Jagadish Chandra Bose: The First Indian Biophysicist

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Sir JC Bose (1858–1937)

The first half of the 20th century witnessed a renaissance of Indian science although India was not yet a free country. Keeping in mind the present scenario of science and technology in India, it is perhaps an opportune time to reflect on some of the scientific developments that took place during this period. The year 2008 marked the 150th birth anniversary of one of the greatest scientists India has ever produced, Sir Jagadish Chandra Bose. On this occasion, it is worthwhile to look back and trace the life and work of this pioneering scientist. In this article, we have focused on Jagadish Chandra Bose's life and scientific achievements, particularly highlighting the interdisciplinary nature of his research and the vision associated with it. We believe that this is an appropriate time to do so, in view of the recent initiatives taken by various scientific departments of the Government of India in broadening and further enhancing science education and research in India.

What is biophysics?

Biophysics is that branch of science which applies the principles of physics and chemistry, and the methods of mathematical analysis and computer modeling to understand how biological systems work. As the name suggests, it is an intrinsically interdisciplinary science that attempts to address issues in biological systems using laws of physics and chemistry. It is believed that many of the unsolved problems in contemporary biology (such as a molecular understanding of brain functioning) would be explored using biophysical approaches.

JC Bose's education

JC Bose was born on November 30, 1858 in the town of Mymensingh in erstwhile East Bengal (now Bangladesh). His early education was in Faridpur (now in Bangladesh). He later moved to Calcutta (now Kolkata) and studied initially in Hare School (named after the Scottish philanthropist and educationist David Hare) and was subsequently enrolled in St. Xavier's school. Bose went on to study physics in St. Xavier's College (the same college where the last author of this article studied almost a century later) after completing his school education. Here Bose came under the tutelage of Father Eugene Lafont who was instrumental in developing

a culture of modern science in Calcutta. Interaction with Father Lafont influenced Bose's early scientific thoughts. After graduating with a BA degree in physics from the University of Calcutta in 1880, Bose traveled to England to study medicine at the University of London. However, he left medicine due to complications arising from ill health, and joined Christ's College in Cambridge. At Christ's College, Bose studied chemistry, physics, and botany for the natural science tripos and graduated with BA degree in 1884. He also received a BSc degree from University of London in 1883. In Cambridge, he came in touch with teachers such as Lord Rayleigh, Michael Foster, Sidney Vines, Francis Darwin, James Dewar, and George Liveing. These initial contacts with the British scientific establishment proved to be useful in his later years as a researcher.

Bose's scientific contributions

Bose joined Presidency College in Calcutta as its first Indian Professor of physics in 1885. Research by Indians in natural sciences was almost non-existent in pre-independent India at that point in time. When Bose eventually started his research in physics around 1894 (almost a decade after his return from Cambridge), his efforts made him a pioneer in practicing western science in India.

Contributions in physics

Bose was influenced by the hands-on approach to science in England. After returning to Calcutta, he followed the same style and started giving extensive demonstrations in his classes in Presidency College. From 1894 to 1900, Bose studied the optical properties of radio waves and the effect of these waves on inorganic matter. He carried out experiments on refraction, diffraction, and polarization in a small makeshift laboratory in Presidency College. Bose designed and developed a number of instruments for his research. Utilizing these instruments, he developed a microwave generator which produced waves of the order of a few millimeters in length – wavelengths much shorter than that had been produced before – and also designed 'coherers' (radio wave detectors). These discoveries made Bose a pioneer in the use of semiconductor crystals in the detection of radiation. In 1895, Bose gave his first public demonstration of electromagnetic waves in the Town Hall in Calcutta. Significantly, this was achieved before the Italian scientist MG Marconi demonstrated wireless communication at longer wavelengths for which he was later awarded the Nobel Prize in 1909.

Contributions in biology

Bose's interest in biological research developed around 1900 and was based on his observation that electrical responses of inorganic and living matter to electrical, mechanical, and chemical stimuli were similar. This led to his later research in plant physiology and biophysics. His expertise in

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instrumentation helped him to make measurements of electrical activities of plants under stimulation (Fig. 1). Bose was the first scientific mind to recognize the ubiquitous importance of electrical signaling between plant cells in coordinating responses to the environment. He provided direct evidence that long-distance, rapid electrical signaling stimulated leaf movements in *Mimosa* and *Desmodium* and also showed that plants produce continuous, systemic electrical pulses. Bose's overall conclusion that plants have an electromechanical pulse (the basis of pulsation theory of ascent of sap), a nervous system, a form of intelligence, and are capable of remembering and learning, was not well received at that time. Interestingly, a hundred years later, concepts of intelligence, learning, and long-distance electrical signaling in plants have entered the mainstream literature (see Brenner *et al.*, 2006). Bose's passion for plant research resulted in the establishment of Bose Institute in Calcutta in 1917.

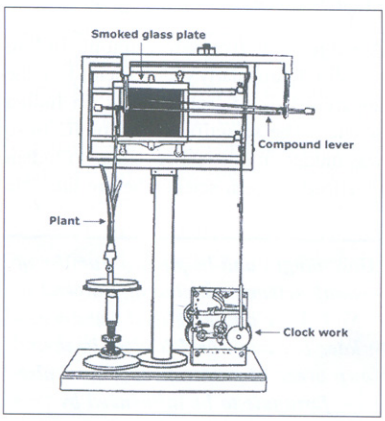

Figure 1. A schematic diagram of crescograph, an instrument designed by JC Bose for measuring the growth of a plant. (Note: 'Crescere' in Latin means 'to bring forth or sprout'.) Adapted and modified from Geddes (1930).

The second area in biology in which Bose left a mark is chronobiology (study of biological rhythms of circadian or cirannual frequencies). In the later years of his research life, he was actively involved in elucidating the diurnal rhythms in plants in an attempt to address the long-standing debate over the endogenous (intrinsic) or exogenous (in response to external stimuli) origin of biological rhythms. His pioneering research in the field of chronobiology included the first report of 'mid-day sleep' in plants due to intense light and short-term movements of the lateral leaflets in *Desmodium gyrans* (Indian telegraph plant). He was also the first to experimentally demonstrate the persistence of endodiurnal free running leaf movements in continuous light and darkness in 1919. Bose coined the term 'nyctitropism' for the diurnal leaf and petal movements and extensively studied the movements of several hundred plants throughout all seasons of the year, which he termed as 'autographs'.

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JC Bose's scientific legacy and its relevance in the contemporary Indian scenario

Bose taught and inspired a number of young scientists including Satyendra Nath Bose and Meghnad Saha who later became world leaders in their own areas of research. Bose was also fortunate to be influenced by contemporaries such as Acharya Prafulla Chandra Ray, Swami Vivekananda, Sister Nivedita, Mahatma Gandhi, and Rabindranath Tagore. His friendship with Tagore was deep rooted and he often wrote to Tagore about his interaction with other scientists and his own belief about commercialization of scientific idea (patenting). Bose was knighted in 1917, and was elected a Fellow of the Royal Society in 1920 (he was the third Indian Fellow of the Royal Society). Recently, the historical electronics museum in Baltimore (USA) honored the life and work of Bose in the year of his 150th birth anniversary by inducting him into Pioneers Hall of the museum as a permanent exhibit. To mark this event, the Christ's College in Cambridge organized a symposium titled "Beyond Boundaries: From Physics to Plant Sciences".

A subject of discussion among Indian scientists (particularly young scientists) is the apparent lack of 'role models' in Indian science. The scientific career of JC Bose was unique in this respect since no Indian practiced western science before him. He

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had to pay a heavy price for it in his career. Although his initial papers in physics were published in the Proceedings of the Royal Society of London, he faced considerable difficulty from his western peers in publishing his later papers on plant physiology and biophysics.

A unique aspect of Bose's career was the early realization (much ahead of time) that science is about addressing problems in nature, and not compartmentalizing knowledge in water-tight compartments with labels such as 'physics', 'chemistry', and 'biology'. Indian science has suffered in the past due to such rigid compartmentalization and it is only now that new institutes such as the Indian Institutes of Science Education and Research (IISERs) are being set up with the goal of providing comprehensive education in a broad area of science at the undergraduate level. If these initiatives bear fruit, Bose's vision would take shape in the context of Indian research in the next few decades.

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