specializes in circadian rhythms at Tel Aviv University. "There's been indirect evidence, but this clearly shows a connection between disrupted circadian cycles and depression."

In mammals, daily rhythms such as sleep, hormone cycles and eating patterns are guided by a master clock in the brain whose rhythms are maintained in part by genes and patterns of light and darkness. The master clock can get out of sync with clocks elsewhere in the brain and body. This discord, for example, produces the out-of-sorts feeling of jet lag, says Jun Li, a statistical geneticist at the University of Michigan in Ann Arbor.

People with depression also often have off-kilter body rhythms. But the molecular and cellular mechanisms behind these disrupted cycles have been hard to pin down. Li and his colleagues took an ambitious approach with an unusual set of samples: the brains, removed just after death, of 34 people with depression and 55 people who didn't suffer from depression. All of the people had died suddenly, from heart attacks or suicide, for example, and each brain was immediately put on ice, Li says.

After determining how long after sunrise each person's death was, the team looked at what genes were turned on in six brain regions, gathering a total of 12,000 records of gene activity. Among non-depressed people, patterns were pretty predictable; some genes' activity consistently peaked at sunrise, others at midday, Li says. But in the depressed brains, gene activity seemed uncoupled from time of day. Their patterns of activity also weren't as predictable.

The research doesn't demonstrate whether depression causes the circadian disruption or vice versa, but it confirms a link and might lead to investigations of the physiological processes that are affected, says Ying-Hui Fu a molecular biologist and geneticist at the University of California, San Francisco.

Each brain analyzed in the study shows gene activity at only one point, the time of death. Circadian rhythm researchers typically take measurements from a person over the course of 24 hours. That strategy works for sampling blood cells, for example, but not brains. The brain data, which were collected with the help of collaborators at several universities including the brain bank at the University of California, Irvine, isn't perfect but is impressive, Fu says.

"The data set is very solid," Fu says. "And to collect 30 to 50 brains? Just getting blood or cheek cells is hard enough.

MENTAL PUZZLES UNDERLIE MUSIC'S DELIGHT

Whether you're rocking out to Britney Spears or soaking up Beethoven's classics, you may be enjoying music because it stimulates a guessing game in your brain.

This mental puzzling explains why humans like music, a new study suggests. By looking at activity in just one part of the brain, researchers could predict roughly how much volunteers dug a new song.

When people hear a new tune they like, a clump of neurons deep within their brains bursts into excited activity, researchers report April 12 in

Science. The blueberry-sized cluster of cells, called the nucleus accumbens, helps make predictions and sits smack-dab in the "reward center" of the brain — the part that floods with feel-good chemicals when people eat chocolate or have sex.

The berry-sized bit acts with three other regions in the brain to judge new jams, MRI scans showed. One region looks for patterns, another compares new songs to sounds heard before, and the third checks for emotional ties.

As our ears pick up the first strains of a new song, our brains hustle to make sense of the music and figure out what's coming next, explains coauthor Valorie Salimpoor, who is now at the Bay crest Rotman Research Institute in Toronto. And when the brain's predictions are right (or pleasantly surprising), people get a little jolt of pleasure.

All four brain regions work overtime when people listen to new songs they like, report the researchers, including Robert Zatorre of the Montreal Neurological Institute at McGill University

The links between the brain's reward center and the three other areas explain how simple sounds strung together in complex patterns can give humans so much joy, Salimpoor says. Music theorists have speculated that new music might tickle people's pleasure centers by engaging their minds in play. But until now, no one had matched up the theory to the neurobiology.

In the study, the researchers examined the brain activity of 19 people as they listened to short clips of new music in an MRI machine. At the end of each clip, volunteers could choose to buy songs they liked, using their own money. The researchers asked them how much they would be willing to pay, $0.99, $1.29 or $2, in a system similar to iTunes. If volunteers did not like a song, they could choose not to buy it.

Then researchers compared brain scans of participants who bid different amounts on songs. Amid the bustle of activity in the brain, the nucleus accumbens leapt to life when people heard songs they wanted to purchase. The more money people chose to spend, the livelier their nucleus accumbens was while listening.

Teaming neuroimaging with the iTunes-like system for buying music was "a very clever idea," says cognitive neuroscientist Aniruddh Patel of Tufts University in Medford, Mass. "It's a nice application of new technology to address an old theory in music cognition," he says. "In fact, the new findings seem to fit well with the old theory," he says.

"The results tap into the fundamental ways our brains deal with sound," says auditory neuroscientist Nina Kraus of Northwestern University in Evanston, I11. "The implications are rather enormous," she says. The work could help scientists better understand how humans decipher other complex sounds, such as speech.