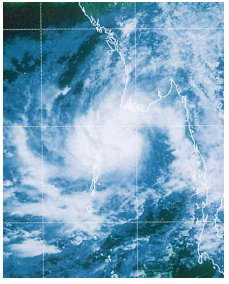
THE TORCH BEARERS OF INDIAN RENAISSANCE

The last decades of the nineteenth and early decades of the twentieth century witnessed a national awakening in all spheres of creativity. The 'Indian renaissance' also produced outstanding scientists. Fired by nationalism, disregarding comforts, and undeterred by severe handicaps, these men did world-class science by indomitable will. We stand on their shoulders today. The thumbnail sketches of the torch bearers present their travails and triumphs. We pay our homage to these masters who gave us strength and confidence.



CHAPTER II

TORCH BEARERS OF INDIAN RENAISSANCE

JAGADIS CHANDRA BOSE*

1858-1937

On November 30, 1858, at Mymensingh (now in Bangladesh), a son was born to Bhagawan Chandra Bose and Bama Sundari Devi. The child was named Jagadis or Lord of the World. True to his name J. C. Bose grew up to be known as a scientist of world repute.

Young Jagadis spent the early years of his life in Faridpur where his father was posted as the Deputy Magistrate. It was the time spent in Faridpur that Bose would value greatly in his later years. He was brought up in a house steeped in Indian tradition and culture and was sent to the village *pathshala* to study with the common folk. As he spent time with sons of farmers and fisherfolk, he learnt the lesson of what constitutes true manhood. From them he also drew his love for nature.

Young Jagadis was a curious lad, always asking questions. When he saw a firefly he had to know what that 'spark' was. The fast-moving river with fallen leaves floating by, the sprouting of seeds and growth of plants, the attraction of the moth towards light, the shooting stars, all were curiosities he was impatient to understand. He wouldn't rest till he found a satisfactory answer. His father was always there to respond to his child's curiosity and encouraged him, saying *as you grow bigger and bigger, my boy, try to find out the truth yourself*. However, it was not all work and no play for Jagadis, who loved sports too. Cricket was his favourite game.

At the age of nine Jagadis was sent to Calcutta. There he enrolled first at Hare School and later, in St. Xavier's where his lack of proficiency in English made him the butt of jokes. His European classmates refused to accept this rustic boy as one of them. One day unable to tolerate the bullying from a champion boxer, he took up the challenge. In the fight that followed Jagadis won and gained the respect of his classmates. Thereafter, no one dared to tease him.

At St. Xavier's, Jagadis studied physics under Father Lafont who was then a name to conjure with for his brilliant and unique methods of teaching physics with actual experiments. From him too, he picked up the flair for lecture demonstrations. However, botany continued to enthrall him. He would pull out germinating plants to check their roots and grew flowering plants and closely observed their growth. Jagadis passed the School Final examination with a First Class.

* His name has been spelled in different ways in the literature

After graduating at the age of 19, Jagadis had a strong desire to go to England and sit for the Indian Civil Service Examination, but his father would not allow him to do so. He told his son in no uncertain terms that he was to rule nobody but himself, was to become a scholar, not an administrator. Hence, in 1880, Jagadis did go to England but to study medicine at the University of London. There, he suffered repeated attacks of malaria, which he had contracted prior to his departure for London and had to move to Cambridge on a scholarship to study Natural Science at Christ's College. At Cambridge, he came under the influence of such illustrious teachers as Lord Rayleigh, Sir James Dewar, Sir Michael Foster and Francis Darwin.

Jagadis passed the Tripos examination with distinction. In 1884, he was awarded a B.A. degree from Cambridge and next year a B.Sc. degree from London University. Once he got his degrees, he did not linger abroad but returned to serve his motherland. In 1885, he was offered the post of officiating Professor of Physics at Presidency College, Calcutta. He was paid a salary half of what the British teachers were paid, so Bose refused to draw his salary at all as a protest. He worked in an honorary capacity for three years, not missing his classes even on a single day.

In England, Bose had appreciated the 'hands on' approach to science. Back in India, he carried on in the same spirit. Instead of boring verbal lectures, he enlivened his classes by holding extensive demonstrations. This was quite an innovation in those days and Bose became extraordinarily popular with his students. He encouraged them to observe, to question, to experiment and to innovate, without depending solely on books or teachers. After three years, the college Principal Twany and Director Croft, impressed by his brilliance, jointly recommended full salary for him from the date of his joining the college. Bose realized that the best way to face the English was to face them with courage and will power. This he did all his life.

In 1887, Bose married Abala Das, daughter of a leading advocate of the Calcutta High Court and a political leader. Bose's wife was his constant companion and helpmate, accompanying him on his trips to religious and historical places in India and on many excursions to the Himalayan peaks and glaciers. Later in life, she joined her husband on all his lecture tours abroad. Bose dedicated his book *Plant Autographs and their Revelation* (1927) to Abala Devi with the note, *To my wife, who has stood by me in all my struggles*.

When Bose first joined the Presidency College, there was no laboratory worth the name. However, Bose went ahead with his research, in a small enclosure adjoining a bathroom that he converted into a laboratory where he carried out experiments on refraction, diffraction, and polarization. Bose would stay on in the laboratory after the classes were over and carry on experiments. He met the expenses for the experiments himself. He even fabricated the equipment he needed by sheer ingenuity.

The experiments performed in the makeshift laboratory finally resulted in the invention of a device for producing electromagnetic waves. In November 1894, Bose gave the first public demonstration of wireless transmission using electromagnetic waves to ring a bell and to explode a small charge of gunpowder from a distance. He used microwaves with wavelengths in the millimeter range, not radio waves. Considering the very primitive workshop facilities available in Calcutta at this time, the compact nature of his apparatus excited many and drew a great deal of appreciation in England. It was described in many textbooks of this period by J. J. Thomson and Poincare. The Daily Chronicle (England) reported, *the inventor has transmitted signals to a distance of nearly a mile and herein lies the first and obvious and exceedingly valuable application of this new theoretical marvel*.

In recent years, some Indian scientists have spearheaded a movement to give Bose his due

recognition as the Father of Wireless Telegraphy. For, it was more than a year after the successful demonstration of his experiment that Guglielmo Marconi patented this invention. It is believed that it was Bose's failure to seek a patent that denied him his due. However, by all accounts, Bose was never interested in money. The British navy was interested in his coherer (device that detects radio waves) to establish radio links between ships and torpedo boats. So it is not as if Bose was unaware of the monetary worth of his findings. He wrote to Rabindranath Tagore in 1901, *....I wish you could see that terrible attachment for gain in this country....that lust for money...Once caught in that trap there would have been no way out for me*.

Later, Bose developed the use of Galena crystals for making receivers, both for short wavelength radio waves and for white and ultraviolet light. His pioneering work in the field was recognized by his peers. Sir Neville Mott, who won the Nobel Prize in 1977 for his contributions to solid state electronics, went on record stating that, *J.C. Bose was at least sixty years ahead of his time.... In fact, he had anticipated the existence of P-type and N-type semi-conductors*.

Bose's first paper published in the *Proceedings of the Asiatic Society of Bengal* in May 1895, deals with the polarization of electric waves by double refraction. In October 1895, his first communication to the Royal Society of London was published in its Proceedings. The next year, he was conferred D. Sc. by London University for his thesis on *Measurements of Electric Rays*, Bose went to England in 1897, where he not only repeated his demonstrations successfully but also speculated on the existence of electromagnetic radiation from the sun. Two years later, Bose unveiled his invention of the mercury coherer with the telephone detector. The same year he unfortunately lost his diary containing the account of his invention and a prototype of the detector.

Bose devoted a great deal of attention to the peculiar behaviour of his coherer, which consisted of a number of contacts between metal filings whose resistance altered under the impact of electric radiation. Detailed investigation led him to the view that this coherer effect was characteristic of a large class of compounds, like selenium, iron oxides, etc. In fact, Bose can be considered a pioneer in the field of investigation of the properties of photo-conductivity and contact rectification shown by this class of semi-conductors. His subsequent study of the fatigue phenomena exhibited by these substances led Bose to postulate his theory of the similarity of response in the living and the non-living. He found that the sensitivity of the coherer decreased when it was used for a long period -it became tired. When he gave the device some rest, it regained its sensitivity which, in his view, indicated that metals had feelings and memory !

During 1897-1900, Bose turned his interest to comparative physiology, plant physiology in particular. The main focus of his investigations was to establish that all the characteristics of response exhibited by animal tissues are equally exhibited by plant tissues. In 1901, Bose submitted to the Royal Society a preliminary note on the *Electric Response of Inorganic Substances*, in which he showed how he had obtained strong electric response from plants to mechanical stimuli. However, the paper was not published due to the opposition of Sir John Burdon Sanderson, the leading electro-physiologist of the time. In 1904, Bose submitted a series of papers, once again to the Royal Society, showing the similarities of both the electric and mechanical responses of plants and animals. But these papers too met the same fate.

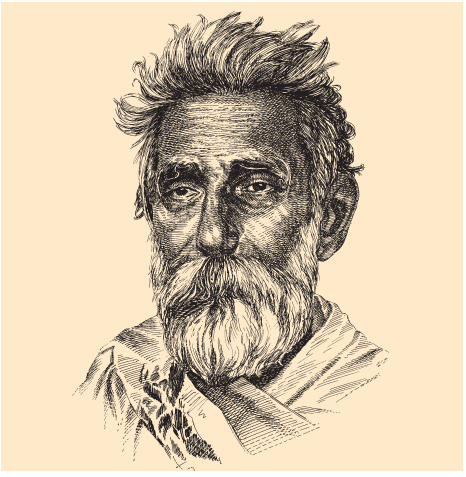
His interest in physiology gave an impetus to his inventive genius. For obtaining the records of mechanical response of plant tissues, he first introduced the optical lever in plant physiology to magnify and photographically record the minute movements of plants. He perfected the resonant recorder that enabled him to determine with remarkable accuracy, within a thousandth part of a second, the latent period of response of the touch-me-not plant, *Mimosa pudica*. He also devised the oscillating recorder for making minute lateral leaflets

of the telegraphic plant (*Desmodium gyrans*) automatically record their pulsating movements. He even took up the problem of recording micrographic growth movements of plants by devising the crescograph. With this instrument, he obtained a magnification of 10,000 times, and was able to record automatically the elongation growth of plant tissues and their modifications through various external stimuli. Later, he perfected his magnetic crescograph obtaining a magnification from one to ten million times. A demonstration of the crescograph at the University College of London on April 23, 1920 led several leading scientists to state in *The Times*: *We are satisfied that the growth of plant tissues is correctly recorded by this instrument, and at a magnification from one million to ten million times*.

The 1900s marked a spell of renewed activity. He attended international conferences and wrote books and research papers. In 1903, he was conferred Companionship of the British Empire (C.B.E.) by the British government. In 1912, he received the Companionship of the Star of India (C.S.I.). The University of Calcutta conferred on him an honorary D.Sc. The Royal Society which had been publishing his papers on physical research since 1894, but had raised serious objections to his physiological research, honoured him in 1920 by electing him a Fellow. In 1933 and 1935, Banaras Hindu University and Dhaka University, respectively, awarded him honorary D.Sc. He formally retired from Presidency College in 1915, but was appointed Professor Emeritus for the next five years.

Bose was not interested in making money. He could have made millions by simply patenting his inventions but more important for him was to spread knowledge. Towards this end, he had nurtured a life-long dream of establishing an institute of excellence. Conceived at least twenty years earlier, the Bose Institute was inaugurated in Calcutta on November 30, 1917. *This is not a laboratory*, he had said, about his Institute, *but a temple*.

Bose died on November 23, 1937, just a week short of his eightieth birthday.



PRAFULLA CHANDRA RAY

1861-1944

An ardent advocate of large-scale industrialization, Prafulla Chandra Ray was the driving force behind the setting up of several industries at a time when the process had hardly begun in India. He was himself a pioneer in the field of pharmaceutical industry in India and started out by making chemicals at home. Looking at foreign companies making excessive profits at the cost of Indian patients, he set up his own company to manufacture inexpensive drugs.

Prafulla Chandra Ray was born on August 2, 1861 in Raruli-Katipara, a village in the District of Khulna (now in Bangladesh). His father, Harish Chandra Ray, was a landlord from a wealthy and cultured family who felt the need to provide education to all. So he set up a middle school in his village and another solely for girls. From his father, Prafulla imbibed an interest in education, rational thinking and sympathy for the poor.

Young Prafulla enrolled in the school his father had set up but often played truant. In 1870, the family moved to Calcutta so that the children could have higher education and Prafulla was admitted to the prestigious Hare School. But a severe attack of dysentery forced him to drop out of school for two long years. This break from the dreary school routine were a blessing in disguise. Prafulla found time to satisfy the passion to study English and Bengali literature. When barely ten years old, he had already learnt Latin and Greek and studied the

histories of England, Rome and Spain.

Prafulla resumed formal education in 1874 at the Albert School which had been set up by Keshab Chandra Sen, a pillar of the Brahmo Samaj movement. Prafulla's knowledge of English literature greatly impressed the teachers of the Albert School, but just when everyone expected his success, Prafulla suddenly left for his village, without even sitting for the examinations. There, he stayed for two years sharing the joys and sorrows of the simple villagers and helping them in whatever way he could.

In 1876, Prafulla returned to Calcutta to resume his studies at the Albert School. This time he worked hard and stood first in the examinations. He passed the Entrance Examination in 1879 and joined the Metropolitan Institute (now called Vidyasagar College). Meanwhile, the sudden demise of his grandfather, Ananda Lal Ray, brought a period of great uncertainty in the family's life, for Ananda Lal breathed his last before he could tell his son where he had buried the store of gold and gem stones-the family fortune, so to say. Prafulla's father tried in vain to find the treasure till the situation got so bad that the ancestral property had to be sold to pay the creditors. To save money, the family shifted back to Raruli while the sons lived on in rented rooms in Calcutta.

At the Metropolitan Institute, Prafulla was immensely influenced by great teachers like Surendranath Banerjee and Prasanna Kumar Lahiri. While pursuing his studies in the Metropolitan Institute, Prafulla would also attend lectures by Alexander Pedlar on Chemistry in the Presidency College. Pedlar's inspiring lectures led Prafulla to take up Chemistry for his B.A., although his first love was literature.

During those days, the London University conducted competitive examinations for the Gilchrist Prize Scholarship for higher studies in Britain. Prafulla decided to take this and he had an added advantage of knowing several languages including Sanskrit and French. And when the results were announced, Prafulla had made it along with a *Parsee* boy from Bombay, named Bahadurji. Although Prafulla's father readily agreed to his son going abroad, his mother was distressed. Prafulla consoled her saying, *When I return from England, I will get a high position. My first duty will be to repay the debts and to repair our ancestral home*.

In 1882, Prafulla left for Britain. The 33-day long voyage left him very weak. Once he reached London, fellow Indian students there helped him out with woollen clothes for the bitter cold of Edinburgh, where he was to join the B.Sc. class in the University.

In 1885, Prafulla wrote an essay on *India before and after the Mutiny*, for the University of Edinburgh prize for the best article. Although the prize went to another student, the judges considered Prafulla's essay of a very high standard. The essay was full of criticism of the British rule in India, it also had a touch of wit. Prafulla had his essay printed and sent copies to his fellow students, appealing to them for help in the task of liberating India. He also sent a copy to the great parliamentarian, John Bright, who was regarded as a friend of India. Bright sent a very sympathetic reply and authorized Prafulla to use the letter in any way he liked. Prafulla lost no time in sending a copy of Bright's letter to the *London Times* and other leading British papers. One fine morning, when the papers came out with the headline *John Bright's letter to an Indian student*, Prafulla became a celebrity.

Prafulla took his B.Sc. degree in 1885 and went on to do research in Chemistry for the D.Sc. degree of the University of Edinburgh. In 1887, at the age of 27 he was awarded the D.Sc. degree. He also received the Hope Prize Scholarship of the University, which enabled him to continue his work for another year. Prafulla returned to India in 1888 with recommendations from his professors. But back home, even with a D.Sc. degree he could not land a job and spent almost a year working with his famous friend Jagadis Chandra Bose in his laboratory. A year later Prafulla Chandra Ray was appointed Assistant Professor of Chemistry in the Presidency College, Calcutta, on a salary of Rs. 250 a month. He was quite satisfied with his teaching job.

His teaching skills made him popular with students. His lectures were marked by spicy humour. By introducing experiments and instances from everyday life he made the classes not only interesting but also inspiring. He would put a pinch of ash in his mouth to demonstrate that bones when cremated retained no trace of their animal origin but became mere chemical compounds. In later years, many of his students would admit that it was Ray's lectures that had inspired them to take to science. Famous Indian scientists, like Meghnad Saha and Shanti Swarup Bhatnagar, were among his students. Prafulla also used his knowledge of literature to good effect. He would recite poems of Rabindranath Tagore and quote slokas from *Rasa Ratnakara*, a book written by the ancient Indian chemist, Nagarjuna.

One thing that Ray felt strongly about was the use of the mother tongue as the medium of instruction in schools. He himself wrote science textbooks in Bengali. He told his students the story of the celebrated Russian chemist Mendeleev, famous for his Periodic Law, who published the results of his work in the Russian language. This compelled the scientists of other nations to learn Russian in order to read this important discovery. He also strongly believed that it was not enough for students to merely acquire degrees to get government jobs, but their real endeavour should be to acquire knowledge, through technical education and start their own business.

At first his own company The Bengal Chemical and Pharmaceutical Works, found it difficult to sell the chemicals it produced. Competition from imported chemicals was tough. But slowly, a chain of supporters grew around Prafulla's venture and started using the chemicals made by his firm. Many graduates in chemistry joined his factory and worked hard for it. Very soon The Bengal Chemical and Pharmaceutical Works became a name to reckon with.

It was not just his own venture that he promoted. With his active cooperation, direct or indirect, several textile mills, factories, industries, and publishing houses were set up. He was associated with establishments such as Bengal Potteries, Bengal Enamel Works, Calcutta Soap Works, National Tanneries and so on. With his inspiring dynamism Prafulla became the driving force behind the industrialization of the country that had just begun.

However, during all these years, Ray was also actively engaged in research in his laboratory at the Presidency College. His work on mercurous nitrite and its derivatives brought him worldwide recognition. He continued publishing scientific papers and guiding doctoral students.

The *charkha* (the spinning wheel) and *khadi* movement started by Gandhiji had a great impact on Ray. Just like Gandhiji, he believed that the spinning wheel could become a good source of income for poor villagers. He began to spin yarn with the *charkha* at least for one hour everyday, wore only *khaddar* (Indian homespun clothes) and even earned the sobriquets *Charkhashri* and *Sir Khaddar* from his friends!

In 1916, Ray retired from the Presidency College but Ausutosh Mookerjee, the Vice- Chancellor of the University of Calcutta, appointed him Professor of Chemistry at the newly set up University Science College. He remained associated with the Institute for twenty years, finally retiring at the age of seventy-five. But even before his retirement, in 1921 he donated, in advance, his entire salary for the rest of his term to the Department he headed. He also set up two annual research prizes in Chemistry -- one named after the great Indian chemist Nagarjuna and the second after Ausutosh Mookerjee.

Throughout his life Ray never let go of any opportunity to do his bit for others. He had inherited his father's penchant for social service. In 1922, a great flood swept north Bengal and many were rendered homeless. He organized a relief committee which included leading European and Indian citizens of Calcutta. He made his college the centre of relief operations. With the help of his students and other citizens, he collected clothes and food as well as large sums of money for the needy. Impressed with his coordinated flood relief operations in Bengal, Gandhiji once called him a *Doctor of Floods*.

Ray also gave away his shares, valued at a 100,000 rupees in The Bengal Chemical and Pharmaceutical Works as an endowment. The profit from this endowment was used for the benefit of widows and orphans. The rest of his savings went to the Brahmo Samaj and in setting up a school in Ratuli village, in his father's name. He often shared his bachelor's accommodation with impoverished students.

The life of this great Indian scientist, the most part of which was spent in selfless service, finally came to an end on June16, 1944, in the same room that he had occupied for twenty-five years.

SRINIVASA RAMANUJAN

1887 -- 1920

When G. H. Hardy, was asked to rate the top mathematicians of his time on a scale of 100, he gave himself 25 marks, Littlewood got 30, Hillbert got 80, while Ramanujan got 100 upon 100. Such was the reputation that Ramanujan enjoyed among mathematicians of his time. In 1984, over hundred mathematicians and scientists contributed money for a bust sculpted by Paul Granlund, that was later handed over to his wife. Ramanujan left behind 4,000 original theorems, despite his lack of formal education and a short life span.

Srinivasa Aiyangar Ramanujan was born in Erode, in Tamil Nadu, on December 22, 1887. His father worked as a petty clerk in a cloth factory. After attending primary school in Kumbhakonam, he entered the Town High School in 1898. From early childhood it was evident that he was a prodigy and at the age of 13, he had already plunged into serious arithmetic and geometry. The turning point in his life came when he chanced upon the book *Synopsis of Elementary Results in Pure and Applied Mathematics*, by George Shoobridge Carr. The book contained theorems, formulae and short mathematical proofs. It also contained an index to papers on pure mathematics published in the European journals of learned societies during the first half of the nineteenth century. It was this book that triggered the mathematical genius in him. He discovered the relationship between circular and exponential functions.

From that moment onwards, Ramanujan's mind was flooded with mathematical ideas – and so many of them that he would solve the problems on loose sheets of paper and jot down the results in his notebooks. The notebooks would later become famous as Ramanujan's frayed notebooks. Even today mathematicians are studying them to prove or disprove those results.

After a first class in mathematics in the matriculation examination Ramanujan entered the Government College in Kumbhakonam in 1904. He was also awarded the Subramanyam scholarship. During that time Ramanujan was particularly interested in relations between integrals and series. In 1906, Ramanujan went to Madras where he enrolled at Pachaiappa's College. He failed twice in the first year arts examination, because he neglected other subjects such as history, English and physiology. Soon he fell ill and had to leave the college. Later, he sat for the examination and again passed only in mathematics.

In 1908, he fell seriously ill and in April 1909 had to undergo an operation. But even during his illness Ramanujan was driven by his passion for mathematics, always scribbling numbers. Fearing for his sanity, his parents married him off to S. Janaki Ammal, then only eight or nine years old, hoping that marriage would bring him around to the real world. But this only thrust upon him a responsibility he was not ready for. He began to look for a job but his unkempt and unimpressive visage did not get

him very far. Wherever he went he showed his frayed notebooks and told people that he knew mathematics and could do clerical jobs. No one could understand what was written in the notebooks and his applications were turned down.

In 1911, he approached Ramachandra Rao, Collector at Nellore and the founder-member of the Indian Mathematical Society. This is what Rao wrote about their first encounter, *A short uncouth figure, stout, unshaven, not over-clean, with one conspicuous feature--shining eyes, walked in with a frayed notebook under one arm. He was miserably poor. He ...began to explain.....but my knowledge did not permit me to judge whether he talked sense or nonsense...I asked him what he wanted. He said he wanted a pittance to live on so that he might pursue his research*. Rao tried unsuccessfully to arrange for a scholarship for Ramanujan.

Ultimately, Ramanujan did find what he was looking for, a clerical job. Francis Spring, the Director of the Madras Port Trust, gave Ramanujan a clerical job on a monthly salary of Rs. 25. Later, some teachers and educationists interested in mathematics who had seen Ramanujan's work, initiated a move to provide him with a research fellowship.

In 1913, Ramanujan sent a letter to G. H. Hardy, the renowned mathematician of Trinity College. He set out 120 theorems and formulae. He also gave a key formula in hypergeometric series, which came to be known after him. Hardy would have ignored the letter from an obscure Indian but as fate would have it, he glanced at the theorems included and was instantly hooked. As Hardy later said, *No one would have had the imagination to cook them up*. It did not take long for Hardy to realize that they had discovered a mathematical genius. Only a mathematician of the highest class could have written those theorems. Subsequent correspondence with Ramanujan was enough to convince Hardy that here indeed was a genius. He asked Ramanujan to come over to England and even made arrangements for Ramanujan's passage and stay at Cambridge University.

All through this eventful decade of Ramanujan's short life, the Madras University came to his help thrice. It offered him the first research scholarship of the University in May 1913; then it offered him a scholarship of 250 pounds a year for five years with 100 pounds for passage by ship and for initial outfit to go to England in 1914; and finally, it granted Ramanujan 250 pounds a year as an allowance for five years commencing from April 1919, soon after his triumphant return from Cambridge with a scientific standing and reputation such as no Indian has enjoyed before.

On March 17, 1914, Ramanujan sailed for Britain. But his decision to travel abroad was not without its usual share of drama, for it raised quite a few eyebrows in his family, as foreign travel by devout Hindus was frowned upon in those days. The story goes that the family deity, Goddess *Namagiri*, appeared in a dream and parental permission was subsequently granted for the voyage.

Ramanujan arrived in Cambridge on April 14, 1914 and found himself a total stranger there. Coming from the sunny climate of India, the English cold was hard to bear. Also, being a *Brahmin* and a vegetarian, he had to cook his own food. However, all through this hardship one factor remained constant--his interest in mathematics. And the company of Hardy and Littlewood made him forget much of his hardship.

During his five years stay in Cambridge, he published 21 papers, five of which were in collaboration with G.H. Hardy. His achievements at Cambridge included the Hardy-Ramanujan circle method in number theory and Roger-Ramanujan identities in partition of integers. He worked on composite numbers, algebra of inequalities, probability theory, continued fractions, and so on. Hardy always regretted that he had not chanced upon Ramanujan during the most fertile years of the latter's life which were spent battling poverty and neglect. Hardy also found Ramanujan an unsystematic mathematician.

In 1916 Ramanujan was awarded the B.A. degree by research of the Cambridge University. He was elected a Fellow of the Royal Society of London in February 1918. In October the same year he was

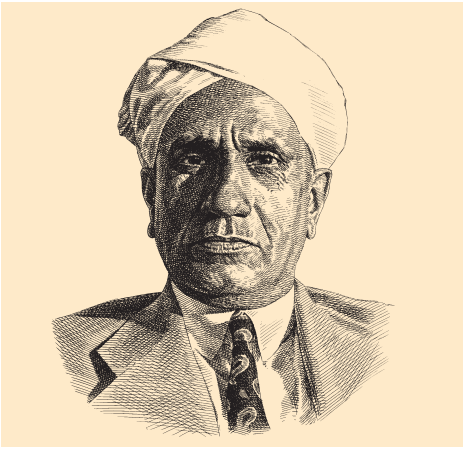
elected to a Trinity College Fellowship -- the first Indian to be elected Fellow of Trinity College. He received a prize fellowship worth 250 pounds a year for six years with no duties or conditions attached. But Ramanujan was not destined to live long enough to enjoy either fame or prosperity.

His health began to fail. Tuberculosis had begun devouring him. He spent a long time in hospitals. His mind, however remained razor sharp. Once, Hardy visiting him in the hospital mentioned that the number of the taxi he had come in was 1729, and that he thought it was *rather a dull number*. From his sick bed, Ramanujan protested, *No, Hardy, it is a very interesting number. It is the smallest number that can be expressed in two different ways as the sum of two cubes*. As usual he was right because 1729 can be written as 103+93 and also as 123+13.

Failing health forced Ramanujan to return to India. Hardy, his mentor wrote, *He will return to India with a scientific standing and reputation such as no Indian has enjoyed before, and I am confident that India will regard him as the treasure he is. His natural simplicity and modesty has never been affected in the least by success--indeed all that is wanted is to get him to realize he really is a success*.

His health may have deserted him but his passion for mathematics did not diminish in the slightest. Even on his deathbed he continued to play with numbers. It was a touching sight to see him lying in bed solving mathematical problems while his wife fed him rice balls with her own hands. On April 26, 1920, Ramanujan died, aged 32 years, at Chetpet in Madras.

Although Ramanujan had taken his notebooks with him to Cambridge, he had no time to delve deep into them. The 600 formulae he jotted down on loose sheets of paper during that one year he had in India after his return from Cambridge, are in the book *Lost Note Book* brought out by Narosa Publishing House in 1987, on the occasion of Ramanujan's birth centenary. The notebooks were found by George Andrews of Pennsylvania State University in the estate of G.N. Watson in the spring of 1976.



CHANDRASEKHARA VENKATA RAMAN

1888-1970

He is often remembered as the genius who won the 1930 Nobel Prize for Physics, working with simple equipment barely worth Rs. 300. Chandrasekhara Venkata Raman was one of the greatest experimental physicists of the century and the first Asian scientist to win the Nobel Prize. His spirit of inquiry and devotion to science laid the foundations for scientific research in India, for not only did he win honour as a scientist but also inspired several generations of students.

Raman was born on November 7,1888, in the town of Tiruchirapalli on the bank of river Cauvery, into a family of traditional agriculturists. It was a departure from family tradition when Raman's father, Chandrasekhara Ayyar, a scholar in physics and mathematics took to teaching in the local school. He loved music. Raman too, grew up in an atmosphere steeped in music, Sanskrit literature and science. His father took another bold decision when he accepted the post of lecturer in physics and mathematics at the A. V. N. College in the harbour town of Vishakhapatnam and moved there with his wife, Parvathi Ammal, and their four-year-old son, Raman.

The next ten years of Raman's life were spent in Vishakhapatnam at the high school and in college. He stood first in every class and his genius became evident, early on. He read far beyond his classroom level and when doubts arose, set down questions like 'How?' 'Why?' and 'Is this true?' in

the margin of textbooks. After his intermediate examination, he moved to Madras in 1903, and joined the B.A. class in Presidency College. In the year 1905, he was the only student who passed in the first class, also winning a gold medal in physics. In 1907, he took his M.A. degree, again obtaining a first division with a record score of marks.

While still a student at the Presidency College, he undertook original investigations in acoustics and optics and also wrote research papers for reputed science journals. The works of the German scientist Helmholtz and the English scientist Lord Rayleigh on acoustics, influenced Raman. When he was eighteen years old, one of his research papers was published in the Philosophical Magazine of England. Later, another paper was published in the scientific journal, *Nature*. At the age of nineteen, he became a member of the Indian Association for the Cultivation of Science.

However, since pursuit of science in India at that time offered little career opportunity, Raman joined the Indian Audit and Accounts Service (I.A.A.S.) standing first in the competitive examination. While he was waiting for the posting to come through he married Lokasundari Ammal on May 6,1907, a girl who proved to be a worthy and life-long companion, and one whose principal interest in life lay in doing all she could to enable to Raman to carry on with his scientific work, uninterrupted. In June 1907, he was posted to Calcutta as Assistant Accountant General in the Finance Department in which he spent the next ten years of his life. Fortunately, a great part of the time was spent in Calcutta, and it was in Calcutta that something happened to give a new turn to his life.

One evening, as Raman was returning from office in a tramcar, he caught sight of the signboard of the Indian Association for the Cultivation of Science (IACS) at 210, Bow Bazaar Street. He got off the tram immediately, and went in. Amritlal Sircar, son of the founder Mahendralal Sircar, was the Honorary Secretary of IACS. Raman walked through spacious rooms and found old scientific instruments, which could still be used for demonstration of experiments. He asked whether he could conduct research there in his spare time. Sircar gladly agreed. Raman moved to a house next door to the Association and a connecting door was opened between his house and the laboratory. During the daytime he attended office but his mornings and nights were devoted to research. The Association thus became his work place for many years.

Raman was transferred to Rangoon, the capital of Burma, in 1909. When his father passed away in 1910, he came to Madras on six months leave. After completing the last rites for his father, he spent the rest of his leave doing research in the Madras University laboratories.

Through his link with IACS, Raman had come in contact with Sir Asutosh Mookerjee who, as Vice-Chancellor of Calcutta University, was instrumental in establishing the University Science College in 1915. When Sir Asutosh wanted a professor to fill the newly created Palit Chair in Physics, he could think of none other than Raman and offered him the post. Well aware that the salary would be much lower, Raman quickly gave up his powerful post in the government all the same, and joined the Calcutta University as Palit Professor of Physics in 1917.

In 1919, after the death of Amritlal Sircar, Raman was elected Honorary Secretary of IACS. He now had the charge of two laboratories — of the College and of the Association. This gave a new stimulus to his research. Raman frequently referred to this period as the golden era in his career. Absorbed in experiments, it was not unusual for him to forget food and sometimes, working late through the night, he would sleep on one of the laboratory tables.

Students came to him from different parts of the country for post-graduate studies and research both at IACS and at the University College. Research workers like Meghnad Saha and S. K. Mitra, who became famous later, worked at these centres. According to the terms of the Palit Chair, he could have kept himself free from teaching work, doing only research. But Raman took immense pleasure in teaching and students were greatly inspired by his lectures.

Some of the areas that interested him at that time were, vibrations and sound; theory of musical instruments; optical studies such as diffraction, colours and interference; colloids; molecular scattering of light; X-rays; magnetism and magneto-optics.

Raman was a great lover of music and used to say, *I should live long, because I have not heard all the music I want to hear*. He was a frequent visitor to a musical instruments shop in Balepet, in Bangalore and collected a variety of musical instruments like the *mridangam*, the *tabla*, the *veena*, the violin and the *nagaswaram*. Around 1918, he had explained the complex vibrations of the strings of musical instruments. He later defined the characteristic tones emitted by the *mridangam*, the *tabla* and so on. Some years later, he was asked to contribute an article on the physics of musical instruments to the *Handbuch der Physik* and he did so for the eighth volume of that series, published in 1927. Few persons would know that he was elected to the Royal Society, London in recognition of his work on the physics of Indian musical instruments.

Raman loved colour, beauty, form, and rhythm in nature. He collected thousands of specimens of butterflies and purchased hundreds of diamonds of different forms. He was so bewitched by the physical properties of the diamond that at one time every researcher in his laboratories was working on the physics of this simplest of all crystal structures.

And then came Raman's discovery of the scattering of light that catapulted him to world fame. The Raman effect, as it is more popularly known, had its origin in the wonderful blue colour of the Mediterranean Sea. Lord Rayleigh had attributed the colour of the sea to the blue of the sky reflected by the water. In 1921, on his way to Oxford to attend the Universities' Conference by ship, Raman was struck by the deep blue opalescence of the Mediterranean water. On board the ship itself, he conducted some experiments using a nicol prism. Soon after returning to Calcutta, he carried out more experiments at his IACS Laboratory, with waters collected from different seas. He came to the definite conclusion that it was the scattering of light molecules by the oceanic waters that made them look blue. For the next seven years, Raman and his students carried out several experiments and established the various laws of molecular scattering of light in diverse media and 56 original research papers were published from Raman's laboratory.

Raman finally decided to clinch the issue and asked K. S. Krishnan to take up the experimental work on the anomalous scattering in liquids and vapours, in collaboration with him. While Raman was checking and confirming the results obtained by Krishnan, a joint letter was drafted and sent for publication to *Nature* on February 16,1928, which was published in its issue of March 31, 1928.

On February 28,1928, Raman had announced the discovery to the press and the public. On March 16,1928, Raman delivered an address to the newly formed South Indian Science Association at Bangalore, under the title: A New Radiation. He also acknowledged with affection the assistance given by K.S.Krishnan and K.Venkateshwaran, who were his students. Immediately on return to Calcutta, Raman had this address printed overnight at the Calcutta University Press and mailed the reprints to thousands of scientists all over the world. The phenomenon captured the attention of research workers all over the world. It became famous as the 'Raman Effect'. The spectral lines in the scattered light are now known as 'Raman Lines'.

Investigations, making use of the Raman Effect, began in many countries. During the first twelve years after its discovery, about 1,800 research papers were published on various aspects of it and about 2,500 chemical compounds were studied. The Raman Effect was perceived as one of the greatest discoveries of the third decade of the twentieth century. In 1929, the British Government conferred knighthood on Raman. And finally, in 1930, he was awarded the Nobel Prize in Physics. No Indian or Asian had received the Prize for Physics till then. At the ceremony for the award, Raman used alcohol to demonstrate the Raman Effect but later in the evening, when alcoholic drinks were served at the dinner, Raman did not touch them.

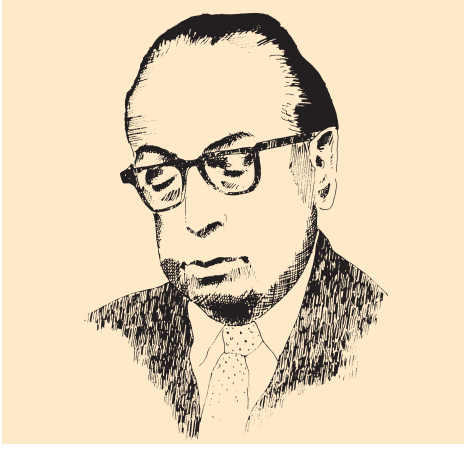
Raman left his indelible imprint on several institutes, some of which he had personally helped to set up. In 1933, Raman was appointed Director of the Tata Institute (later renamed Indian Institute of Science) at Bangalore. Under his able guidance and inspiration the Institute soon became famous for the study of crystals. In order to encourage scientific research in India, Raman established the Indian Academy of Sciences in 1934, drawing in distinguished and active scientists from various parts of India as its foundation fellows. The Government of the princely state of Mysore granted 24 acres of land free of cost to promote the activities of the Academy.

His earnest desire was *to bring into existence a centre of scientific research worthy of our ancient country, where the keenest intellectuals of our land can probe into the mysteries of the Universe*. It led him in 1948 to establish a Research Institute at Hebbal, Bangalore. He gave away all his property to the Institute that later came to be known as the Raman Research Institute. At the Institute, he wished to concentrate on things that interested him and the entrance displayed a board bearing the words, *The Institute is not open to visitors. Please do not disturb US.*

In 1954, Raman was bestowed with the greatest honour the Government of India confers on an Indian -- the Bharat Ratna.

During the last few years of his life Raman became increasingly isolated from other scientists in India. He was generally critical of the post-Independence scientific efforts in India and disapproved of young scientists leaving India to build their careers. Raman wanted the young persons working with him to take up independent positions and to serve the nation. He saw his laboratory as a centre for training young talent, not a permanent storehouse.

Towards the end, Raman became an Institution in himself and work was all that mattered to him. He never dreamt of a life without work. He had told his doctor, *I wish to live a hundred per cent active and fruitful life*. Every year he used to deliver a popular science lecture on the occasion of Gandhi Jayanti. On October 2,1970, he spoke on the new theories about hearing and the eardrum. This was his last lecture. After a short illness he passed away on November 21, 1970.



SISIR KUMAR MITRA

1890-1963

Remembered for his contributions to the development of broadcasting in India, it was Sisir Kumar Mitra who started the radio industry in the country. Mitra specialized in radio physics, wireless and industrial research. It was due to his untiring efforts that radio science gained importance as a subject and began to be taught in Indian universities.

Mitra was born at Konnagar, a suburb of Calcutta, on October 24,1890. He was the third son of Joy Krishna Mitra, a school teacher. His mother, Sarat Kumari, who had been trained at the Campbell Medical School in Kolkata, obtained a post in the Lady Dufferin Hospital in Bhagalpur and the family moved to that town. And so it was that Mitra first went to school in Bhagalpur. When he was a young boy, he witnessed a man called Ram Chandra Chatterjee demonstrate how one could ascend by balloon. Not getting a satisfactory answer from his elder brother, he began looking for the answer in science books and magazines. In due course he came across the writings of J. C. Bose. This was the beginning of his interest in science.

But then tragedy struck. His two elder brothers died and his father became paralysed. Had it not been for the insistence of his mother that he continue his education, Mitra would have had to leave school. After clearing school and college from Bhagalpur he managed to secure admission in 1908 to the Presidency College, Calcutta, where in 1912 he headed the list of successful candidates for the M.Sc. degree in Physics. At the Presidency College he had the privilege of watching closely J. C. Bose and P. C. Ray doing research. In fact, Bose's pioneering equipment for generating and detecting radio waves influenced him to take up research in radio science. In 1916, it was an offer for the post of lecturer at the newly formed postgraduate Department of Physics of Calcutta University that marked the beginning of his scientific career.

In 1919, after being awarded the D.Sc. by Calcutta University for his thesis on the *The Interference and Diffraction of Light*, he went to work under Professor Fabry, at the Sorbonne. He obtained his Doctorate degree there in 1923, and then worked for some time at the Institute of Physics in the University of Nancy, where he studied the behaviour of thermionic valves. He also came across scientists carrying out research on radio frequency oscillations in discharge tubes. It was then that he decided to change his line of research and study the propagation of radio waves.

In 1923, Mitra was offered the Khaira Chair of Physics in the University of Calcutta where he started to teach wireless at the postgraduate level. Soon afterwards, a wireless laboratory was set up in 1925. For years to come, this laboratory would provide facilities for researches on electron tubes and propagation of radio waves. Next, Mitra constructed a radio transmitting station in the laboratory with the call sign 2CZ. Along with other amateurs in Bombay and Madras, this station in Calcutta broadcasted regular programmes for general reception. It was not until the Indian Broadcasting Company started transmissions in 1927, that 2CZ was closed down. 2CZ proved to be a valuable training ground in radio and electronic techniques for future engineers in broadcasting organizations.

In scientific circles, Mitra is renowned for his contributions to the study of the ionosphere. The ionosphere is composed of several layers designated as D, E, F and so on. Based on his researches Mitra found that the ultraviolet radiations emitted by the sun produced the E layer. This was a wonderful achievement as the presence of this layer had baffled scientists the world over.

Mitra also found out why the night sky appears dusty black and not jet-black, as it should. He attributed this to the presence of ions in the F layer which emit some light, the process being called night sky luminescence.

In 1935, Mitra was appointed to the Ghosh Chair of Physics, which he held until his retirement. On a visit to England and the United States in 1944 he was impressed by the manner in which radio and electronics were being taught in the universities. Back home, Mitra worked tirelessly until he succeeded in establishing a new Institute of Radio Physics and Electronics in 1949. Mitra became the first head of this Institute. In 1952, the Institute was transferred to a new building and in 1955, a separate Ionospheric Field Station was set up in Haringhata.

Setting up just one station was not enough. Mitra realized that observatories ought to be set up in more places other than Calcutta, if a fruitful synoptic study of the ionosphere was to be made in India. He worked hard at realizing this goal until a Radio Research Committee was finally set up in 1943 and Mitra became its first Chairman, a post he held until 1948.

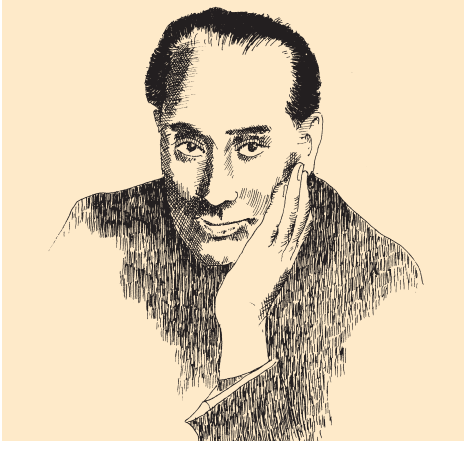
Mitra was acclaimed in international scientific circles for his book *The Upper Atmosphere*. The book was written with the help of an enthusiastic team of research workers. But none of the European or American publishers were ready to publish it. Eventually, M. N. Saha, who was then the President of the Asiatic Society of Bengal, persuaded the Society to bring it out as one of its memoirs. The book was published in 1947 with a printrun of 2,000 copies, which were sold out within two years. A

revised edition was published in 1952. Mitra's reputation in international circles rests on this book.

In 1955, he retired from the University and relinquished the Ghosh Chair of Physics. In 1956, he was appointed Administrator of the Board of Secondary Education in West Bengal, a post he held until 1962, when he was appointed a National Research Professor by the Government of India. He was General Secretary of the Indian Science Congress Association (1939-1944) and was elected its General President in 1956.

Those who had the opportunity of knowing Mitra well in India held him in high regard because of his devotion to duty, his meticulous observance of rules and regulations, and his concern for precision and perfection in speech and writing. During his lifetime Mitra won several awards. He was elected to the Fellowship of the Royal Society in 1958 and in 1962, he received the Padma Bhushan.

An attack of cardiac asthma took the life of this great Indian scientist on August 13,1963 in Kolkata.



BIRBAL SAHNI
1891-1949

In 1932, Sir Philip Hartog came to Lucknow to meet Birbal Sahni, then already a renowned palaeobotanist. As he was being shown round the Botany Department, he casually asked, *Where does Professor Sahni work?* On being shown a table in the corner of the botany museum he exclaimed, *What! Professor Sahni has no room of his own?* Then he added smilingly, *Yes, great scientists have worked only in garrets*.

That was a glowing tribute to Birbal Sahni, the most eminent palaeobotanist India has ever produced and the man who pioneered research in palaeobotany in India. He founded the Institute of Palaeobotany at Lucknow in 1949 the only one of its kind in the world, now named after him. So intense was his love for the subject that he donated his entire life's savings for setting up the Institute.

Sahni was born on November 14, 1891 at Bhera, now in Pakistan, into a family which was unusually enlightened, and which held education in high esteem. His father, Lala Ruchi Ram Sahni, was a scholar. He encouraged the boy to collect plants, rocks and fossils, and during vacation time took him to the Himalayan mountains and other places.

Birbal had his early education at Lahore, first at Mission and Central Model Schools and then at the Government College. After obtaining the B.Sc. degree from the University of Punjab in 1911, he travelled to England and entered Emmanuel College, Cambridge. Graduating from Cambridge in 1914, he settled down to research at the Botany School where he came under the spell of A.C. Seward. The years that he spent under Seward's tutelege were the most fruitful ones of his life. Sahni always had the greatest regard and affection for his master and in many ways he seems to have taken Seward as his model.

Sahni began his research work at Cambridge with conventional investigations of morphology and anatomy of living plants, but before long he took up the study of fossil plants. He published his first paper in the *New Phytologist* entitled *On the presence of foreign pollen in the ovules of Gingko biloba, and its significance in the study of fossil plants*. For his researches on fossil plants he was awarded the D.Sc. degree of London University in 1919. The University of Cambridge recognized his work by the award of ScD. in 1929, said to be the first such award to an Indian scientist. Seven years later, he was elected a Fellow of the Royal Society, London.

Sahni's first introduction to the rich stores of fossil plants in India was in 1917 when he joined

Seward in the production of a *Revision of Indian Gondwana Plants*. This work dealt with gymnosperms of varied types. In 1919, after working for a short period at Munich under the renowned German plant morphologist Goebel, Sahni returned to India. He held the Chair of Botany at the Banaras Hindu University for one year and for another year was Professor of Botany in the University of Panjab.

In 1920, he married Savitri Suri, younger daughter of Sunder Das Suri, Inspector of Schools in Punjab. His marriage was a happy one, for his wife took very active interest in all his work and was his life-long companion.

The turning point in Birbal Sahni's life came in 1921 when he took charge of the newly opened Botany Department of Lucknow University as Professor. He undertook, with great energy and enthusiasm, the work of organizing the department and of providing teaching on the same plan as at Cambridge. Very soon, he had established that apart from being a keen researcher, he was also a teacher par excellence. A former student of his had this to say about him: *Professor Sahni always believed that the junior classes should be handled to a certain extent by their seniormost teachers. So he always insisted on his lecturing to the B.Sc. classes and sharing the undergraduate class practical work also, along with junior members of the staff*. He wrote a *Textbook of Botany* with Lowson which was used the world over.

Sahni's lectures to the undergraduate classes were exceedingly simple in style and direct in approach—at first stressing on the obvious and the important and then filling in details. But he never missed telling them briefly about the latest developments nor failed to refer to work in progress in India. In the practical classes too, he rarely left the room but was always busy correcting drawing books, explaining some difficult point or giving some tips about methodical and accurate practical work.

His reputation as a teacher and his fame as an investigator attracted students from all over India. Gradually, he became surrounded by a band of young and enthusiastic research workers. But Birbal Sahni had long realized that a student of botany cannot do justice to paleobotanical studies without adequate background of geology. He always kept in mind the geological background and implications of plant fossils that he chanced upon in the course of his excursions. He believed that "fossil plants represent the debt that botany owes to geology". At the same time, he also believed, and demonstrated too, that palaeobotanical research can not only be of considerable help in solving stratigraphical problems but also throw light on past climates and earth movements and thus contribute to economic geology.

It was this belief that led Sahni to make untiring efforts to set up a Department of Geology at Lucknow University in 1943. He became its first Head and taught dynamic geology and palaeobotany. He also gave introductory lectures on stratigraphical geology to the postgraduate students before they started their regular morphology course. He did more than anyone else to convince the geologists that study of plant fossils yielded results of a far-reaching nature that the geologist could not afford to ignore.

Among Sahni's more important discoveries was the recognition of a type of gymnospermous plants of Jurassic age, which Sahni named the Pentoxyleae, and which attracted worldwide attention. One of the problems that occupied much of Sahni's research career was the revision of the Indian Gondwana plants. Geologists had long established, on the basis of fossil records, that the Indian subcontinent was originally part of a supercontinent comprising South America, Africa, India, Australia and Antarctica. They named this supercontinent Gondwanaland after the Indian kingdom from where fossil plants, typical of all these continents some 300 million years ago, were first described. The most abundant among these plants were the *Glossopteris* type, the fossils of which were discovered in India. It was earlier believed that the *Glossopteris* plants were quite adapted to growing in a very cold glacial climate. But Sahni demonstrated with his fossil studies that the presence of *Glossopteris* indicated not glacial but cold temperate conditions.

He also explored the Rajmahal Hills of Bihar, which is a treasury of plant fossils. From detailed studies of plant fossils found in the region he came to the conclusion that the Gondwana flora was *Jurassic* (geological period lasting from about 213 to 144 million years ago) with not a single species characteristic of the Cretaceous (geological period lasting from about 144 to 70 million years ago).

The reconstruction of past flora, on the basis of plant parts often found scattered in fossil beds at different times, is an exciting aspect of palaeobotany. Sahni had an uncanny ability to hunt up and fit together scattered fragments of one and the same stem or a leaf and a stem. One of the most well-known reconstructions done by Sahni was that of a cycad-like plant, fossils of which were discovered near Amrapara in Santhal Pargana district of Bihar. Fossilized stem, leaves and flowers of the plant had already been studied by other workers who had described each of them as belonging to a different group. But Sahni's own investigations convinced him that the flower and the leaves and stem earlier described, all belonged to the same plant. He named the plant *Williamsonia sewardiana*, in honour of his guru A. C. Seward who, in 1900, had first described the leaves of the plant from Rajmahal fossils. Sahni's investigations also led to the reclassification of a new genus and species of a cone-bearing plant with fern-like leaves which has been named *Pentoxylon sahnii* after him.

Sahni travelled widely and made himself popular wherever he went. He also took active part in the promotion of science in India. He was one of the founders of the Indian Botanical Society and was its President in 1924. The Royal Asiatic Society of Bengal awarded him the Barclay Medal for biological research and he received the Sir C. R. Reddy National Prize for Natural Science in 1947.

In 1929, he had conceived the idea of establishing a central Indian museum for fossil plants. However, lack of official encouragement saw his idea wither away. But during the last ten years of his life, he relentlessly pursued another idea—that of establishing an institute devoted to palaeobotany. Birbal Sahni and his wife provided most of the funds, contributions from various donors were added from time to time, and grants were received from the Government of India and from the Provincial Government of Lucknow. A governing body was set up and the work of the Institute was begun in the Department of Botany and Geology in the University of Lucknow. Soon a piece of land could be secured for the Institute's own building. On April 3, 1949, Jawaharlal Nehru laid the foundation stone of the Institute of Palaeobotany. The foundation stone was itself quite unique. Designed by Sahni himself it was a mosaic of plant fossils collected from various continents of the world.

Tragically, Sahni did not live to see his dream come true. Five days after the foundation-laying ceremony, he succumbed to a severe heart attack. The legacy that Birbal Sahni left behind continues to inspire generations of palaeobotanists even today.

MEGHNAD SAHA

1893-1956

Fearless and frank in his criticism of government policies, imbued with the spirit of nationalism and self-sacrifice, so much so that when the British Government divided Bengal in 1905, a 12-year-old schoolboy boycotted the Governor's visit. He paid a heavy price with his name being struck off the school rolls. The boy grew up to become an astrophysicist of world repute whose theories of thermal ionization of

elements and selective radiation pressure revolutionized astrophysical thought. That was Meghnad Saha, one of the foremost scientists that India has produced and one who not only raised the status of science in independent India but also served the cause of the poor.

Meghnad was born on 6 October 1893 in Seoratali village of Dacca district, now in Bangladesh. He was the fifth child of his parents Jagannath Saha and Bhubaneshwari Devi. His father was a petty grocer who barely managed to feed his large family. Meghnad, therefore, worked for some time at his father's shop even as he pursued his education in the village primary school. His father wanted the boy to start earning for the family from his very childhood, but some teachers who recognized his calibre early on, persuaded his father to allow him to continue schooling beyond the primary stage.

Reluctantly, his father arranged for his son to be sent to an English school 11 kilometres from the village. Meghnad's eldest brother, who took a great deal of interest in his education managed to persuade Ananta Kumar Das, a local medical practitioner, to let Meghnad stay in his house, free of board and lodging. He would never forget the help and kindness of Das at the start of his educational career. Meghnad stood first in the middle school examination and was awarded a scholarship which enabled him to get admission to the Collegiate School in Dacca in 1905. And then came the boycott episode, after which his name was struck off the rolls of the school and he had to forfeit his scholarship as well. Meghnad was then admitted to the Kishori Lal Jubilee School with a free studentship with his brother chipping in with the remaining expenses. In 1909, he passed the Entrance Examination standing first among those who appeared from East Bengal.

After passing the Intermediate Examination from the Dacca College he won a scholarship and joined the Presidency College in Kolkata. Here he was not only taught by eminent teachers like J. C. Bose and P. C. Ray, but also had brilliant contemporaries like S. N. Bose, P.C. Mahalanobis and Nil Ratan Dhar. He also made the acquaintance of Subhash Chandra Bose who was three years his junior, two of his older brothers being Meghnad's classmates.

Meghnad secured the second position in first class both in B.Sc. in mathematics and in M.Sc. in applied mathematics. He thought of competing for the Indian Finance Examination but was not allowed to appear because of his association with revolutionaries like Jatindra Nath Mukherjee, Pulin Das and Subhash Chandra Bose. With all hope gone of a government job, he decided to carry on research in applied mathematics and physics. He also took on the responsibility of educating his youngest brother. He would earn money by giving tuitions morning and evening, cycling to distant places, to support himself and his brother.

In 1917, Sir Asutosh Mookerjee was looking for exceptionally talented persons to man the newly created postgraduate departments in science at the University College of Science in Calcutta. He invited Meghnad Saha and S. N. Bose to join the Department of Mathematics. But since these two could not get along with the Ghosh Professor of applied mathematics, both were transferred to the Department of Physics with Sir Asutosh Mookerjee's permission. Without the guidance of any senior professor Saha plunged heart and soul into theoretical and experimental researches in physics. Very soon he had published original papers in noted journals of physics, like the *Philosophical Magazine* of London and the *Physical Review* of USA. On the basis of these papers he was awarded the D.Sc. degree by Calcutta University in 1918.

Meghnad Saha's claim to fame rests on his theories of thermal ionization of elements, and of selective radiation pressure. Saha had been intrigued by one problem of astrophysics as he pored over books to prepare for his lectures. The spectrum of sun's chromosphere had been observed by Lockyer and Jansen as early as 1868. Gustave Robert Kirchoff had shown that the spectral lines comprising the spectrum told of the elemental composition of the sun, but astronomers could not make out what caused them. Saha put forward an ionization formula that explained

the presence of the spectral lines. The formula also enabled an astronomer to arrive at the temperature, pressure and several other aspects of the interior of the sun or any other star. The formula proved to be a breakthrough in astrophysics and very soon made him internationally famous. An eminent astronomer even called it the twelfth major discovery in astrophysics. Almost a decade after his discovery, Saha was elected a Fellow of the Royal Society, London.

The very next year he was awarded the Premchand Roychand studentship that enabled him to set out on a two-year study trip to Europe in September 1919. On his arrival in London he found that the funds he had were inadequate for a sojourn in Oxford or Cambridge. At the suggestion of one of his friends, Saha joined Fowler's spectroscopy laboratory at the Imperial College of Science and Technology, London. Working in Fowler's laboratory, he acquainted himself with the rapid advances in the classification of spectra which were taking place in Germany and England. He also discussed his theory of thermal ionization with Sir J.J.Thomson. During his stay in London he met S.S.Bhatnagar for the first time. Their acquaintance soon ripened into a close friendship. Saha would call him 'Steam Ship Bhatnagar' for his extraordinary energy.

Later, Saha worked for about a year in Nernst's laboratory in Berlin. It was during his stay in Berlin that he received an invitation from Sir Asutosh Mookerjee to return to the Calcutta University where a new Khaira Chair in physics had been created. On his return from Europe in 1921 Saha joined the post but it turned out to be a great disappointment. Sir Asutosh had a showdown with the Bengal Government and could not give Saha either a laboratory or an assistant.

Saha received offers from the Aligarh Muslim University, Banaras Hindu University and the Allahabad University. He chose Allahabad but things were not very smooth for him there either, to begin with. His colleagues were not cordial, nor were there sufficient grants to improve the laboratory. It was only after 1927 when he was elected a Fellow of the Royal Society that things began to happen. The Governor of the Province was pleased to make a research grant of Rs. 5,000 per year as personal recognition and Saha soon managed to establish cordial relations with his colleagues as well.

While at Allahabad, Saha showed brilliance as a teacher. He built one of the finest departments of physics, shouldering the responsibility of teaching frontier areas, like spectroscopy, X-rays and wireless. His lectures were famous, not only for the mastery of exposition but also for the large number of carefully designed demonstrations of experiments. In a few years' time Allahabad's contribution to physical science which had been negligible, began to rise with new life, as young researchers gathered around Saha from all parts of the country. Very soon the Department of Physics at Allahabad University gained international status.

One of Saha's achievements at Allahabad was the foundation of the UP Academy of Science in 1931, which was later renamed The National Academy of Sciences, India in 1934. Sir Malcolm Hailey who took a great interest in the inauguration of the Academy, sanctioned a sum of Rs. 4,000 per year for the Academy at Saha's request, in spite of the economic depression of 1931.

Saha returned to Calcutta in July 1938 as Palit Professor of Physics in the University College of Science and Technology. His reputation was at an all-time high. The subject that he chose for himself was nuclear physics. Otto Hahn discovered nuclear fission in 1939 and Saha at once realized its tremendous possibilities. He founded the Department of Nuclear Physics at Calcutta University, which in 1948 grew into the Saha Institute of Nuclear Physics. It was the fruit of Saha's genius and industry.

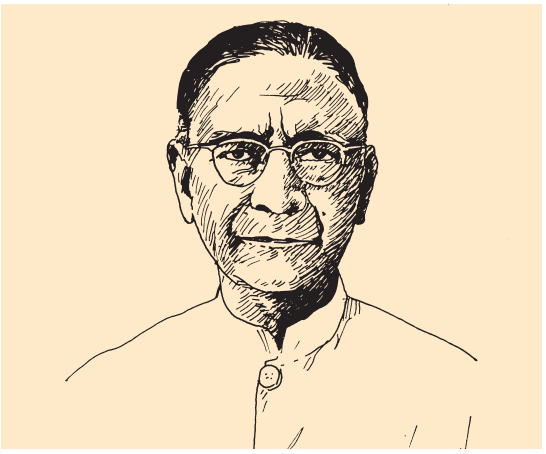
Saha is also remembered for his extensive studies on the origin and control of floods. He wrote a series of essays on floods, river management, irrigation and allied topics. In fact, a number of river valley projects, such as the Hirakud, Damodar Valley and Bhakra-Nangal projects, are the result of the work that he started. He was the chief architect

of the Damodar Valley Project which he had proposed in considerable detail in 1944.

Saha's intellect also did not fail to notice the mismanagement at every conceivable level. He wrote numerous articles based on an in-depth study of developmental plans of several countries, he also exposed the critical lacunae in our Five Year Plans. Critical of the neglect of the problem of population he observed, *In an overpopulated country like ours, the rate of population growth should be kept down as far as possible...It does not appear possible that the government can take much of an active step in this direction except by propaganda and education*.

As a young man, Meghnad had seen flood disasters and poverty at first hand. His heart bled for the sufferings of the common man. He would often organize relief work, whether it was for flood victims or for refugees uprooted as a result of communal disturbances. For days on end, he would work tirelessly visiting the refugee camps and making plans for their relief and rehabilitation.

This great scientist and planner who had a deep concern and vision for his country died on February 16, 1956.



P. C. MAHALANOBIS

1893-1972

The breathtaking beauty of Taj Mahal is a delight to behold. But if you happen to lay your hands on a guide written by India's best-known statistician, perhaps you may be able to appreciate its architecture still better. Prasantha Chandra Mahalanobis was the first Indian statistician to receive world recognition. In fact, the history of statistics in India reads more like Mahalanobis's biography.

Prasantha was born into a well-established family in Calcutta on June 28, 1893. His father had a flourishing business dealing in sports goods and his shop was a very popular rendezvous of athletes and sports lovers. His mother Nirodbashini was the sister of Sir Nilratan Sircar, a famous physician, educationist and industrialist. The family was imbued with liberal *Brahmo Samaj* traditions and had close contacts with the great intellectuals and social reformers of Bengal. All this had a deep influence on the young Prasantha and, in a way, prepared him for the active life he was to lead for seventy-nine years.

He passed the Entrance (later called Matriculation) examination from the Brahmo Boys School in Calcutta in 1908. After passing the Intermediate Science Examination in 1910 and the B.Sc. examination in 1912 from Presidency College, Prasantha left for London in the summer of 1913 to study for B.Sc. But as chance would have it, one day while on a visit to a friend at Cambridge, he missed the last train and stayed overnight with a friend. M. A. Candeth, an Indian undergraduate at King's College happened to drop by. Mahalanobis told him how deeply impressed he had been with the Chapel at King's. Candeth suggested that he should try to get into King's College. The very next day, an interview with Provost James ensured for him a seat at King's College. In 1914, he took Part I of the Mathematical Tripos but changed over to Physics and passed the Natural Science Tripos, Part II, with a first class in 1915.

Prasantha was no bookworm. He actively participated in social and cultural events, group discussions, the university union and was also fond of cross-country walks. He also had occasion to spend time with the great Indian mathematician Ramanujan.

After finishing his Tripos in physics, Prasantha arranged to work with C. T. R. Wilson at the Cavendish Laboratory, Cambridge. As the vacations approached, he planned to leave for India. But World

War I was on and there was some delay in starting his journey. One morning, while browsing in the King's College library, he chanced upon W. H. Macaulay who drew his attention to some bound volumes of *Biometrika*. On reading it, Mahalanobis was so thrilled that he brought along several volumes of the journal when he came to India for his vacation. He read the volumes on the boat during his journey, studied and worked out exercises on his own, during his spare time in Calcutta, and saw that statistics was a new science connected with measurements and their analysis, and capable of wide application. He tried to look for problems where he could apply the new knowledge. He found some interesting problems in meteorology and anthropology. It was this brush with statistics that would later become a life-long passion for him.

Another event that changed Mahalanobis's life forever was the World War. He decided not to go back to Cambridge to join the Cavendish Laboratory during war time, so he took up a lecturership in physics at Presidency College in Calcutta. But in spare time, he continued with studies in statistics. Many people thought that he was wasting his time. Statistics was known in India only in the sense of official data. The universities, research institutes or academic bodies did not recognize it as a separate discipline. Even the government bureaucracy was averse to introducing new methods or making changes in the existing practices. Mahalanobis had a great struggle ahead to advance the cause of statistics in India.

But there were three persons who realized the importance of the discipline and encouraged him—Rabindranath Tagore who had known him from childhood, Sir Nilratan Sircar, his maternal uncle, and Brajendra Nath Seal, Professor of Philosophy at Calcutta University, one who had himself, in his younger days, made original researches in mathematics. Seal took a personal interest in the statistical studies of Mahalanobis and predicted that one day statistics would become a basic scientific tool.

Another person who stood by him was his wife Nirmal Kumari, daughter of a great educationist and leader of the *Brahmo Samaj* movement. Soon after Mahalanobis returned from abroad, he fell in love with Nirmal Kumari and married her on February 27,1923. Though herself a strong-willed person, Nirmal remained a devoted wife and a constant companion to Mahalanobis throughout his life, accompanying him on his frequent tours abroad and within the country.

Mahalanobis did not consider statistics as a narrow subject confined to the mathematical theory of probability, or routine analysis of data in applied research, or collection of data as an aid to administrative decisions. He took a wider view of statistics as a *new technology for increasing the efficiency of human efforts in the widest sense*. Mahalanobis successfully applied statistical principles to problems in subjects, like anthropology, epidemiology, demography and meteorology. Impressed by his successes, various authorities approached him with their problems. For instance, in 1922, engineers attributed a disastrous flood that hit North Bengal to a rise in the river beds and advised the government to raise the embankments. When Mahalanobis was consulted he arrived at a different conclusion, using the figures of rainfall and floods for the past 50 years. He told the authorities that a better drainage system was required to ensure a smoother flow of the rivers. He did a similar study of floods in Orissa. The Hirakud hydroelectric project and the Damodar Valley multipurpose hydroelectric project are both based on his statistical studies.

These initial successes gave birth to the idea of starting the Indian Statistical Institute. The idea was mooted by Mahalanobis and a group of young persons in the 1920s, who were interested in applying statistical methods to the solution of practical problems. The Institute started as a workshop called the Statistical Laboratory which was located in Mahalanobis's room, who was then professor of physics at the Presidency College. On April 28, 1932, the Indian Statistical Institute (ISI)

was registered as a non-profit society under the Societies Registration Act.

To begin with, the Institute had only one part-time computer and the yearly expenditure was Rs. 228. *Sankhya*, the Indian Journal of Statistics was started in 1933,of which Mahalanobis was the editor. Among the first problems the Institute took up was developing a new technique of estimating acreage and yield of crops in a large region by random sampling and applied it to the jute crop in the province of Bengal in 1937. The first Indian Statistical Conference was organized by the Institute in 1938. Postgraduate studies in statistics were opened for the first time in Calcutta University in 1941 with Mahalanobis as the head of the Department. A central statistical unit was established by the Government of India in 1949, to work under the technical guidance of Mahalanobis. Two years later a Central Statistical Organization was formed for coordinating all statistical activities of the government and a few years later a new Department of Statistics was created.

In 1949, Mahalanobis became the Chairman of the Indian National Income Committee. He helped fill gaps in information for computing national income and in 1950, he established the National Sample Survey for the collection of socio-economic data through sample surveys covering the entire country. In 1954, the then Prime Minister of India called on Mahalanobis to initiate studies in Planning at the ISI to help in the formulation of the Five-Year Plans for he realized that the models suitable for developed countries might not be applicable for developing countries. In 1959, the ISI was declared as an institute of national importance empowered to award degrees by the Parliament. The Indian Statistical Service started in 1961. Within a short span of time, with his untiring efforts and meticulous organization Mahalanobis was able to raise statistics to a high pedestal. Some also call this period the Mahalanobis era in statistics.

Several of Mahalanobis's contributions to statistics such as *Mahalanobis distance* and *fractile graphical analysis* have been included in textbooks. Mahalanobis was elected a Fellow of the Royal Society, London, in 1945.

Mahalanobis remained active almost to the last day of his life. He was mentally alert and physically strong. He could spend long hours arguing or discussing with his colleagues even to the point of tiring them out. This visionary and the best-known statistician of India died in 1972 at the age of 79.

S. S. BHATNAGAR

1894-1954

When Shanti Swarup Bhatnagar died, the eminent Indian statesman C. Rajagopalachari stated that but for Bhatnagar, India would not have been so organized in its scientific efforts. Bhatnagar was an institution builder, who played a remarkable role in the development and management of scientific research in the country. The Council of Scientific and Industrial Research (CSIR), which he set up almost single handed, today spans a network of nearly 40 laboratories spread throughout the country. An eminent scientist and also a poet in Urdu, Shanti Swarup Bhatnagar was truly a man of many parts.

Bhatnagar was born on February 21, 1894, at Bhera in Shahpur district in Punjab. His father, Parmeshwari Sahay Bhatnagar, was a distinguished graduate of the Panjab University. His mother, Parvati, was the eldest daughter of Pearey Lal who was one of the first engineers to graduate from the famous Roorkee College.

But Shanti Swarup had a troubled childhood. His father lost his share of the family property and was disinherited because he had embraced *Brahmo Samaj*, and when he died he left his wife and young children in dire poverty. Parvati left Lahore with her two-year-old daughter and eight-month-old son, Shanti, and went to live with her father in Sikanderabad. It was here that Shanti developed a taste for engineering and science under the influence of his grandfather who had become a distinguished engineer and was employed in railway construction work. From an early age he became interested in his grandfather's instruments, Euclid and algebra, and in making mechanical toys.

Shanti's earliest schooling was in a private *maktab* which he joined in 1901 after which he studied in A. V. High School till 1907. In 1908, while attending a wedding, he had a chance encounter with Bishwanath Sahai, a science graduate from Lahore, and impressed him with his keen intellect. Back home, Bishwanath reported Shanti's prowess to his father Lala Raghunath Sahai who was the headmaster of Dyal Singh High School at Lahore. As it turned out, he learnt that young Shanti was the son of a close friend and former classfellow. He found young Shanti especially good in literature and sciences and persuaded his mother to send Shanti to the Dyal Singh High School. This was the turning point in Shanti's life.

The headmaster who later became his father-in-law was a great inspiration during that formative period. No sooner had he joined the school than Shanti secured a high-school scholarship in open competition and went on to earn his living by teaching young boys privately. Under the guidance of his science teacher, Moulvi Talib Ali Paband, he would often experiment with gadgets. As early as 1911, young Bhatnagar published a letter in *The Leader* of Allahabad on a method of making substitute carbon electrodes for a battery by heating molasses and carbonaceous matter under pressure. Later, as a scientist in 1942, in one of the CSIR laboratories, he developed a process for carbon electrodes in which indigenous materials were employed to meet the shortage of imports during the War.

Matriculating in the first division and securing a university scholarship Bhatnagar joined the Dyal Singh College in Lahore in 1911. Soon he was collaborating with N. N. Godbole on the *Fermentation Phenomenon of Pomegranate Juice* and published the results in *Raushni*, journal of the Society for Promoting Scientific Knowledge launched by Lahore Medical College students.

While still at college, Bhatnagar became an active member of the Saraswati State Society which was launched by Norah Doyle Richards, a London stage actress who had come to India as the wife of an English teacher. Encouraged by her, Bhatnagar became an amateur playwright in Urdu and wrote a one-act play called *Karamati* (Wonder Worker). The play satirized a miracle maker humbled by modern medicine. Bhatnagar played a caricature of himself in the play. The play was translated into English and he was awarded a medal of the Saraswati Stage Society for the best play of the year 1912.

When Bhatnagar passed the intermediate examination of the Punjab University in 1913 in the first division, Welinker, Principal of Dyal Singh College, wrote, *Mr. Shanti Swarup was one of the ablest students in that large class of about 100 students; indeed I am of the opinion that in all-round ability he was the ablest. He is a young man of more than usual ability and I feel sure that if he is given opportunities of developing talent in some great European or American centre of scientific research he will do some remarkable work in science and will thus be in a position to render high service to his country*.

Bhatnagar joined the Forman Christian College for a B.Sc. degree but was failed by the examiner. He had written in the physics paper that X-rays can be reflected, refracted and polarized like light. This was the latest finding of researches that he had read in journals, but it contradicted what was stated in Mellor's textbook. Not anticipating the setback, he had married Lajwanti, daughter of his school headmaster, during the vacations. He

had to take the B.Sc. degree all over again and to support himself and his wife, he again took up private tuitions. He also earned some money by developing a substitute for the German hektographic pad supplies that had been cut off by the War so that a local stationer could operate his duplicating machines.

Ruchi Ram Sahni took a special interest in Bhatnagar and was largely responsible for the award of a scholarship from the Dyal Singh College Trust for his studies abroad. Bhatnagar sailed for America from Bombay in August 4, 1919. When he reached England he found that all tickets for America had been booked for the American troops which were then being demobilized. Bhatnagar asked permission from the Trustees of the Dyal Singh College to do his post-graduate research in England and they agreed. He presented himself at the Ramsay Laboratory of F. G. Donnan, of the University College, London. Donnan set him a problem and satisfied enough with Bhatnagar's solution to accept him as a research student in emulsification, a branch of colloidal chemistry. The Privy Council of Scientific and Industrial Research granted Bhatnagar an annual grant of £ 250 which enabled him to spend some time in France and Germany, interacting with prominent scientists. In April 1921, he successfully defended his thesis on *Inversion of Emulsions* and was awarded the D.Sc. He was soon flooded with offers from India.

On his return to India in 1921, he took up the physical chemistry chair at the newly established Banaras Hindu University (BHU). There, he worked for three years creating an active school of physico-chemical research, which soon had a reputation comparable to that of the Indian School of Chemistry under P. C. Ray. Bhatnagar also composed the *kulgeet* (university song) in Sanskrit which to this day is sung by the students of BHU on ceremonial occasions.

While he was attending the 1923 Liverpool session of the British Association for the Advancement of Science, Bhatnagar came across an advertisement in *Nature* for the post of Director of the University Chemical Laboratories in Lahore. When he applied for the post he found himself in direct contest with his former professor Willsden. However, Bhatnagar was appointed for the post.

In Lahore, he resumed his research on problems in colloidal and photochemistry. There was no dearth of research workers, as students flocked to his laboratory from all over India including some from BHU. Between 1929 and 1939, Bhatnagar and his students published about 20 papers in Indian, British and German journals. Besides, his team also produced solidified hessian sheets which were better than thatch as rain-proof roofing and less expensive than slates for village houses in the hills. With Ram Narayan Mathur he devised an interference balance to measure the very small changes in the magnetic susceptibilites of substances in chemical reaction. The balance was later licensed to Adam Hilger and Company in London for manufacture. Commissioned by Macmillan, Bhatnagar also published a textbook, *Physical Principles and Applications of Magneto-chemistry*, in 1935. The book was well reviewed in scientific journals abroad and was viewed by many in India as a token of recognition in the west of the authority of an Indian scientist.

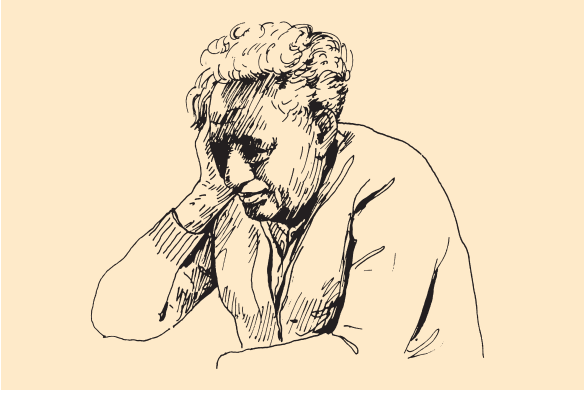
One of Bhatnagar's major achievements is the work he did for a British oil company. While drilling for oil at Rawalpindi the drilling mud would set into a solid mass when it came into contact with saline water. It hardened further and rendered all drilling impossible. Bhatnagar solved the problem by the addition of an Indian gum that lowered the viscosity of the mud suspension and protected it from the coagulating action of the electrolytic salts. The company was so pleased with the result that they offered Bhatnagar Rs. 1,50,000 for his research work on any subject of petroleum interest. Bhatnagar asked the company to place the money with the University instead. With this amount he engaged six research scholars and started a Department of Petroleum Research under his direction. This

department carried out important investigations on deodorization of waxes, increasing the flame height of kerosene, lubrication, prevention of corrosion and utilization of waste products in the vegetable oil and mineral industries.

When Arcot Ramaswamy Mudaliar convinced Viceroy Linglithgow of the need for a Board of Scientific and Industrial Research to mobilize Indian talent to meet the requirements of the World War II, Linglithgow wanted Bhatnagar to be its Director. Linglithgow even wrote to Governor Craig to get on lien for two years the man he considered *the most admirably qualified to help us in an issue of real significance*. Soon the laboratories of the Board started functioning from the Government Test House in Cal;cutta. When threats of Japanese invasion became more intense these were shifted to the Delhi University and the name was changed to the Council of Scientific and Industrial Research. Very soon several products of great importance had been developed by Bhatnagar and his staff such as gas masks with indigenous components, lubricating oil for bronze bearings in locomotives, air-foam solution, glass substitutes and plastics from Indian wastes. Bhatnagar had managed to harness science to propel India on the path of industrialization.

When the country gained its independence, the CSIR governing body was reconstituted with the Prime Minister as its President. Nehru and Bhatnagar shared a great rapport that was sustained to the end of Bhatnagar's life. Not only did Nehru retain Bhatnagar for six years after retirement at CSIR, but created a separate Department of Scientific and Industrial Research of which Bhatnagar was made the Secretary. Bhatnagar envisaged the establishment of a chain of laboratories throughout the length and breadth of the country that would not only become centres of excellence but would also provide gainful employment to thousands of countrymen. As his vision unfolded, the CSIR network started expanding. Before his death, twelve of these laboratories were fully functioning.

Ever since the death of his wife in 1946, Bhatnagar had become a workaholic. Maulana Azad who had appointed him the first Chairman of the University Grants Commission feared a breakdown of Bhatnagar's health and insisted on his taking a fortnight's rest and recuperation in Switzerland. But once back in India, Bhatnagar returned to his old ways. On a visit to the Himalayan Institute of Mountaineering, B. C. Roy found Bhatnagar having difficulty in breathing and advised him to take care of his heart. Not heeding the advice, Bhatnagar carried on till he suffered a heart attack on the night before New Year's Day 1955 while preparing for the Science Congress at Baroda. Maulana Azad had this to say to Bhatnagar, *I have lost a friend*. India, however, lost one of the most able administrators of science that the country has ever seen.



SATYENDRANATH BOSE
1894-1974

When the post of a professor fell vacant in Dacca University, S. N. Bose who had not yet got his doctorate, approached Albert Einstein for a recommendation to make things easy for him. Einstein was surprised. He wrote to the authorities of Dacca University, *Can you find another scientist as proficient as Satyendranath? He is quite fit for the post.*Bose was appointed Professor and Head of the Department of Physics.

Satyendranath Bose was born on January 1, 1894, in Calcutta. He was the eldest of seven children and the only son among six daughters. His

father Surendranath Bose was a trained accountant who held a responsible post in the Executive Engineering Department of the East Indian Railways. Amodini Devi, his mother, suffered from poor health all through her life. Surendranath took special care to see that nothing came in the way of the boy's education.

Young Satyendranath attended a neighbourhood elementary school in Calcutta. In 1907, he joined the Hindu School. His eyesight was weak but his intelligence and memory were sharp. He was deeply interested in science right from school days. After passing high school in 1909, Satyendranath entered the Presidency College. He recalled the period of his stay in Presidency College as the Golden Age. It was here that the company of good friends and classmates and the guidance of illustrious teachers shaped his future. Some of the most renowned scientists, Meghnad Saha, Nikhilranjan Bose, J. C. Ghosh, J. N. Mukherjee and Girijapathi Bhattacharya, were his classmates. He had as his teachers eminent scientists like J.C. Bose, P. C. Ray and S. N. Maitra. Satyendranath not only shared the excitement of acquiring scientific knowledge in the midst of illustrious company but also imbibed patriotic fervour from the Swadeshi movement, which was at its height.

Bose took his B.Sc. examination in 1913 and the M.Sc. degree in 1915 from the Calcutta University, standing first in both. It was around this time that Sir Asutosh Mookerjee laid the foundation of the University College of Science for postgraduate studies and research. In 1915, some of those who had secured the master's degree approached Sir Asutosh Mookerjee and requested him to open postgraduate courses in modern physics and modern mathematics in Calcutta University and allow them to teach. Among them were Meghnad Saha, Jnanachandra Ghosh, and Satyendranath Bose. In 1916, the University started M.Sc. classes in modern mathematics and modern physics. M. N. Saha, J. C. Ghosh and S. N. Bose were all appointed lecturers.

Bose began to learn French and German in order to read the European scientific literature. But because of World War I, it was difficult to order books from abroad. Bose and Saha then approached P. J. Bruhl, an instructor in the Bengal Engineering College, who possessed advanced textbooks on physics. After reading up on the developments in new physics, they took over the task of teaching postgraduate students and even began to teach relativity to their students, not attempted till then. Within a few years the Calcutta University became recognized as the leading institution for higher learning in the sciences.

After five years at the Calcutta University, Bose moved to Dacca University in 1921. It was around this time that his friend D. M. Bose returned from Berlin and brought with him new publications on the quantum theory. He gave Planck's *Thermodynamik und Warmestrahlung* (Thermodynamics and Heat) to Bose to read. The book contained all the original papers of the great physicist. Bose started working on the equations and formulae himself. At one place, Bose found that Planck had assumed some hypothesis and calculated an equation approximately. Bose worked out a better way to calculate the equation. He sent his four-page research paper, *Planck's Law and Light Quantum Hypothesis*, to an Indian journal and to several journals abroad. But all of them rejected it. In desperation Bose sent the paper to Einstein in 1924. Einstein was so impressed with the daring concept that he himself translated it into German and sent it for publication to a German journal, *Zeitschrift fur Physik* which published the paper in its August 1924 issue. Einstein also explained at length the significance of the subject matter of the paper and added a comment: *An important forward step*.

Bose's original approach struck Einstein who later systematically adapted Bose's approach in his own work and the particular field of Bose's research came to be known as *Bose-Einstein Statistics*. Of late, it has come to be known merely as *Bose Statistics*. Elementary particles, such as photons that obey

Bose statistics, are called `Bosons' thus ensuring a permanent name for Bose in science.

Bose managed to get a two-year study leave and sailed for Europe from Bombay in September 1924. After a brief sojourn at Paris he reached Berlin where he eventually fulfilled his long-cherished desire of meeting Einstein, whom he considered his guru. On his return to Dacca, Bose was appointed Professor of Physics in 1927. Bose was greatly loved and admired as a teacher by his students, and his colleagues held him in high esteem. He was informal and kept his door always open to anyone who cared to drop in. His bedroom also served as his study.

Bose returned to Calcutta University in 1945 as Khaira Professor of Physics. During another visit to Europe in 1954, Bose had wanted to go to the United States to meet Einstein again. However, since he had happened to visit Russia earlier the Americans thought of him as a communist and did not give him a visa. Tragically, Einstein's death soon after, dashed Bose's hope of meeting his guru again.

In 1954 the Government of India conferred the honour of Padma Vibhushan on him and Bose retired from Calcutta University in 1956. The University honoured him by appointing him Emeritus Professor. Later he became the Vice-Chancellor of the Visvabharati University. In 1958, he was made a Fellow of the Royal Society, London.

Though Bose was primarily a scientist, he was equally interested in literature, art and music. He could read and enjoy poems in Sanskrit, Bengali, English, French and Italian. Bose had made a deep study of several works in Bengali and English literature and also translated some French short stories. Very few people know that Bose could play well on the bowstring musical instrument, *Esraj*. A gifted musician and critic of music, he also created a few new ragas.

At a time when the majority of the Indian elite craved proficiency in English, Bose understood the importance of the Indian languages. He believed that if science is to be understood by laymen, it should be taught in the regional languages. He founded a science association named *Bangiya Vijnana Parishad* in Bengal in 1948 and all its correspondence was carried out in Bengali. From its inception, the association has been bringing out a periodical entitled *Jnan o' Bijnan*.

Within a few days of completing 80 years, Bose suffered a severe heart attack and breathed his last on February 4, 1974.

HOMI JEHANGIR BHABHA

1909-1966

Homi Jehangir Bhabha will always be remembered as the architect of India's nuclear energy programme. One of India's most outstanding scientists and an imaginative administrator with a multi-faceted personality, Bhabha was an ardent nationalist.

Bhabha was born in Bombay on October 30, 1909. His father, Jehangir H. Bhabha, once a student of Oxford University and a reputed advocate, had served Tata Enterprises. Meherbai, Bhabha's mother, was the grand-daughter of Sir Dinshaw Petit, First Baronet, and widely respected in Bombay for his philanthropic endowments. His paternal grandfather was the Inspector-General of education in the State of Mysore.

Bhabha was educated at the Cathedral and John Cannon High School, Elphinstone College and the Royal Institute of Science, Bombay. His parents took a keen interest in nurturing Bhabha's love for science. He had access to his grandfather's large

library which contained many books on science. At the age of 15, he had already read Einstein's book on Relativity. Apart from science it was his father's and aunt's collections of music and his grandfather's fine collection of books on painting and art that imbued him with a love for nature and a deep interest in painting, music and literature. His pencil sketches and some of his paintings are preserved in British art galleries. Since his paternal aunt was married to Sir Dorab Tata, as a young boy Bhabha would often go across the road to the ancestral home of J.N.Tata, the founder of the house of Tatas. There he would hear discussions relating to projects for the industrial development of India, ranging from iron and steel to the manufacture of heavy chemicals. All this developed a strong nationalism in him and the resolve to dedicate himself to India's progress and development.

Bhabha loved physics and mathematics. But bowing to his father's and Sir Dorab Tata's wishes, who wanted him to become an engineer and join the Tata Iron and Steel Company at Jamshedpur, Bhabha left for Cambridge in 1927 to study engineering. He wanted to change to mathematics but his father promised finance for further studies in mathematics, only if he got a first in engineering. He passed the Mechanical Engineering Tripos in the first class in 1930 and then went on to study theoretical physics as a research scholar. During the two years of his work at the Cavendish Laboratory, Bhabha won several scholarships, travelled across Europe and worked with Pauli in Zurich, Enrico Fermi in Rome and Kramers in Utrecht. His first scientific paper in 1933, dealing with the part played by electron showers in the absorption of gamma radiation won for him the Isaac Newton Fellowship in 1934. Three years later, he was awarded a senior studentship and he continued to work at Cambridge until the Second World War began in 1939.

Bhabha came into close contact with famous scientists such as Rutherford, Dirac, Niels Bohr and Heitler and when the discovery of the positron in 1932 opened up a wide field for theoretical physicists, he threw himself into this field of high-energy physics. Most of the 50 scientific papers he published were concerned with high-energy physics. In 1937, along with Heitler, he presented the Cascade Theory of Electron Showers which is today known as the 'Bhabha-Heitler Cascade Theory'. The theory explains the process of electron showers in cosmic rays.

Bhabha returned to India in 1939 and accepted the post of Reader at the Indian Institute of Science in 1940. He was in charge of a special cosmic ray research unit set up for him with funding from the Sir Dorab Tata Trust. During the five years of his stay in Bangalore, Bhabha gradually began to be identified with India's great culture. He analyzed the socio-economic problems of the day and was convinced that science was the only means for his country's progress. Bhabha dreamt of the 'great adventure' of building a modern India.

In 1941, he was elected a member of the Royal Society and became a Professor in 1942. The University of Cambridge awarded him the Adams Prize. He also received an offer from the Oxford University which he declined, for his heart nursed the desire to build an excellent institution of research in his own homeland. In 1944, Bhabha wrote a letter to the Dorabji Tata Trust in which he said: *There is at the moment no big school of research in the fundamental problems of physics. It is absolutely in the interest of India to have a vigorous school of research in fundamental research. When nuclear energy has been successfully applied to power production in, say, a couple of decades from now, India will not have to look abroad for its experts, but will find them ready at hand.*

Bhabha's plan was the embryo which was born as a school of physics. The next year, in 1945, the Tata Institute of Fundamental Research (TIFR) was inaugurated in a house in Bombay, the foundation stone of the present building was laid in 1954 and the Institute started functioning in 1962. Today, TIFR is one of the finest research institutions in the world.

The great expansion in the Indian economy demanded a steady increase in the country's electricity generating capacity. Bhabha believed that the only way of overcoming power hunger was through the introduction of nuclear power in a phased manner. In 1948, the Atomic Energy Commission was formed and Bhabha was appointed its Chairman. The Commission's responsibilities included: a survey of Indian soils for the materials required for nuclear research, construction of atomic reactors, the purification of atomic materials, conducting fundamental research, and development of training programmes.

The Commission utilized the services of scientists at TIFR. Soon the Commission's scope was enlarged and the Atomic Energy Programme began to take shape. The Department of Atomic Energy thus came into existence as a separate Department of the Government of India in 1954, under the direct control of Prime Minister Nehru. Bhabha became the ex-officio Secretary of the Department.

Shortly after the formation of the Department of Atomic Energy, it was decided to create the Atomic Energy Establishment at Trombay for the application of atomic energy to peaceful purposes. While the construction work at Trombay was still in progress, Bhabha spent many sleepless nights and finalized the layout for the campus. He became its first Director in 1957. At a ceremony attended by well-known international figures, on January 12, 1967, Prime Minister Indira Gandhi renamed the Trombay Establishment as Bhabha Atomic Research Centre.

Bhabha worked to make the country self-reliant in the nuclear field. He stressed that while India needed to draw on the expertise already built up in other countries, her objective must be to exploit her own resources of scientists and technologists as well as the raw materials. With the support and encouragement he got from J. R. D. Tata and Jawaharlal Nehru, Bhabha enjoyed considerable freedom to carry on his work with ease and efficiency. Reactors like Apsara, uranium and zirconium plants, the Van de Graff and cyclotron equipment—were all Bhabha's gifts to the nation.

He was awarded honorary doctorates by several Indian and foreign universities including the University of Cambridge, Padua, Perth, Banaras, Agra, Patna, Lucknow, Allahabad, Andhra and Aligarh. In 1954, the President of India bestowed him the Padma Bhushan honour for his outstanding contributions to nuclear science. In 1955, Bhabha was elected President of the first International Conference on the 'Peaceful Uses of Atomic Energy', organized by the United Nations at Geneva. Bhabha was the first scientist to advocate the peaceful use of atomic energy at international forums.

The crowning success of Bhabha's life-long passion came on May 18, 1974 when India conducted its first nuclear explosion for peaceful purposes at Pokhran in Rajasthan. India became the world's sixth nuclear power. However, Bhabha did not live to see his dream prosper further.The Air India Boeing 707 'Kanchenjunga' in which Bhabha was travelling to attend an international conference crashed in a snowstorm on Mont Blanc on January 24, 1966, bringing to a tragic end the life of one of the great scientists of India.

VIKRAM AMBALAL SARABHAI

1919-1971

Had he so wished, he could have become an industrialist. But Vikram Ambalal Sarabhai's heart was in basic research in mathematics and physics and the interest of his motherland uppermost in his mind in whatever he did. He encouraged students to go abroad

for higher studies in the latest areas of S&T but insisted that they return to serve India. He was confident that if the right atmosphere was created for the young scientists to pursue their chosen line of research in India, they would gladly return.

The Sarabhais were a famous industrialist family in Ahmedabad. They were also dedicated social workers. When their first daughter, Mridulaben, was just three years old, father Ambalal and mother, Sarala Devi began to think about her education. The Montessori system of education was gaining fame during that time, but there was no school here yet in this system. So, the Sarabhais started a school in their own house with their own eight children. Vikram was born into the Sarabhai household on 12 August 1919. As the children grew, more teachers were employed. At one time, the school had thirteen teachers for the eight children, teachers to teach languages, the sciences, the arts, gardening, and technology. The school also had its own laboratories and workshops. Vikram showed great earnestness and interest in his studies and was specially enthusiastic about mathematics and science.

Vikram came under the influence of many great persons — Mahatma Gandhi, Rabindranath Tagore, J. Krishna Murthi, Motilal Nehru, V. S. Shrinivasa Shastri, Jawaharlal Nehru, Sarojini Naidu, Maulana Azad, C. F. Andrews, and C. V. Raman — who stayed with the Sarabhai family whenever they visited Ahmedabad. Vikram loved adventure. As a child he impressed people with the many tricks he could perform with his bicycle. As the bicycle shot forward, he would raise his hands, stretch his legs forward, close his eyes and pedal.

After completing his college education, Vikram went to Cambridge University and took his Tripos in Physical Sciences in 1939. Vikram's first love was cosmic rays. Cosmic rays are a stream of energy particles reaching the earth from outer space. On their way to the earth they are influenced by the sun, the atmosphere and the magnetism of the earth. His basic interest was to find out how the rays vary with time and the implications of this phenomenon.

After his return, he did research for a while at the central meteorological station in Poona, and in 1943, he went to the Himalayan peaks in Kashmir to study the intensity of cosmic rays. He was so thrilled that he decided to establish a high altitude research centre. In 1945, when World War II ended, Sarabhai once again went to Cambridge to continue the study of cosmic rays and received his Ph.D. in 1947.

Shortly after he returned from Cambridge, he established the Physical Research Laboratory (PRL) at Ahmedabad, an institution devoted to the study of cosmic rays and outer space. Starting with just a few students and laboratory assistants, the group soon developed into a dedicated team of scientists and research workers. Today, it is a premier institution that provides the technology and the scientists needed for the country's space research programme. In spite of his many duties in later years, Sarabhai maintained close contact with PRL all through his life. In 1955, Sarabhai set up a branch of the Physical Research Laboratory at Gulmarg in Kashmir. Impressed by the work done at this centre, the Atomic Energy Department of the Government of India established a full-fledged High Altitude Research Centre at the same place — the only research centre in the world at such an altitude.

Sarabhai will always be remembered as one who ushered in the space age in India by expanding the Indian Space Research Organization (ISRO) which he served as Chairman. He was also responsible for the establishment of the Space Science and Technology Centre at Thumba and the Experimental Satellite Communication Earth Station at Ahmedabad. He established the Rocket Launching Stations at Thumba and Sriharikota. To Sarabhai goes the credit for the many achievements of the Indian space programme during its early years, although he did not live to see the fruits of his labour. Among the projects he planned was the one under which India's first satellite, Aryabhata, was launched in 1975. The groundwork for the Satellite Instructional Television Experiment (SITE) in 1975-76 which sought to bring education to

five million people in 2,400 Indian villages, was also done by Sarabhai.

Although he had enormous wealth and rich industrial experience, Vikram Sarabhai was a very modest, soft-spoken and simple man. He looked on all persons as equal and judged each only by the measure of work and responsibility. Sarabhai working in his laboratory at midnight was a common sight and he hated to waste time. Even when waiting to board a plane, he would get together with students in some corner of the airport to discuss work. There was a big pharmaceutical factory of the Sarabhais in Baroda and every Friday he would go there to supervise the work and give instructions. On the train journey from Ahmedabad to Baroda, he would take one or two students to travel with him and discuss their research problems.

In 1947, at the age of 28, he was entrusted the organization of the Ahmedabad Textile Industry Research Association (ATIRA). He had then no experience of textile mills or textile technology. Yet, his intellect and confidence helped him build the institution. In 1956, when the Productivity Congress met in Japan he led the Indian delegation. He was only 37 then.

Sarabhai built a number of institutions during his lifetime-- and not all of them were scientific institutions. In 1963, he established the Nehru Foundation for Development, for the study of social and educational problems. In 1966, under its auspices, he established the Community Science Centre, whose object was to spread scientific knowledge, to create interest in science and to promote experimentation among students, teachers and the general public. Few may know that it was Sarabhai who established the Indian Institute of Management at Ahmedabad.

Vikram Sarabhai received several honours for his services to science and society. In 1966 he received the Padma Bhushan. Vikram Sarabhai breathed his last on 31 December 1971 at the young age of 52. After his death, the Government conferred on him the honour of Padma Vibhushan in 1972. The International Astronomical Union named a crater after him on the moon in the Sea of Serenity.

Sketchs of J.C. Bose, P.C. Ray, S. Ramanujan, C.V. Raman, S.S. Bhatnagar and H.J. Bhabha in this chapter have been prepared by V.N. O'Key, published in Architects of Modern India.

Humanity needs practical men, who get the most out of their work, and, without forgetting the general good, safeguard their own interests. But humanity also needs dreamers, for whom the disinterested development of an enterprise is so captivating that it becomes impossible for them to devote their care to their own materials profit.

Without doubt, these dreamers do not deserve wealth, because they do not desire it. Even so, a well-organized society should assure to such workers the efficient means of accomplishing their task, in a life freed from material care and freely consecrated to research.

- Marie Curie