COMING OF AGE – BOSE INSTITUTE UNDER D.M. BOSE

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Bose Institute was established in 1917 by Sir Jagadis Chandra Bose (JCB) using his own savings and donations received from different sources to undertake research involving both the living and non-living. JCB was a physicist by training and did pioneering work in physics that was much ahead of his time, till the end of nineteenth century. His focus shifted from physics research to biological research at the beginning of twentieth century when he aspired to establish an institute of international repute on interdisciplinary science involving both the living and non-living. He was the director of the institute from its inception till his death in 1937 and was the first person to introduce 'biophysical research' in India, a term unknown at that time. Debendra Mohan Bose (DMB) inherited the position of directorship in 1938 after the death of JCB, when he was Palit Professor of Physics at the Calcutta University. Incidentally, DMB was also a renowned physicist with experience of working abroad and at par with his contemporaries like M.N. Saha, S.N. Bose, C.V. Raman and others. It was a challenging task for him to maintain the reputation of the institute established by JCB as well as to enhance its research programme with the progress of time. This article presents a brief review of the development of the institute during DMB's directorship which covers a span of about thirty years. This is a story of struggles and challenges faced and the fight to overcome difficulties in order to build the modern institute that we see today. Individual contributions of scientists or of individual departments are kept to a minimum because detail research activities of the institute have been published in Annual Reports of the institute which are available online.

Introduction

Bose Institute was established at a time when Jagadish Chandra Bose's work on living and non-living systems was not accepted undisputedly in Europe and other places abroad, and when support for science research from the colonial powers was apathetic. He felt the urge to establish an institute to undertake this type of interdisciplinary research at his own pace and will, to show the world the worth of Indian ability to produce new science, and to prove that we are no less capable in scientific research than European scientists. He received enormous support from all the country and abroad, and the institute, which is a 'temple' his own words, was inaugurated on 30th November 1917.

Bose Institute witnessed two World Wars, the infamous Bengal famine of 1943, India's independence and partition, a shift from self-controlled administration to government-controlled bureaucratic system but maintained its supremacy in science research for a century which is not a trivial feat. However, D.M. Bose, successor of J.C. Bose, faced the brunt of it all. Unfortunately, while there exist several books on J.C. Bose,there is not a single book on his creation—the Bose Institute, except for a recent article authored by M. Siddiqui and S. Raha.[1]

The purpose of the present article is to complement other articles published in this issue focussing only on the changes and modernisation, development and expansion of

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science research, notable achievements made during the period when DMB, who succeeded JCB as the Director after his death in 1937, was at the helm of all affairs at the institute. It is not possible to present all the work done in the institute during this period (1938-1967), instead we will focus only on the efforts he put in for the betterment of the institute. Overall research contribution made by the scientists is important. Keeping this in mind, we refrain from mentioning names of individual scientists associated with the work, unless there are compelling reasons to do so. Some of these aspects have been discussed in a recent book on D. M. Bose authored by these authors.[2] The summary of work done under the Directorship of D. M. Bose is to be found in "Research activities in the Bose Institute from 1938 to date (1977).[3,4]

Winds of Change

Administration : D.M. Bose joined Bose Institute (BI) as its Director in 1938 leaving Calcutta University where he was Palit Professor of Physics. Incidentally, DMB was the nephew of JCB and grew up under the tutelage of his uncle. In order to understand the development of the institute and the progress of research instilled by DMB, it is important to understand the situation of Bose Institute when he inherited the legacy.

When JCB was at the helm of the institute, he enjoyed supremacy in all aspects of administering the institute and his personality did not allow anyone to question or criticize any of his actions. In fact, in a communication dated April 21, 1921 from the Education Department of Government of Bengal it was declared that during J.C. Bose's lifetime "his presence as Director should be considered as guarantee that the institute continues to carry out the objects of its foundation and to maintain a high standard of research".[5] As a result, during his lifetime certain powers were vested in him which included those of nominating his successor, filling up vacancies in the Governing Body and the appointment of professors and scholars.

According to the Annual Report (AR) for the year 1935-36 (AR for 1936-37 is not available online), members of the Governing Body (GB), who decided about the policies of the institute, were J.C. Bose, Abala Bose, D. M. Bose, N. C. Nag, A. N. Mitter and S. M. Bose. This was a group of people who were known to be either members of the Bose family or its friends. Immediately after DMB took charge of the institute, some understanding regarding the constitution of the Governing Body (GB) had to be reached with the Government of India, from whom the institute was receiving funds, however small it may be. A new Governing Body was constituted with eminent persons from different walks of life with the following persons as members: Rabindranath Tagore, Lady Abala Bose, Sir Nilratan Sircar, J. N. Basu – M.L.A., Birbal Sahni, S. C. Mukherji, B. M. Sen – Principal Presidency College, S. K. Mandal, S. M. Bose - Secretary B. I., N. C. Nag – Assistant Director, A. N. Mitter, Superintendent, and D. M. Bose – Director.[6] All the powers which were enjoyed by JCB were vested in the Governing Body.

Though BI was a "private" institution in character, but as it was getting some grant from the Government of India, the government gradually decided to get some control in the administration of BI. In January 1940, an Inspection Committee (with members: H. B. Dunnicliff – Chief Chemist, Central Revenues Control Laboratory, New Delhi; Wali Mohammed – Head of the Department of Physics, Lucknow University, and S. Krishna – Biochemist, Forest Research Institute, Dehra Dun) appointed by the Government of India was sent to review the work of BI, and if necessary, make suggestions on its scientific activities and administration.[7]

The Review Committee suggested changes in the constitution and in the plan of research work.[8] The Governing Body prepared a draft of regulations and byelaws which was sent to the Government of India for its approval.[9] As a result of this development, the central government agreed to provide grants. The draft which was sent in December 1942 was accepted as Regulations and Byelaws of BI in a meeting of March 1, 1945.[10] The new constitution was implemented on 1st April 1946. The government wanted to have some stake in the institute activities and accordingly, it proposed to constitute a Council in addition to the Governing Body. Also, the mode of appointment of the employees of the institute was changed from the sole discretion of the Director to appointment through advertisements. The Director was asked to advertise posts for the newly formed departments.[11] The Council made the following appointments: K. T. Jacob - Head of Department of Botany; J. K. Chowdhury - Head of Department of Chemistry and A. M. Mitter – a temporary Registrar.[12]

As expected, with the involvement of the government, bureaucracy increased. The pay scale recommended for the employees by the Review Committee in 1940 was abysmally low and was unattractive for highly qualified scientists. DMB, who knew the value of good quality scientists, fought against it and in 1947-1948 the central government revised the pay scales.[13]

After India's independence, the 2nd Reviewing Committee, consisting of M.S. Vallarta – Chairman, J.N.

Mukherji and S.P. Agharkar appointed by the Government of India, visited the institute on March 20-22, 1948. Subsequently, the constitution was amended by creating a Council as proposed earlier, in addition to the existing Governing Body and Trustees "to take up the responsibility of the administration and research of the institute through the Director".

DMB prepared a Memorandum for the use of the Committee, which included "a short account of the work of the Institute since the visit of the last Committee of Enquiry, and a scheme for expansion of the activities of the Institute. The latter included proposals for augmenting the staff of the Institute, for improvement of the scale of pay of its staff and for expansion of research activities."[14]

And further: "At the same time the methods and apparatus introduced by Sir J.C. Bose for physical and plant physiological investigations were to be further developed and utilized for the study of 'a nascent science which includes both Life and Non-life.'"[15]

Suggestions were also made in the Memorandum that "the Institute should be developed as an All India Institute for Research in Plant Science, with emphasis on Plant Physiology and Plant Genetics. The study of the sciences of Biophysics, Biochemistry[16], Microbiology and Animal Physiology should be considered as ancillaries to the main purpose of the Institute, …".[17]According to the AR of Bose Institute for 1953-1954, the Institute had many workers from outside Bengal in the past but they left for various reasons, one of them being better pay offer elsewhere. The general impression was that "An Institute with limited resources like this cannot compete with the government departments and the universities in the matter of emoluments."

Regulations and Bye-laws of BI were revised again and were sent to Ministry of Scientific Research and Cultural Affairs (SRCA) in July 1956. Surprisingly enough, the approval was not received even after 5 years, as has been reported in the AR of 1960-61. The Council decided the appointment of the Reviewing Committee on a regular basis at intervals of five years to review the progress of research and put in their recommendations in regard to research and infrastructure. The ministry of SRCA appointed a Review Committee in 1962 with Dr. D. N. Wadia, FRS, as the Chairman and Prof. S. N. Bose, Dr. H. Santapu, Dr. B. C. Guha and Dr. K. Mitra as members.

Major changes in the pay structure were implemented in 1960-1961, separating the two different kinds of structures for faculty and other staff (academic and non-academic). Designations of academic staff were also revised. Designations of the following ranks of academic staff existed till 1961: Head of the Department, Senior Research Fellow, Research Fellow were re-designated as Professor, Reader and Lecturer respectively. Academic staff were allowed to enjoy the UGC pay and allowances as adopted by the Calcutta University with effect from 1.4.1961; while the non-academic staff had to follow the pay scale and allowances at par with CSIR.

Organizational Re-structuring, Collaborations and Grants-in-aid: After DMB became the Director, parallel with the changes in administration, major changes were brought about in the organizational structure of research activities as well. While research was performed in four different areas of science during JCB's time, namely physics, plant biology, agricultural chemistry and anthropolgy, these were restructured into distinct departments within a year after DMB assumed charge of BI. As reported in the AR of the year 1937-38, following were the departments: a) Department of Plant Physiology b) Department of Biochemistry and Agricultural Chemistry c) Department of Genetics d) Department of Anthropology e) Department of Zoology f) Department of Physics.

The most important thing to notice is that during the modernization of research activities of the institute, DMB did not ignore the plant physiological investigations started by his uncle. For example, he continued research on photosynthesis in plants along the lines of JCB. It was shown by JCB that organic acids can serve directly as a substitute for CO_2 in photosynthesis of plants. In photosynthesis plant leaf produces carbohydrate from CO_2 and water with the help of light energy. JCB found resemblance of photosynthetic reactions under increasing concentration of CO_2 and malic acid. Malic acid is known to break into sugar and CO_2 under the influence of light. Thus it can be assumed that a part of the malic acid is converted to glucose by light, while the products produced in the process (CO_2 and H_2O) are fixed again in the plant by the ordinary process of photosynthesis, as represented by the following chemical reactions.

with CO_2: $6CO_2 + 6H_2O = C_6H_{12}O_6 + 6O_2$;

with malic acid: $6C_4O_5H_6 = 3\ C_6H_{12}O_6 + 6CO_2 + 6H_2O = 4\ C_6H_{12}O_6 + 6O_2$

Assuming this, when CO_2 concentration in an aqueous solution is equivalent to the CO_2 released from a malic acid solution, the increase of weight after photosynthesis of a plant in a malic acid solution will be four times that in the CO_2 solution. A sensitive torsion balance was fabricated to use the torsion balance method as was described by JCB. Experiments with *Hydrilla* and *Thankuni* leaves did not produce the expected results and the investigation was abandoned.

Regarding his role as a successor of Acharya Bose, DMB opined "As I see it, the role of his successor has been to consolidate and extend his teachings, to supplement the biophysical with biochemical approach to Living Nature, to study the beginning of life from inanimate matter, the mechanism through which the continuity of living organisms maintained through generations, and how the organisms adapt themselves to changes in environmental conditions". There is no doubt that most of the research work in this area now being carried out in the institute had been initiated or supported by D. M. Bose.[18]

DMB put in his best efforts to pick up good researchers to shape the future of the institute. He appointed Dr. B. K. Kar, a Ph.D. from the University of Leipzig and Member of the "Deutsche AkademieMunchen", in the Department of Plant Physiology and Genetics; Dr. J. K. Chowdhury, a Ph.D. from Birmingham, in the Department of Chemistry and Dr. N. B. Das who was working with Nobel Laureate Prof. Hans von Euler-Chelpin in the Department of Physics.

D. M. Bose also realized that in addition to continuing research in selected areas of physics, chemistry and biology, practical applications of the results of such investigations to agriculture, industry and medicine were equally important for the development of the nation. In order to achieve this he reorganized the research groups and it was he who introduced research in microbiology in India at Bose Institute and ventured to produce new antibiotics. The institute in collaboration with Government Cinchona Plantation at Mungpoo started a suitable method of vegetative reproduction of cinchona plants in Calcutta and Darjeeling.[19] This project 'for devising a quick vegetative method of propagation of cinchona trees by auxin treatment' was a part of a long term programme.[20] In addition, the Institute of Rural Reconstruction, Visva Bharati, was contacted for scientific cooperation in their scheme of afforestation and soil reclamation at Surul and its neighbourhood in the Birbhum distrtict.[21]

A year later, the institute, jointly with the Department of Health, Government of India, started (i) physiological investigations and (ii) cytological investigations on cinchona.[22] The roots and buds of about 50 lots of *C. ledgeriana* and *C. succirubus* plants were smeared with aceto-carmine and analyzed to determine the time of division. The materials were microtomed for cytological studies.[23]

Thereafter, research grants from industries started coming. The Bengal Immunity Co. Ltd. gave a grant for applied research in Microbiology and research on the vernalization of paddy in Bengal.[24] The Raymus Corporation gave a grant for a project on "Investigations on Glass production."[25]

BI proposed a project to the Department of Agriculture, Bengal; and to All Indian Central Jute Committee "on the production of new mutants of Jute by irradiation with X-rays, γ-rays and neutrons."[26] It was found that the treated plants attained greater basal diameter.[27] In the year 1949-1950, Indian Central Oilseeds Committee came forward and sanctioned a grant of Rs. 60,000 for an investigation 'on the effect of x-ray irradiation on Brassica and Sesamum.'[28]

DMB also changed the character of the relationship between the director and research workers of the institute. Research workers were given freedom to select their own research programmes and were not merely an assistant to the Director which was the practice followed so far. He realized that with a meagre sum of Rs. 1,12,274/- (the total funds available as per the audit report of 1938-39), it was impossible to work on the different projects that he was envisaging in order to convert the institute into a modern research centre. Even grants received from different government organizations and industries were not enough. He devised means to increase funding by the Government in the form of grants-in-aid, which continue to be the financial backbone of research activities of Bose Institute even today. The first grant-in-aid from the Board of Scientific and Industrial Research (later known as Council of Scientific and Industrial Research) was obtained in 1940 for the construction of a high-powered ultrasonic generator. The powerful ultrasonic generator was built soon enough and was used for "testing and cutting of quartz plates for the radio industry" by the year 1942-43.[29]

DMB was a member of the committee which recommended the formation of the Atomic Energy Commission (AEC). In May 1946, members of the AEC decided on four important operational strategies for future atomic research programmes in India. One such strategy was that "a capital and recurring grant would be given to D.M. Bose for research on the trans-uranic elements in Bose Institute".[30] This paved the path for receiving huge grants from the AEC for research in nuclear physics, cosmic rays, construction of neutron generator and other research activities. He also obtained research grants for agricultural research, especially for improving the yield of cash crops through radiation-induced mutation.

When DMB retired as the Director of the institute in 1967, BI had the following four departments: (i) Physics and Biophysics; (ii) Chemistry including Plant Chemistry, Physical and Biochemistry; (iii) Botany including Plant Physiology, Cytogenetics, Plant Breeding; and (iv) Microbiology including Soil Microbiology and Genetics of Microorganisms.[31]

Expansion of Laboratories

Soon after DMB became the Director he started building new research laboratories. This deserves special mention as this will help understand the evolution/ progress of the institute under DMB's leadership. We have highlighted a few of the developments here because of paucity of space.

- A new section 'Microbiology' was started; while 'Theoretical Physics Section' was closed down.
- On the top of the workshop, a new Chemical Laboratory was constructed.[32] It contained a small room for low temperature work.[33]
- According to the AR for the year 1945-1946, four bighas of land adjoining the Falta Experimental Farm was taken on lease to provide additional land for grant-in-aid investigations on jute and rice. The Government of West Bengal was requested to provide grants for the extension of staff quarters and laboratory in the Falta Experimental Farm.[34] At the suggestion of the Minister of Agriculture and of Land Record, a three year scheme was submitted in November 1947. This included research in cotton, jute, rice and pulses. Allotment of another 40 bighas of agricultural land was suggested.[35]
- The erection of Centenary Memorial Laboratory in 125 bighas of land near Madhyamgram was proposed in 1960. The Govt. of India sanctioned Rs. 1,37,500/- to meet half the cost of land and the Govt. of West Bengal agreed in principle to share the cost of the land on 50:50 basis. Apparently, nothing moved much in this direction as the Centenary Laboratory was finally built elsewhere.
- According to the AR of the years 1966-67, BI located at 93/1 Acharya Prafulla Chandra Road reached a saturation point leaving not much space for future laboratory expansion. DMB in concurrence with the Council approached the Chairman, Calcutta Improvement Trust (CIT) for a plot of land of about 4 bighas in the Manicktala Extension. CIT allotted 78 cottahs of land to BI on lease, where the present Centenary Building is situated, at a total cost of Rs.7,02,000/- . 10% of the total cost as a 1st instalment was deposited on 12 January 1967.
- The methods and apparatus introduced by Sir J.C. Bose for physical and plant physiological investigations were further improved[36] which involved Capital Grants (i) Rs.1,70,000 for building (ii) Rs.2,50,000 for equipment and laboratories and (iii) Rs.3,00,000 for purchase of apparatus, and recurring Grants of Rs.2,00,000 for staff salaries and Rs.1,00,000 for other recurring expenditure."[37]
- An air conditioned glass house was built for physiological investigations in cinchona under controlled conditions such as temperature and humidity.[38]
- The Trustees of the J.C. Bose Funds donated Rs.50,000 for the construction of a laboratory above the lecture hall.[39] A cosmic ray laboratory was set up on the roof of the main building with controlled temperature and humidity. The laboratory was used for continuous record of cosmic ray intensity by using pressure ionization chamber built indigenously at BI. A counter telescope system was also set up in a small hut built in the institute garden for investigations on secondary radiation produced under cosmic ray absorption in different thicknesses of lead.
- In October 1950, a plant pathological laboratory was started in Mayapuri, Darjeeling, for investigations on the viral, fungal and bacterial diseases affecting economic crops of the Darjeeling district. A scheme for placing this laboratory on a permanent footing was submitted to the Ministry of Agriculture, West Bengal, and was subsequently approved.[40]
- The construction of the "Western Block" which was started[41] during J. C. Bose Centenary was completed in 1961. In the northern half of the ground floor was the workshop administrative unit, a refrigeration assembly and repair workshop. On the first floor on the southern side, a modern seminar room with accommodation of 100 persons was constructed. The northern wing of the first floor was divided into two mezzanine floors and was equipped with an enzyme laboratory.[42]

- A special air-conditioned room to house Jagadis Chandra Bose's papers and documents was constructed.[43]
- The Neutron Generator laboratory was built in the northern side of the 'West Building'. The AR of 1947-48 mentions that "The ceiling of the basement and the walls of the upper room are being shielded with soil and reinforced concrete, so that the neutron dose nearest to the residential quarter is much less than the tolerance dose even when the machine is operated at its optimum efficiency"[44].

Difficult Years - WWII and India's Partition

Several disturbing events affected the general situation in India and had an adverse effect on research activities during DMB's tenure. These included the second world war (1939-1945), Bengal Famine (1943) partition of India (1947) and National Emergency during Indo-China war (1962). Bengal being the hotbed of political activities suffered the most. In this context, it will be worth quoting from the contemporary Annual Report, which described the situation under the title 'War Measures' as follows: "The construction of a large glass house commenced in November, was not completed; the panes of plate glass have been stored in a safe place, the roof covered with corrugated iron sheets, and the sides blocked with wooden planks. … Air raid shelters have been provided for the staff of the Institute in some rooms on the ground floor. Other rooms on the ground floor with bricked up doors and windows are being utilised for the storage of books and apparatus and chemicals. Some valuable books and apparatus have been sent to Mayapuri, Darjeeling. … The front hall of the Institute has been placed at the disposal of the A.R.P. authorities for shelter purpose. Slit trenches have been dug in the lawn of the Institute."[45]Referring to the Annual Report of BI for 1943-1944, the December 8, 1945 issue of *Nature* reported that the Institute had difficulty in securing chemicals, photographic- and glass materials.[46]

During war time valuable apparatus and books and other volumes of the library of the Institute were stored in a leased house in Santipore. After about one year, these were brought back, but "the historical collection of Sir J.C. Bose's instruments" were still kept in Mayapuri, Darjeeling.[47] As a result, scientific activities of Bose Institute were hit the worst. It was reported that due to shortage of materials coupled with migration of qualified staff, research work was severely hampered. Anticipating that the days of British Empire after the war were limited, and the changes thereafter may be difficult to handle, several important research posts were not filled up.[48]

The second bout of bad period was during the partition of India. Historically, two states suffered the most : Bengal and Punjab. Calcutta was one of the most affected cities in India due to riots. Understandably, educational institutions and their work suffered and B.I. was no exception. It was reported: "During and after the August disturbances the work was on several occasions interrupted, and at other times carried on with depleted staff, due to the difficulty which the staff found in coming to the Institute, which is situated in a disturbed area. The boundary walls of the Institute have been raised and other protective measures have been taken."[49]

During the partition, non-Muslims were forced to migrate from East Bengal to India. Many eminent scientists located at Dacca University and Lahore University migrated to India which, in a sense, was a gain for India. Prof. J.K. Chowdhury of Dacca University joined Bose Institute and later became the Head of the Department of Chemistry. His grant-in-aid projects such as "Desulphurisation of Coal" and "Impregnation of jute yarns with suitable synthetic resins" were also transferred to B.I.[50]

Visits, Lectures and Seminars

During J.C. Bose's time the institute was an island of excellent science which worked in isolation,hardly connected with other scientific activities worldwide. JCB himself went abroad several times on invitation to demonstrate his scientific works and to deliver lectures, but holding seminars, lectures or visits by international scientists at the institute was uncommon. According to the annual reports available for the period 1927 to 1937, we find that no seminar or lectures were arranged during that period and only one scientist, Prof. Hans Molisch, visited BI and worked here for sometime. Probably his personality, versatility and originality allowed him to do that.

In general, exchange of ideas between scientists is considered to be the backbone of good research. DMB realized this, as he was one of the very few privileged physicists who had studied abroad and had come in contact with renowned scientists like J.J. Thomson, C.T.R. Wilson, M. Planck, A. Einstein and Heinrich Rubens and others. Nobel Laureate Professor Robert Millikan was probably the first foreign scientist to visit Bose Institute after J.C. Bose's death. He came with his colleagues in November 1939 while they were In India in connection with cosmic ray investigations.[51] In a meeting of the Indian Physical

Society held at BI, Millikan delivered a lecture on the historical survey on cosmic ray investigations.[52]

Bose Institute has the distinction of having Prof. A.V. Hill, one of the Secretaries of the Royal Society of London delivering a lecture titled "On the measurement of heat developed in muscles and nerves".[53] Prof. Hill was visiting India to declare four Indians (K.S. Krishnan, Birbal Sahni, H.J. Bhabha and S.S. Bhatnagar) as Fellows of the Royal Society of London since they could not attend the ceremony due to WWII. DMB reached out and managed to organize a lecture by Prof. Hill, taking advantage of his visit to India.

After the end of WWII, the flow of visitors at Bose Institute increased significantly as is evident from the annual reports of BI. On an average, five to six foreign scientists visited the institute every year. Connectivity with international scientists opens up opportunities for working in foreign laboratories of importance. Visits of eminent scientists from abroad gradually helped the institute to get an international character and helped some of its scientists to work at different laboratories abroad[54,55,56]. Experiences gained by working at foreign laboratories were well utilized for the progress and development of the institute. The Annual Report of 1952 mentioned "Two research fellows recently returned from the United States and Canada are constructing apparatus for cosmic ray investigations, which will be taken to Darjeeling next spring for experiments at high altitudes."[57] We found mention of several research workers working in the laboratories of eminent scientists including some Nobel Laureates[58,59,60].

"Acharya J.C. Bose Memorial Lecture" was launched in 1938 and has been continuing since then. The first speaker was Rabindranath Tagore. Due to ill health, Tagore could not physically attend the meeting, and his talk was read out by Ramananda Chattopadhyay.[61] The second memorial lecture - "World, Atom and Nuclei", was delivered by M.N. Saha.[62] In the same year, DMB initiated a Physics Seminar in cooperation with the Department of Physics and Applied Mathematics of Calcutta University. H.J. Bhabha delivered four lectures under this programme.[63] In addition to established scientists, younger research workers were also encouraged to deliver lectures on current topics to keep abreast of the recent developments in physics. It may be noted that 17 such lectures were delivered in 1940-41. It is a matter of great regret that this series of lectures, initiated in 1938, has been reduced in scale and regularity over the years.

An international seminar on "Structure and Functions of Living and Non-living Systems" was organized on the occasion of the Golden Jubilee of Bose Institute in 1967, where Academician A.I. Oparin was the key speaker.

Legacy Continued

The workshop of Bose Institute played a pivotal role in science research from the time of Jagadis Chandra Bose, as all the equipment he used for his phenomenal work were made at the workshop of the institute. D.M. Bose, capable of building his own apparatus (he built the cloud chamber after his return to India from Germany), continued to maintain this legacy and encouraged research students to build their own apparatus and use innovative ways to solve problems. This legacy continued even years after his death. Presented below are examples of some instruments built in the institute for competitive research.

- Radioactive ^{60}Co was prepared in the laboratory by irradiating a solution of sodium cobalticyanide with a small quantity of cobalt nitrate by thermal neutrons obtained from Ra-Be source placed in a paraffin moderator for a period of three months.
- As has been reported in the AR of 1947-48, a self-rectifying hot cathode X-ray tube of 15mA current was constructed. This was meant for irradiation work to study mutation in seeds etc. by irradiation.
- Within another three years (1950-51) a second X-ray tube with demountable incandescent cathode capable of continuously running at 40 kV and 30 mA capacity was constructed. Both the tubes were used for irradiating seeds of economic plants such as jute, cotton and oilseeds.
- X-ray dosimeter was constructed which gave a reading of 100μA when a 1mg Ra source was placed at a distance of 5 cm from the ionization chamber.
- A new rectangular cloud chamber with dimensions 24"x24"x12" was constructed to discriminate different kinds of particles emitted during nuclear interactions with high energy primary cosmic radiation. A low pressure Wilson chamber filled with hydrogen at 20 cm pressure was built to study fission fragments.
- Dr. S.D. Chatterjee fabricated a uranium coated ionization chamber to study neutron induced fission in uranium in 1939 (fission was discovered in 1938 by Otto Hahn). By using a simple neutron source he observed spontaneous fission in uranium. But while he was confirming that the signatures he was receiving were not from other external sources, the

announcement of the discovery of spontaneous fission by Flerov in the Soviet Union (1941) was made. Flerov is considered as the discoverer of spontaneous fission.

- Dr. Chatterjee was able to obtain pure helium from the thermal spring at Bakreswar. Helium obtained in this way is now used in the ion source of Variable Energy Cyclotron Centre in Kolkata.
- A (d,t) neutron generator was built indigeneously at Bose Institute in the early fifties. This was the second such generator in the country, coming only after the commissioning of the first neutron generator at Tata Institute of Fundamental Research in Bombay. Very important studies on neutron cross sections were carried out using this neutron source.
- D.M. Bose himself improved the photographic emulsion technique to make it a quantitative tool for radiation research and used it in collaboration with Bibha Chowdhury for cosmic ray studies.
- The physics laboratory was one of the first in the world to use methyl borate thermal neutron detector in 1957.
- Paper and column chromatography were indigenously developed at Bose Institute in the early fifties and were successfully applied in the field of plant biochemistry. The nitrogenous substances in the nodules, roots and sterile roots of plants were successfully separated with this technique.[64] Also, sugar-constituents in jute hemicellulose were studied.[65]
- A powerful ultrasound generator was constructed with the huge grants received from CSIR, all of whose constituent parts were constructed at the institute workshop. This generator was used in studying physical properties of liquids, its effect on living organisms etc.
- An irradiation facility to irradiate biological samples with gamma rays, known as 'Gamma Garden' was built at Nilganj near Barrackpore. It contained a 20 Ci cobalt-60 source. The source, when not in use, was stored in a steel tube 20 feet below the surface of the earth. The facility was handed over to the Jute Agricultural Research Institute, Barrackpore, in 1962.
- Another facility at the main campus of Bose Institute to irradiate samples with uniform dose by rotating the samples about their own axes was built to study changes of physical properties of different substances such as viscosity with dose etc.

Necessity is not the Only Tool for Invention

Necessity is not the only method of invention; scarcity of resources also forces one to invent ways to survive. Bose Institute is a good example to showcase how competitive research can be pursued on a global scale using very limited resources. The condition prevailing at Bose Institute during the period under discussion may be realized from the following remarks made by a senior professor of physics "sources (radioactive) available for research were scarce, detectors had to be fabricated from scratch, electronic equipment are not available commercially, and had to be home-built using whatever components were available, information flow in the form of books, journals and reports was almost nonexistent, financial and human resources were severely limited and communication and contacts with more advanced laboratories abroad were few and far between. Research was more inclined to be an art in pursuit of science."[66]

An important aspect of that time was that although each group was under the leadership of an individual, membership of the group was not exclusive and any member of one group was free to involve himself/herself in investigations which were in the area of interest of another group. This flexibility accounted for a large number of publications and achievements in which various members from different groups were involved. In fact, collaborative research flourished during D. M. Bose's time.

Building innovative and customised by scientists instruments for their own research as described above helped overcome funding problems for acquiring sophisticated equipment from abroad. Foreign exchange was a rare commodity at that time. Under this difficult situation scientists became highly innovative in arriving at simple solutions to complex problems which the West would solve by using computers or other expensive instruments. At that time computers were available only at TIFR and at some commercial houses. Development of a uniform response photon counter which measured the scattered gamma rays with uniform efficiency over a range of photon energies is one such example. The efficiency of all radiation detectors are energy dependent and so proper detection of scattered photons with varying energies requires suitable corrections for each energy using complex mathematical artifacts. Use of uniform response photon counter eliminated the use of a computer for applying these corrections.

Another good example was the development of the spherical symmetry method for determining the neutron absorption cross section in uranium. The method depended on the simple fact that a spherically symmetrical system has no preferred direction. As a result, scattered neutrons do not contribute in any way to the fraction of neutrons emitted by a centrally placed source which pass through the spherical absorber. DMB proposed through the journal *Science and Culture* that India should build a nuclear reactor for training and research purposes for which various thermal neutron cross sections were necessary, specially in uranium. The published values are ambiguous with huge uncertainty due to inaccurate methodology applied and this motivated scientists to invent a more accurate method as described above.

In the absence of high resolution germanium detector used gamma rays, to detect which were prohibitively expensive at that time, a detecting system was developed by light division method using the commonly available sodium iodide crystal, enabling separation of two closely, but not too close, lying photon energies.

Historic Events

Nuclear Energy Programme in India : When people talk about nuclear energy or atomic energy programme in India, names of M.N. Saha and H.J. Bhabha come up. It is a matter of sheer irony that D.M. Bose and Bose Institute are not mentioned, in spite of the fact that the contribution of DMB and Bose Institute is no less significant in shaping the nuclear programme of India.

The turning point in the history of nuclear physics was the discovery of nuclear fission in 1938 when Otto Hahn and Fritz Strassmann observed that a uranium atom bombarded with thermal neutrons breaks into two lighter fragments, releasing a huge amount of energy. The dropping of atomic bomb in Hiroshima and Nagasaki demonstrated the potential (mis)use of such energy. The utility of fission reaction both for war purposes and as a source of industrial power had been gaining momentum all over the world. An Atomic Research Committee was formed by the Council of Scientific and Industrial Research in which D.M. Bose and Bose Institute along with some other selected persons and institutes were invited to participate in shaping the Nuclear Energy programme of India[67].

Bombing at Hiroshima and Nagasaki posed a serious question before the scientists on the role of nuclear fission. According to the journal Nature "… the Atomic Research Committee of the Council of Scientific and Industrial Research, India, has recommended an intensive geological and physico-chemical survey of the thorium-bearing minerals in Travancore, and set up a sub-committee to draw up proposals for a similar survey of uranium-bearing minerals in India." The centre recommended the Tata Institute of Fundamental Research in Bombay to build a 300 MeV betatron with a team of ten workers; approved grants to Prof. M.N. Saha for operational expenses of a cyclotron to be set up at Calcutta University, and funds for research on the trans-uranic elements to Prof. D.M. Bose at Bose Institute."[68]

In one of the ARs under the title "Nuclear Physics" we find that it was proposed to restrict the atomic investigations to "fissionable properties of nuclei of the heaviest atoms like Uranium, Thorium etc., with a view to the utilization of the energy released in atomic piles built up of fissionable materials, for the purpose of industrial development; also it was proposed to utilize the radioactive fission products as trace elements for biological investigations."[69] However, getting radioactive material from abroad was not only expensive but also difficult. After the WWII the situation was changed and the Government of independent India was willing to invest money. From the allotted grant, BI bought a 160 mCi of Ra-Be neutron source from Canada.[70] Neutron absorbers were also ordered.[71] Researchers at Bose Institute began to study: "(i) transuranic Elements (ii) nuclear fission in Uranium and other heavy elements, by double ionisation chamber and Wilson chamber (iii) scattering and absorption cross sections for neutrons in Thorium and Uranium"[72] In 1950-1951 investigations on the absorption cross section of uranium oxide for neutrons were continued[73].

Separation of U and Th using "microphoretic method" was started at the same time. The method was invented for the separation of some ions of the first transition group of elements. As many as fifty experiments were performed to separate Th from U, but from the results it was concluded that the method was not satisfactory : "No clear separation of the U and Th cations could be obtained."[74]

From the analysis of black sand from the seashore near Puri it was shown that "Loss of ignition in the case of U_3O_8 (0.0022%) and ThO_2 (0.09%) were 1.59% and 35.64%, respectively. It was concluded that the sample was a mixture of silica, Bauxite, Ilmenite and Monazite (nearly 1%)".[75]

Spontaneous Fission Observed : Excited by the discovery of nuclear fission, Shyamadas Chatterjee immediately started studying neutron induced fission in uranium by fabricating a uranium coated ionization chamber. To his surprise he observed distinct counts even when there was no neutron source and the apparatus was well shielded so that no cosmic ray could enter. Before realizing that these pulses were arising from spontaneous fission of uranium, Chatterjee got engaged in trying to rule out that these pulses were due to any other spurious source. In the meanwhile this phenomenon was reported by two Soviet scientists Georgi Flerov and Konstantin Petrazhak in their paper “Spontaneous fission of uranium”, and they are credited for the discovery of spontaneous fission. Chatterjee later calculated the half-life of spontaneous fission in uranium from his experimental results. The data, published after WWII, showed that similar values were obtained by other scientists as well.[76]

Cosmic Ray Research and Misplaced Honour : During his stay in Berlin, DMB had worked under E. Regener, one of the experts in cosmic ray research. As a result he was conversant with cosmic ray research much before M.N. Saha or H.J. Bhabha entered this field. As JCB was not interested in this field, it can only be DMB who can be credited with the introduction of cosmic ray research at BI, even before he became the Director. It is evident from R.C. Ghosh’s article where he stated that work was done with suggestions from Prof. D.M. Bose.[77] By the middle of the 1930s BI had two research stations, one at Calcutta and another at Darjeeling. Ghosh studied the problems of east-west and north-south asymmetry at both these places.[78]

There is an interesting story related to the application of photographic plates in cosmic ray investigation. In the Science Congress session in 1938, R. Taylor and W. Bothe discussed the investigation on the tracks of ionizing particles recorded in photographic plates. This discussion led DMB to study cosmic rays using photographic plates. In a series of articles published in *Nature,* DMB and his co-worker Bibha Chowdhury identified a cosmic particle having an average mass close to 200 times the mass of electron (later known as mu-meson), by exposing Ilford half-tone photographic plates to cosmic rays during 1939-1942 in Darjeeling. Unfortunately, due to World War II restrictions, full tone photographic plates were not available in India at that time. However, C.F. Powell used the exact same method independently for determining the mass of mesons (found to be 216 times the mass of electron) but with improved full-tone photographic emulsion plates. In recognition of this achievement, Powell was awarded the Nobel Prize in 1950 “for his development of the photographic method of studying nuclear processes and his discoveries regarding mesons made with this method.” Powell, to his credit, admitted in his book, *The Study of Elementary Particles by the Photographic Method*, that the method developed by Bose and Choudhuri in 1941 on distinguishing between tracks of proton and meson in an emulsion was indeed the first attempt, and commented that “the physical basis of their method was correct and their work represent the first approach to the scattering method of determining momenta of charged particles by observation of their tracks in emulsion.” Thus a chance of winning the Nobel Prize was missed by a whisker. The details of the work done by DMB and his co-worker have been described elsewhere.[79] After the departure of Bibha Chowdhury, there was a brief pause in cosmic ray research till M.S. Sinha returned from abroad and rejoined Bose Institute[80].

In cooperation with the Regional Meteorological Observatories, Alipore, Bose Institute sent up small batches of plates in pilot balloons which carried radio sonde arrangements for recording altitudes, temperature and humidity. The balloons reached an altitude up to 40,000 ft., and the balloons burst at this height[81]. This resulted in the enclosed instruments getting scattered and lost. To get the instruments and recording plates back, the recording instruments were then enclosed in a light bamboo cage. The cage included an announcement of a reward to be given to the person who would return it to BI. A similar reward was declared for the finders of the packets containing the recording plates.[82]

B.I. had the distinction of being one of the organisations in India which took part in the IGY (International Geophysical Year) Cosmic Ray Programme (January to December 1958; January to November 1959). It was reported that “Sudden decrease in cosmic ray intensity associated with the solar flare and magnetic storms have been observed on the following dates: March 25, May 29, September 15, 1958 and May 11, July 17, 18 and September 2, 1959. Similar variations in cosmic ray intensity have also been observed by participating laboratories in other parts of the world..... Data obtained by means of combination of fast recording ionisation chamber and Geiger counter on interaction of high energy nuclear active particles with matter obtained at Darjeeling, have been analysed mainly to evaluate the following properties of the nuclear active particles (i) energy spectrum, (ii) charge to neutral particle ratio, (iii) interaction cross section with lead and aluminium.”[83]

Discovery of Cholera Toxin : Sambhunath De is an unsung hero in the scientific community, in spite of his immense scientific contribution towards the discovery of “The ligated ileal loops of rabbit to demonstrate luminal fluid accumulation by *Vibriocholerae* culture filtrate”. Being a non-believer of the poison theory of Robert Koch who discovered *Vibrio cholerae*, the bacteria responsible for cholera, De was interested in finding a suitable animal model for reproducing the symptoms of cholera. The discovery of exotoxin promoted a new paradigm in research on cholera and in finding a treatment aimed directly at neutralizing the cholera exotoxin. Bose Institute was instrumental in the discovery because the facility for toxin isolation were made available to De who worked at BI as an honorary worker since 1954. He did receive international recognition for this work including the nomination for the Nobel Prize by none other than the Nobel Laurate Professor Joshua Lederberg, as has been mentioned by Eugene Garfield.[84] In 1978, several years after his retirement, The Nobel Foundation sought him out (though their first letter did not reach him), requesting him to participate in the 43rd Nobel Symposium on Cholera and related diarrheas.[85]

Beginning of Studies on History of Science in India : The beginning of the studies on of Science in India was originated after the 'National Symposium on the History of Sciences of India' under the sponsorship of the National Institute of Science of India (now known as INSA) at Bose Institute in 1961 under the leadership of DMB.

Major Achievements

Major scientific works and achievements have been amply presented in Annual Reports and at different times and on different occasions such as "Research activities in the Bose Institute from 1938 to date" (1977)[86]; Progress of Research from 1938 to 1955.[87] In order to avoid repetitions and paucity of space, we present here only some of the notable scientific works done at the institute. This report is not exhaustive and therefore may be subject to omission of some works for which the authors beg to be excused.

When DMB left the Calcutta University to join Bose Institute, R. C. Majumdar, A. K. Datta, S.D. Chatterjee, M.S. Sinha and Bibha Chowdhury also accompanied him.[88]DMB sent A.K. Dutta to Berlin to work with Peter Debye, Nobel Laureate, on the theoretical and experimental aspects of ultrasonic waves.[89] Debye was famous for his observation of diffraction pattern produced when ultrasound passes through a liquid[90]. A theoretical explanation of the observed position and intensity of diffraction bands was also given by C.V. Raman and N.S. Nath[91]. Bose Institute is known to be the first in Kolkata to start ultrasonic research seriously after the return of A.K. Dutta. However, sudden breakdown of the ultrasonic generator hampered the progress of research[92]. In addition to physics research to study properties of liquids, detection of flaws in casting or under-water depth measurement, anomalous absorption of ultrasonic radiation in benzene, carbon tetrachloride and carbon disulphide etc. were also undertaken.[93,94]

Ultrasonics were also applied to biological research. Bactericidal action of ultrasonic oscillation on different kinds of bacteria like *E. Coli* and *S. Aureus* was studied. It was found that the ultrasonic radiation has lethal action on large micro-organisms like yeast, paramecium and spirogyra but was found to be ineffective in killing bacteria belonging to the cocci group[95]. Cytological observations were made on the effect of ultrasonic on the root tips of four species of plants. It was found that despite a marked difference in chromosome and nuclear sizes, no significant differences were noted due to ultra sound radiation. The changes observed were attributed to mechanical factors, such as higher frequency and intensity.[96]

Nuclear and Radiation Physics

The huge grant sanctioned by the Atomic Energy Committee helped to form a respectable programme on nuclear and radiation physics. At the beginning of the 1950s there were nine scientists in the Department of Physics under the project "Board of Research on Atomic Energy (BRAE)".[97] M.S. Sinha, I.L. Sarma, A.M. Ghose and N.K. Ganguly were responsible for "Transuranic elements and nuclear fission of heavy elements"; S.P. Dutta for "Use of photographic plates for the study of nuclear disintegration"; and A.N. Banerjee and H. Raha for "Setting up of medium voltage positive ray discharge tube".[98]According to the AR for the year 1952-1953, a new project on the use of C^{14} and P^{32} as radioactive tracers and as mutagenic agent in plant was sanctioned by the BRAE. For this work radioactive $BaC^{14}O_3$ and $Na_2HP^{32}O^4$ were imported. It was reported that "the mutagenic action of beta-radiation P^{32} will be studied by absorbing $Na_2H_3PO_4$solution in roots of seedling of different growing plants."[99]

The availability of a large variety of radioactive sources made in Indian reactors operated by the Department of Atomic Energy, and indigenously developed detectors and associated electronics (through ECIL) in the late fifties allowed Bose Institute to revisit its research plan to take advantage of the situation.[100] Measurements of interaction cross sections of fast neutrons (14.8 MeV) and gamma rays were the main subjects of investigation. Emphasis was on the development of newer methodologies to obtain precise values as well as on the development of detectors with specified energy response. Precise neutron and gamma ray scattering cross sections were measured using suitable methodologies for these interactions. Using measured gamma ray scattering cross sections and semi-empirical methods to determine effective form factors, it was possible to observe the electronic structure of heavy elements like lead from experimental measurements for the first time.

A methodology to apply the radioactive tracer technique to study physical properties of liquids such as diffusion was developed. The accuracy attained by this method was almost an order of magnitude better than that obtained by any of the other existing methods.

Biological Sciences

Paper chromatography and column chromatography developed at the institute were applied extensively in the field of plant biochemistry. Free amino acids present in the leaves of *Mimosa pudica* and *M. Speggazzini* were investigated. A fair number of amino acids were found to be present in the leaves. In cooperation with the Microbiology Department, the free amino acids present in the nodules and roots of certain leguminous plants were separated. "The technique was also applied to study the enzymatic breakdown of pectin and of pectin like substances supposed to be present in jute."[101] The nitrogenous substances in the nodules, roots and sterile roots of leguminous plants were successfully separated with this technique.[102] Sugar-constituents in jute hemicellulose were also studied.[103] For instance, R. Consden, A.R. Gordon and A.J.P. Martin had "observed that in the case of phenol saturated with water as the developing solvent, R_F values of amino-acids increase with increase of temperature, since the water-content of phenol varies directly with temperature within the range studied. The reverse is the case with collidine, …. The water-content of solvents which are completely miscible with water can be suitably adjusted, the phase-composition remaining unaffected by temperature." D.P. Burma of BI was of the opinion that if "the change in phase-composition of the developing solvent is the only cause of alterations of R_F values with temperature, they should be independent of temperature in case of miscible solvents." He proved that the above observations were not correct.[104]

S.P. Sen and D.P. Burma studied the nodules and root tissues of four legumes, *Cicer arietinum* (gram), *Pisumsativum* (pea), *Lens esculenta* (lentil), and *Lathyrussativus*; which were grown on molecular and/or combined nitrogen. They were analysed for ninhydrin-reacting substances by paper chromatography. Seventeen known amino acids and five unknown substances were detected in the tissue. Out of them only one was unique for the nodules. "This was an unidentified substance with a high mobility with phenol-water but very low mobility with benzyl alcohol-acetic acid-water."[105] The authors also found: "The products of fixation and assimilation of inorganic nitrogen have been found to be essentially similar except for the occurrence of certain unidentified substances in the roots and nodules of plants utilizing both forms of nitrogen."[106]In the beginning of the 1960s, chromatographic techniques were used "for the separation and identification of 16 natural coumarins and related compounds." Water was found to be the most suitable solvent.[107]

W. Matthias developed a chromatographic technique in which substances to be chromatographed were applied near the edge of a strip of paper, the end of which was made in the form of a cone; thus the substances were at first radially distributed. Consequently, it led to a better separation of colours.[108] N.C. Ganguli*et al.* improved the technique in such a way that the substances formed either rings or arcs. This helped to increase the distance of separation between substances of close R_F values and therefore resulted in improved separations.[109] The detailed primary results were published in *"Science and Culture."* It was proved that if "the wick is introduced near the periphery of the paper rather than at the center, better resolution is possible and various samples can be developed simultaneously on the same paper."[110]

In 1956, B.B. Biswas reported that information regarding the chemical nature of nucleic acids in Cyanophyceae is very little, and deoxyribonucleic acid and ribonucleic acid have not been isolated chemically from this group. He isolated nucleic acids in *Nostocmuscorum* using the conventional method.[111] He found out that the deoxyribonucleic acid separated from *Nostiocmuscorum* gives a positive test with the Dische reagent, indicating the presence of depoxypentose-sugar. Further, "Ribonucleic acid which was precipitated from deoxyribonucleic acid filtrate by alcohol gave a positive reaction in the orcinol test, indicating the presence of pentose sugar. Chromatographic analysis … gave four spots corresponding to guanine, adenine, cytidylic acid and uridylic acid".[112] With that, he proved that the ribonucleic acid of Cyanophyceae shows no qualitative deviation from the normal type. Biswas, then in the Plant Physiological Laboratory of the Department of Chemistry, later found that "the nucleoproteins associated with RNA and DNA of *Nostocmuscorum* … contain 10-15 amino acids."[113]

Biologically active compounds (glucose 1-phosphate, adenylic nucleic acids, *cis*- and *trans*-crocetin dimethyl ester, crocin and picrocrocin), which are required for physiological and microbiological studies of plants, were prepared. Also *cis*- and *trans*-crocetin dimethyl ester, crocin and saffranol were isolated from saffron.[114] As per AR 1945-46, "A new phenomenon of enzyme activation by very small electric current has been observed. Investigations are being continued to standardize the necessary experimental conditions."[115]

Variation in chemical changes of the respirable substrate accompanying the process of fruit development and ripening of different varieties of the tropical fruit *Magniferaindica* were investigated.[116] In the case of *Mangiferaindica* it was "found that the effect of ethylene is more marked in the pre-climacteric phase of the fruit, and in the post-climacteric phase the effect is not pronounced."[117] A study on the auxin effect on Desmodiumgyrans indicated that "at low concentrations the auxin is a respiratory catalyst for some substrates present in the cells of Desmodiumgyrans, and that malate is one of the substances on which this auxin acts."[118] In Microbiology Section, a special retting substance named 'Hiparol' was discovered which was "capable of retting jute, coco-nut and other fibrous plants in 8-18 hours instead of the 6-10 weeks in the natural process."[119] A theory of the mechanism of enzyme action, which was based on the assumption of differential catalysis for reversible enzymic processes was confirmed in potato.[120] As published in a short report in *Nature*, "The effect of penicillin in inhibiting the growth of soil organisms and producing cytological effects on plant cells has been studied. Penicillin has been found to prevent the transformation of tadpoles into frogs; tadpoles kept for some time in a dilute penicillin solution and then transformed to their normal habitat in water have continued to grow and increase in size for six months without metamorphosing into frogs."[121]

V.M. Cutter, G.R. Dubé and K.S. Wilson studied the development and growth of the coconut fruit. They detected the presence of free nuclei suspended in the milk. By centrifuging the coconut milk they isolated the nuclei in the living state. Scientists of BI checked whether "the fruit with its exposed nuclei can be used as a living receptacle for testing the direct effect of antibiotics and other substances on chromosomes."[122]

Work on palaeobotany was started as early as 1947 to estimate the age of the Punjab saline series, a vexed problem in the Indian geology, on the basis of the microflora from the Cambrian strata of that region. E.R Gee and C.N. Fox had assigned a 'Cambrian' or 'pre-Cambrian' age to this series. On the other hand, Indian authors B. Sahni and Sahni and B.S. Trivedi, based on the evidence of microfossils (like woods of conifers, cuticles of grasses, angiospermous wood elements), were against 'Cambrian' or 'pre-Cambrian' age."[123] In the beginning of the 1950s A. K. Ghosh and A. Bose continued researches on Cambrian.[124] From Geological Survey of India, K. Jacob, Chinna Jacob and R.N. Shrivastava found a few spores and fragments of tracheids of vascular land plants from authentic samples of the Neobolus Shales of the Salt Range, the Middle and Upper Cambrian of Kashmir and the Cambrian of Spiti. They tentatively predicted these spores to the Pteridophyta and the Pteridospermæ; and speculated that some may even belong to the primitive Gymnospermæ.[125] In 1953, A. Bose wrote that the possibility of the existence of plant life in the Vindhyans began with the report of the discovery of coal by Franklin in 1833. The definitive existence of vascular plants in the Vindhyans was established by him and Ghosh. Three years later, other workers, in specimens of Jones's original collection, found "Suket shales, fragments of woody elements and five or six types of spores belonging probably to the primitive pteridosperms and pteridophytes and to doubtful primitive gymnosperms. However, they did not recover winged spores".[126] This investigation was carried out with the help of a grant received from Burmah Oil Company. Palaeobotany continued to be one of the important subjects of investigation since then.

Important work was done on caste determination and polymorphism in some species of ants. It was noted that workers or so called neuters in aggressive red ants *Oecophyllasmargadina*Fabr. are present in nests throughout the year while males and queens appear in the nest only from February to April. Fertilized eggs of the queen give rise to neuters and unfertilized eggs give rise to males. Workers lay parthenogenetic eggs throughout the year and as a rule workers come out of them. It was demonstrated that polymorphism depends on nutritional difference i.e. in the quality and quantity of food administered.

Cytogenetics was another field of research, which was studied at the Bose Institute. K.T. Jacob played an important role in these investigations. For instance, he studied the morphology[127] and chromosome characters of seven types of Asiatic cotton, and depending on their lengths and morphology, classified them into seven groups.[128] So far as the importance of this topic was concerned, the author wrote: "A detailed critical study of the nucleolar chromosomes in cotton has not been made by an investigator before." The necessity for such a study was felt by R.R. Gates, U.K., in 1938.[129] According to an Annual Report: "The breeding experiments with Coimbatore and Lyallpur cottons at Falta station have been continued. The former grow fairly well and give a good yield with good ball opening. The yield of these plants is not so high, it is about 70% of the yield obtained at Coimbatore."[130] Additionally, cytological studies of Jute, which was treated with X-rays, gamma rays and neutrons were carried out. The observations showed the following peculiarities: "(1) Cytomixis in all stages up to Metaphase

II, leading to variations in the number of chromosomes in meiosis, (2) Presence of fragments, (3) Chromosome and chromatid bridges in Anaphase I and II, (4) Degeneration of pollen mother cells, tetrads and spores."[131]

From July 1946, K.T. Jacob was on leave to join the Andhra University as Reader and Head of the Botany Department. He returned in March 1947.[132]Cytological studies on jute was continued, and meiotic abnormalities, such as "unequal number of chromosomes at different poles" and "cytomisis" were observed.[133]One of the major objectives was to induce mutation for economic benefit. Important and systematic work on this line was conducted at BI since 1942. It may be mentioned here that some of the interesting observations made during this period have been confirmed during the subsequent years from freshly irradiated materials. From the economic points of view, the improvements have been in yield, earliness and quality.[134]

Nature, while reporting on the Bose Institute, stated: "Preliminary investigations started during the past year have disclosed that the beta-radiation from radioactive phosphorous, which is selectively absorbed in plant nuclei, is a very convenient tool for inducing mutation in plants; for example with this method, new types of effects are being obtained in certain varieties of jute plants in addition to those obtained with the same kind of plants after irradiation trials with X-rays extending over many years."[135] Until the middle of 1950s the mutants of economic plants was done by X-rays and beta-rays from radioactive phosphorous and sulphur. The future plan was to study the effect of powerful source of gamma radiations from cobalt-60. Subsequently, a 'Gamma Garden' was built at Nilgunj near Barrackpore with a 20 Ci cobalt-60 source.

B. B. Biswas of BI, who is considered as one of the greatest experts in genetics, "first reported the cytological study and isolation and characterization of DNA and RNA from cyanobacteria."[136] In 1956, he wrote:

"The available information regarding the chemical nature of nucleic acids in Cyanophyceae is very meagre, and deoxyribonucleic acid and ribonucleic acid have not been isolated chemically from this group. As the blue-green cell is peculiar in its nuclear structure, the chemical nature of its nucleic acids may be different in kind or degree from that of other sources. With this in view, the nucleic acids were isolated from *Nostocmuscorum* …"[137]

The contribution of Bose Institute in the field of genetic is to be found in "Genetics – The key to understanding the music of life"[137], which is written by N. C. Mandal, a student of Professor Biswas.

Conclusion

We find that the DM Bose era of Bose Institute formed the stepping stone for Bose Institute to become a modern laboratory of international standard. D.M. Bose's exposure to working in England and Germany and his contact with many of the reputed scientists of that time coupled with his own outstanding scientific achievement helped him to promote science research in Bose Institute at a level at par with international science both in terms of quality and modernization. D. M. Bose, as if, opened the windows of Bose Institute built by J. C. Bose to allow the knowledge and wisdom to come in from outside which invigorated the scientific minds of the institute.

References

1. M. Siddiqi, S. Raha, Bose Institute – A historical perspective 1917-1947 (in: Science and modern India: An institutional history, c.1784-1947, History of Science, Philosophy and Culture in Indian Civilzation, vol. 15, Part 4, Das-Gupta U. (Ed.)), Pearson Longman, Delhi 2011, pp. 966-988.
2. S. C. Roy, D.M. Bose - A Scientist incognito (editorial), Sci. Cult. 76, 491-493, 2010. S. C. Roy and R. Singh, D.M. Bose and cosmic ray research in India, Ind. J. Hist. Sci. 50, 438-455, 2015, R. Singh, D. M. Bose – His scientific work in international context, Shaker Publisher Aachen 2016. S. C. Roy and R. Singh, D. M. Bose: A Scientist Incognito (Book to be published by Bose Institute, Kolkata), (2017)
3. http://resources.boseinst.ernet.in:8080/xmlui/bitstream/handle/123456789/902/Page-06-BOSE%20INSTITUTE%20AFTER%20-%20J%20C%20BOSE-1917-80.pdf?sequence=7. Aug. 16, 2016.
4. D. M. Bose Birth Centenary Celebration Commemoration Volume, 1985, Published by D. M. Bose Birth Centenary Celebration Committee.
5. http://resources.boseinst.ernet.in:8080/xmlui/bitstream/handle/123456789/2765/ BI-BRI-APPENDIX-I-1917-38.pdf?sequence=1&isAllowed=y. June 24, 2017.
6. AR 1938-1939.
7. AR 1939-1940.
8. AR 1940-1941.
9. AR 1942-1943.
10. AR 1944-1945.
11. AR 1945-1946.
12. AR 1946-1947.
12. AR 1947-1948.
13. AR 1947-1948.
14. AR 1947-1948.
15. For the history of Plant-biochemistry in India, see Save P.V., Plant Biochemistry Research in India, (in: D. P. Burma, M. Chakravorty, (Eds.), From Physiology and Chemistry to Biochemistry, History of Science, Philosophy and Culture in Indian Civilzation, XIII –Part II, Pearson Education, Delhi 2011, pp. 189-228. See the development of biophysics, see, M. Vijayan, Biophysics and structural biology in India – A historical survey, (in: D. P. Burma, M. Chakravorty, (Eds.), From Physiology and Chemistry to Biochemistry, History of Science, Philosophy and Culture in Indian Civilzation, *XIII –Part II, Pearson Education,* Delhi 2011), pp. 367-400.

16. AR 1947-1948.
17. See, Bose Institute after J.C. Bose 1917-1980.
18. AR 1939-1940.
19. AR 1942-1943.
20. AR 1939-1940.
21. AR 1946-1947.
22. AR 1947-1948.
23. AR 1943-1944.
24. AR 1944-1945.
25. AR 1944-1945.
26. AR 1945-1946.
27. AR 1949-1950.
28. AR 1942-1943.
29. R. S. Anderson, Nucleus and nation, University of Chicago Press, Chicago 2010, pp. 190-191.
30. AR 1959-1960.
31. AR 1939-1940.
32. AR 1940-1941.
33. AR 1947-1948.
34. AR 1947-1948.
35. AR 1947-1948.
36. AR 1947-1948.
37. AR 1947-1948.
38. AR 1949-1950.
39. AR 1952-1953.
40. AR 1959-1960.
41. AR 1959-1960.
42. AR 1959-1960.
43. AR 1947-1948.
44. AR 1941-1942.
45. Anonymous, Bose Research Institute, Calcutta – Annual reports, *Nature* **156**, 696-697, 1945.
46. AR 1944-1945.
47. AR 1944-1945.
48. AR 1947-1948.
49. AR 1947-1948.
50. AR 1939-1940.
51. AR 1939-1940.
52. AR 1943-1944.
53. AR 1945-1946.
54. AR 1950-1951.
55. AR 1950-1951.
56. Anonymous, Bose Institute, Calcutta, Anniversary meeting, *Nature* **169**, 105-106, 1952.
57. AR 1945-1946.
58. AR 1950-1951.
59. AR 1950-1951.
60. AR 1938-1939
61. AR 1939-1940.
62. AR 1940-1941.
63. AR 1951-1952.
64. AR 1951-1952.
65. A. M. Ghose, *Sci. Cult.* **72**, 330-336, 2006.
66. AR 1945-1946.
67. Anonymous, Atomic research in India, *Nature* **159**, 192, 1947.
68. AR 1946-1947.
69. AR 1947-1948.
70. AR 1947-1948.
71. AR 1947-1948.
72. AR 1950-1951.
73. AR 1950-1951.
74. AR 1950-1951.
75. AR 1945-1946.
76. R. C. Ghosh, On the angular distribution of cosmic rays, *Trans. B.R.I.* **11**, 169-175, 1935-1936.
77. R. C. Ghosh, On the angular distribution of cosmic rays, *Trans. B.R.I.* **11**, 169-175, 1935-1936.
78. S. C. Roy, R.Singh, D. M. Bose and cosmic ray research in India, *Ind. J. Hist. Sci.* **50**, 438-455, 2015. Republished in *Science and Culture* **82**, 364-377, (2016).
79. AR 1945-1946.
80. AR 1950-1951.
81. AR 1950-1951.
82. AR 1959-1960.
83. G. Balakrishna Nair and Yoshofumi Takeda, *Ind. J. Medical Research* **133**, 127 (2011).
84. A. Sen and J.K. Sarkar, Life and work of Sambhu Nath De, *Resonance* **17**, 943 (October 2012).
85. http://resources.boseinst.ernet.in:8080/xmlui/bitstream/handle/123456789/902/Page-06-BOSE%20INSTITUTE%20AFTER%20-%20J%20C%20BOSE-1917-80.pdf?sequence=7. Aug. 16, 2016.
86. Transactions of Bose Research Institute **Vol. XX,** 1955: D. M. Bose Birth Centenary Commemorative Volume etc.
87. *Trans. Bose Res. Inst.* **27**, xxii, (1955).
88. AR 1937-1938.
89. P. Debye and F. W. Sears, On the scattering of light by supersonic waves, *Proc. Nat. Acad. Sci. (USA)* **18**, 409-414, (1932).
90. C. V. Raman, N. S. N. Nath, The diffraction of light by high frequency sound waves - Part I, Proc. IAS **2**, 406-412, (1936); C. V. Raman, N. S. N. Nath, The diffraction of light by high frequency sound waves of high frequency - Part II, Proc. IAS **2**, 413-420, (1936); C. V. Raman, N. S. N. Nath, The diffraction of light by high frequency sound waves - Part III - Doppler effect and coherence phenomena, Proc. IAS **3**, 75-84, (1936); C. V. Raman, N. S. N. Nath, The diffraction of light by high frequency sound waves - Part V – General considerations – Oblique incidence and amplitude change, Proc. IAS **3**, 459-465, (1936).
91. AR 1946-1947.
92. AR 1950-1951.
93. AR 1959-1960.
94. AR 1950-1951.
95. AR 1950-1951.
96. AR 1950-1951.
97. AR 1951-1952.
98. AR 1952-1953.
99. A. M. Ghose, *Sci. Cult.* **72**, 330-336, (2006).
100. AR 1950-1951.
101. AR 1951-1952.
102. AR 1951-1952.

103. D. P. Burma, Effect of Temperature on the R_F Values of the Amino-acids during Paper Chromatography with Solvents completely Miscible with Water, *Nature* **167**, 565-566, (1951).

104. S. P. Sen, D. P. Burma, A study with paper chromatography of the amino acids in legume nodules, *The University of Chicago Press Journal* **115**, 185-190, (1953).

105. S. P. Sen, D. P. Burma, A study with paper chromatography of the amino acids in legume nodules, *The University of Chicago Press Journal* **115**, 185-190, (1953).

106. D. P. Chakraborty, B. K. Barman, K. R. Guha, A paper chromatographic study of some natural coumarins and related compounds, *Trans. Bose Res. Inst.* **24**, 211-214, (1961).

107. N. C. Ganguli, Modified Horizontal Migration Method in Paper Chromatography, *Nature* **174**, 189 – 190, 1954.

108. N. C. Ganguli, Modified Horizontal Migration Method in Paper Chromatography, *Nature* **174**, 189 – 190, (1954).

109. N. C. Ganguli, Circular Paper Chromatography, *Sci. Cult.* **19**, 460, (1954).

110. B. B. Biswas, Chemical Nature of Nucleic Acids in Cyanophyceae, *Nature* **177**, 95 – 96, (1956). B. B. Biswas, *Curr. Sci.*, **22,** 348, (1953).

111. B. B. Biswas, Chemical Nature of Nucleic Acids in Cyanophyceae, *Nature* 177, 95 – 96, 1956. B. B. Biswas, *Curr. Sci.*, **22**, 348, (1953).

112. B. B. Biswas, Studies on the nucleoproteins of *nostocmuscorum*, *Trans. Bose Res. Inst.* **24**, 25-30, (1961).

113. Anonymous, Bose Research Institute, Calcutta – Annual Reports, *Nature* **156**, 696-697, (1945).

114. AR 1945-1946.

115. B. K. Kar and H. N. Banerjee, Effect of ethylene on *Magniferaindica*, *Nature* **144**, 597-598, (1939).

116. B. K. Kar and H. N. Banerjee, Effect of ethylene on *Magniferaindica*, *Nature* **144**, 597-598, (1939).

117. Anonymous, Bose Research Institute, Calcutta – Annual Reports, *Nature* **156**, 696-697, (1945).

118. Anonymous, Bose Research Institute, Calcutta – Annual Reports, *Nature* **156**, 696-697, (1945).

119. Anonymous, Bose Research Institute, Calcutta – Annual Reports, *Nature* **156**, 696-697, (1945).

120. Anonymous, Bose, Calcutta – Anniversary meeting, *Nature* **169**, 105-106, (1952).

121. M. Dutt, Dividing nuclei in coconut milk, *Nature* **171**, 799-800, (1953).

122. A. K. Ghosh, A. Bose, Occurrence of Microflora in the Salt Pseudomorph Beds, Salt Range, Punjab, *Nature* **160,** 796-797, (1947).

123. A. K. Ghosh and A. Bose, Spores and Tracheids from the Cambrian of Kashmir, *Nature* **169**, 1056-1057, (1952). A. K. Ghosh and A. Bose, *Trans. Bose Res. Inst.* **18**, 71, (1950). A. K. Ghosh and A. Bose, Microfossils from the Vindhyans, *Sci. and Cul.* **15**, 330, (1950).

124. K. Jacob, C. Jacob and R. N. Shrivastava, Spores and Tracheids of Vascular Plants from the Vindhyan System, India: the Advent of Vascular Plants, *Nature* **172**, 166 – 167, (1953).

125. A. Bose, Plant Life in the Vindhyans, *Nature* **178**, 927–928, (1956).

126. K. T. Jacob, Preliminary observations on the chromosome morphology in Asiatic cottons, etc. *Trans. Bose. Res. Inst.* **14**, 191-199, (1939-1941).

127. K. T. Jacob, Studies in cotton. V. The origin and development of the lint Cells in *Gossypiumarboreum* var. *typicum* (KI), *Trans. Bose. Res. Inst.* **15**, 167-175, (1942-1943).

128. K. T. Jacob, Preliminary observations on the chromosome morphology in Asiatic cottons, etc. *Trans. Bose. Res. Inst.* **14**, 191-199, (1939-1941).

129. AR 1943-1944.

130. AR 1945-1946.

131. AR 1946-1947.

132. AR 1947-1948.

133. K. T. Jacob, II. X-Ray studies in Jute II - A comparative study of the germination percentage, size, and external morphology, with different doses of X-rays, *Trans. Bose Res. Inst.* **18**, 23-29, (1949-1951).

134. Anonymous, The Bose Institute, Calcutta, *Nature* **179**, 388-389, (1954).

135. Anonymous, The Bose Institute, Calcutta, *Nature* **177**, 781-782, (1956).

136. B. B. Biswas, Chemical Nature of Nucleic Acids in Cyanophyceae, *Nature* **177**, 95-96, (1956).

137. N.C. Mandal, Genetics – The key to understanding the music of life (in: D. P. Burma, M. Chakravorty, (Eds.), History of Science, Philosophy and Culture in Indian Civilzation, vol. 13, Part 2 - From Physiology and Chemistry to Biochemistry, (Pearson Longman, Delhi) (2011), pp. 267-366.