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A SKETCH OF HIS LIFE AND CAREER

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# SIR J. C. BOSE\*

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## PARENTAGE

JAGADISH Chander was born of an ancient and respectable family of Bikrampur, a village in Dacca, the Muslim capital of Bengal. From a very early age Jagadish showed a marked bent towards inventions. His father the late Bhagwan Chander Bose, who was a Sub-divisional Officer at Faridpur, gave a careful nursing to this inclination of his son. Bhagwan Chander Bose was a man of strong character and much originality. His son has given some interesting portraits of him. He observes:—

“He established industrial and technical schools, and it was then that the inventive bent of my mind received its first impetus. I remember the deep impression made on my mind by the form of worship rendered by the artisans to Viswakarma, God in his

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\* The writer of this sketch has made free use of a contribution on this subject which appeared recently in the *Century Review* from the pen of Mr. Phanindranath Basu.

aspect as the Great Artificer; His hand it was that was moulding the whole creation; and it seemed that we were the instruments in His hand, through whom He intended to fashion to some great design."

The late Bhagwan Babu trained his son with great care and gave him the education which he thought best. When the present system of education was yet in the first years of its infancy, people used to be undecided whether to accept the new methods or follow the older ways of instruction in pathasalas. The first impetus of Western education impressed itself on some in a dead monotony of imitation of things Western, while in others it awakened all that was greatest in the national memory. To this latter category belonged the illustrious father of Sir Jagdish Chander. He, accordingly, sent his son not to an English school, but to a village pathasala to study with the common folk of the soil.

"In educational matters," says Dr. Bose, "my father had very definite ideas which are now becoming more fully appreciated. English schools were at that time regarded as the only efficient medium for instruction. While my father's subordinates sent their children to the English schools intended for gentle folks, I was sent to the vernacular school where my comrades were hardy sons of toilers and of others who, it is

now the fashion to regard, were belonging to the depressed classes. From these who toiled the ground and made the land blossom with green verdure and ripening corn, from the sons of fisher-folk, who told stories of the strange creatures that frequented the unknown depths of mighty rivers and stagnant pools, I first derived the lesson of that which constitutes true manhood. From them too I drew my love of nature."

A vivid and touching picture of his mother, he also draws:—

"When I came home accompanied by my comrades I found my mother waiting for us. She was an orthodox Hindu, yet the 'untouchableness' of some of my school-fellows did not produce any misgivings in her. She welcomed and fed all these as her own children; for it is only true of the mother heart to go out and enfold in her protecting care all those who needed succour and a mother's affection."

#### EARLY EDUCATION

Dr. Bose was sent only to an old-fashioned village pathasala. He bears testimony to its value in these words: "I now realise," says Sir J. C. Bose, "the object of my being sent at the most plastic period of my life to the vernacular school, where I was to learn my own language, to

think my own thoughts and to receive the heritage of our national culture through the medium of our own literature. I was thus to consider myself one with the people and never to place myself in an equivocal position of assumed superiority."

The person to whose sole charge the boy was confided by his father was not an up-country durwan, as is the custom with the well-to-do men of Bengal, but surprisingly enough a lawless dacoit. This dacoit has a special history of his own. When Bhagwan Babu was the Sub-divisional Officer at Faridpur, the district offered a stronghold to a body of desperate dacoits. Once he arrested one of the great leaders of these dacoits, single-handed, without any sort of help from outside. The dacoit was subsequently sentenced to a long term of imprisonment. Strangely enough, when he was released, he came to Bhagwan Babu and sought for a new occupation as it was then simply impossible for him to revert to his particular vocation.

"My father took the unusual course," says Dr. Bose, "to employ him as my special attendant to carry me, a child of four, on his back to the distant village school. No nurse could be tenderer than this ex-leader of lawless men, whose profession had been to deal out wounds and deaths. He had accepted a

life of peace but he could not altogether wipe out his old memories. He used to fill my infant mind with the stories of his bold adventures, the numerous fights in which he had taken part, the death of his companions and his hair-breadth escapes. Numerous were the decorations he bore."

Though this lawless leader of fierce dacoits had not an inch of respect for the laws of the country, yet he possessed a deep and high veneration for the moral laws. He never abused the great trust placed upon him. "The trust imposed on this marauder," observes Dr. Bose, "proved to be not altogether ill-placed, for once in a river journey we were pursued by several long boats which came too near for us to effect an escape, and the erstwhile dacoit leader, my attendant, stood up and gave a peculiar cry, which was evidently understood. For the pursuing boats vanished at the signal."

#### STUDY AT CAMBRIDGE

Mr. Bose watched his son's educational progress with keen interest. When Jagadish graduated himself from St. Xavier's College, Calcutta, he had a strong desire to go over to England and read for the Civil Service Examination. This was the tempting path lying wide open to him. He sought the approval of his father for his ambitious

scheme. But Bhagwan Chunder would not allow him to do so. Though an able and just administrator himself, he had no intention of sending up his son for that kind of work. He foresaw like a prophet the great possibilities lying in the womb of the future. He wished him, therefore, to be a scholar—of what fame, he left to the future to unfold. “When later I wished to go to Europe,” says Sir J.C. Bose, “and to compete for the Indian Civil Service, his refusal as regards that particular career was absolute. I was to rule nobody but myself. I was to be a scholar not an administrator.”

He longed to get a scientific education in England; as nothing stood in his way, he went over to Cambridge and passed his B. A. examination, in 1884 from the Christ College. Next year he secured the B. Sc. degree from the London University.

After completing his education abroad he returned to Calcutta. Who could have dreamt that Jagadish would again go over to the land of his education to preach a startling and original theory! Who could even imagine that Jagadish would one day assume the position of a teacher in the land, where he earnestly sought for light, the light of science!

HIS LABOURS IN THE CAUSE OF SCIENCE

Though Dr. Bose got the Professorship



of Physics in the Presidency College, he could not obtain any facilities to carry on his researches. "When I first came," Sir Jagadish said, "there was no laboratory worth the name in the Presidency College. I had to work in my private laboratory." Yet the new professor never lost heart. The watchword of his, nay, of every great scientist, has been patience. And patience did beget good results. For, "ten years later," we are told, "a provision was made for a small laboratory. That was a blessing in disguise for me."

He began writing a series of scientific articles as early as 1895. His first contribution was on "the Polarisation of Electric Ray by a Crystal." It was published in the *Journal of the Asiatic Society of Bengal*, in May, 1895.

Then followed two articles about Electricity which were published in the *Electrician*, the leading electrical journal, in the same year.

Now came the turning point in his scientific career, and that was the result of his essay on the "Determination of the Indices of Electric Refraction." The Royal Society at once appreciated the highly scientific value of the research. It was then considered a high honour to a scientist to have his essay published by the Royal Society in

its journal. They not only published the paper, but did great honour to the Indian scientist by offering him "a subsidiary from the Parliamentary grant made to the Society for the advancement of science." This was indeed a unique honour, and we have it from Prof. Bose himself that: "Two years after the Royal Society had offered a grant to me for the continuation of my work, the Government of Bengal came forward and offered me some facilities. - No Government could afford to spend money on prospective geniuses."

One doubts whether the Bengal Government would have come forward to his help, had not the Royal Society offered him the grant.

All along Dr. Bose has been an ardent student of science. To learn, to wait, was to him, the key to success. In a humble scale he worked and worked and never looked forward for a reward. But soon the reward did come in the shape of an astonishing discovery. It was in the year 1896 that he sent the result of his research to the Royal Society which had lent such a helping hand to his noble cause. The learned Society was literally amazed at the important contribution made by him for the advancement of science. Then the University of London came forward to pay homage to the great

Indian savant and conferred on him the Degree of Doctor of Science.

#### WIRELESS TELEGRAPHY

A devoted apostle of science, Dr. Bose now turned his attention in another direction. The possibility of transmitting electric telegraphic signals through space without the use of wires that run directly from the transmitting to the receiving instrument engaged the attention of three master-minds of the world at one and the same time—Professor Marconi of Bologna University, a great scientist of America and Dr. Bose in India. This has not been the only occasion when great scientists of different places have been deeply engaged in solving one of the greatest riddles. Now, these three men of science were driving hard at how to transmit electric telegraphic signals. And it was Dr. Bose who first clearly demonstrated it. So far back as 1895, at an experimental demonstration in the Calcutta Town Hall in the presence of the Governor, he transmitted ether wave through a solid wall and a line of men and made it displace a heavy weight, ring a bell and explode a miniature mine placed in a closed room.

#### LECTURES BEFORE THE ROYAL INSTITUTION

For a scientist, to be asked to deliver lectures on his own researches before the

Royal Institution rendered famous by the works of Davey and Faraday, is a signal honour. But Dr. Bose was thrice asked to give discourses on his momentous discoveries.

It was in 1897 that he was first asked to deliver before the Royal Society the Friday evening discourse. He acquitted himself very creditably and spoke on electrical waves.

Four years later he delivered his second Friday evening discourse before the same august body. He demonstrated this time fully and elaborately the identical nature of reactions in plant and animal. He was invited again, in 1915, to deliver for the third time another Friday evening discourse. A well-known *Review*, writing in 1914, said:—

The great honour of delivering a Friday evening discourse before the Royal Institution of Great Britain has again been offered to Dr. J. C. Bose. The subject of Dr. Bose's discourse will be his recent psycho-physiological research, which opening out a new line of research has created much interest in the scientific world. Professor Bose has also been invited to deliver a course of lectures before the University of Oxford. That this is the third time that Professor Bose has been invited to lecture at the Royal Institution is a very rare distinction indeed. To this may be added that he has been invited by the Cambridge University too, to deliver a course of lectures. If time permits he will fulfil his engagements to lecture before some learned societies in France and Germany, but it will not be possible, perhaps, to include America in his forthcoming tour.

The third appearance of Dr. Bose before

the Royal institution was part of an extended tour to which we shall presently return.

### LECTURES IN PARIS

It must be mentioned here that in 1900, he was sent by Sir John Woodburn the Lieutenant-Governor of Bengal and the Government of India to represent this country at the Paris Congress of Science and he acquitted himself so well that by universal consent it was declared that he had shed lustre on the Government which chose him and the country he represented. A little later he was invited to deliver a series of lectures at Paris on his new discoveries. The first lecture was given before the Society De Physique, the Second at the Saiborne, the third before the Society De Zoologique. He was elected about the year 1902 to the Council of the Society Francaise De Physique.

### HIS TOUR ROUND THE WORLD

We referred to Dr. Bose's third Friday evening discourse. He was also invited by the Oxford University to deliver a series of lectures. His assistant, Mr. B. Sen, wrote of them :—

Dr. Bose gave his first lecture at Oxford on the 20th May. The most distinguished scientists were present. When they saw the experiments they were convinced that "Life is one." Before this, results of Dr. Bose's enquiry were so astonishing to them as to challenge their belief. Nothing short of actual visua-

lisation could convince them. It was a great success. They all unanimously said that the significance of Dr. Bose's discoveries was far-reaching. Indeed, they do appreciate him now. As regards his instruments, they simply marvel at their ingenuity. They all ask "where did you get them made ;" and with real pride did Dr. Bose reply, "in India." To-morrow the President of the Royal Society is coming to this house to see some of his experiments.

In June he addressed the Cambridge University. Both Prof. Seward who was in the chair and Sir Francis Darwin spoke in memorable terms of the completeness of the demonstrations provided by his instruments. Interest was so keen that the Botanical department of Cambridge imported soil from India to give Dr. Bose's plants the most favourable conditions for exhibiting their specific reactions. Professor Starling, Oliver and Carreth Read were also deeply impressed with the demonstrations. Mr. Balfour paid his laboratory a long visit and was much struck with the significance of Dr. Bose's discoveries to psychologists. On the 27th June Prof. Bose gave an address illustrated by experiments before a meeting of savants at Vienna. Prof. Molisch, the Director of the Pflagen Physiologisches of the Imperial University of Vienna, while proposing a vote of thanks said that Europe was indebted to India for the method of investigation initiated by Dr. Bose. Some of the workers in plant physiology expressed a wish to be

trained in his methods in Prof. Bose's laboratory at Calcutta.

Prof. Bose visited America also during this tour. He was flooded with invitations from Maine to California. Learned bodies such as the New York Academy of Science, the Brooklyn Institute of Arts and of Sciences, the Harvard, the Columbia and the Chicago Universities listened with delight to him and presented him with addresses.

In reply to one of the numerous addresses of welcome which were presented to him, Dr. Bose observed :—

This was the fourth occasion on which he has been deputed to the West by the Government of India on a scientific mission, and the success that has attended his visit to foreign countries has exceeded all his expectations. In Vienna, in Paris, in Oxford, Cambridge and London, in Harvard, Washington, Chicago and Columbia, in Tokyo and in many other places his work has uniformly been received with high appreciation. In spite of the fact that his researches called into question some of the existing theories, his results have notwithstanding received the fullest acceptance. \* \* \* In these new investigations on the borderland between physics and physiology, they held that Europe has been left behind by India, to which country they would now have to come for inspiration. It has also been fully recognised that science will derive benefit when the synthetic intellectual methods of the East cooperate with the severe analytical methods of the West. These opinions have also been fully endorsed in other centres of learning and Dr. Bose had received applications from distinguished Universities in Europe and America for admission of foreign post-graduate scholars to be trained in his Laboratory in the new scientific methods that have been initiated in India.

## HONOUR IN INDIA

Though a prophet is seldom respected in his own country Dr. Bose has received ample recognition in India. The University of Calcutta paid him due homage and conferred upon him the title of Doctor of Science.

The Punjab University also expressed its deep appreciation of his novel scientific discoveries by inviting him, in 1913, to deliver a course of three lectures illustrated with experiments. This was the first time that a Bengali Professor was asked by the University of the land of five rivers to deliver a course of scientific lectures to its students. The second man, so honoured, was Dr. P. C. Ray, the founder of the Bengal School of Chemistry. The Punjab University offered Dr. Bose a fee of Rs. 1,200. But Dr. Bose with his natural generosity made over the entire sum to the University to be given to a research scholar in monthly instalments of Rs. 100.

Dr. Bose opened his address by alluding to the historic journey of Jivaka, who afterwards became the physician of Buddha, making his way from Bengal to the University of Taxila in quest of knowledge. Twenty-five centuries had gone by and there was before them another pilgrim who had journeyed the same distance to bring, as an offering, what he had gathered in the domain of



knowledge. He called attention to the fact that knowledge was never the exclusive possession of any particular man, nor did it ever recognise geographical limitations. The whole world was independent, and a constant interchange of thought had been carried on throughout the ages enriching the common heritage of mankind. Hellenic Greeks and Eastern Aryans had met here in Taxila to exchange the best each had to offer. After many centuries the East and West had met once more and it would be the test of the real greatness of two civilizations that both should be finer and better for the shock of contact. The apparent dormancy of intellectual life in India had been only a temporary phase. Just like the osculation of the seasons round the globe, great pulsations of intellectual activity pass over the different peoples of the earth.

With the coming of the spring the dormant life springs forth; similarly the life that India conserves, by inheritance, culture and temperament, was only latent and was again ready to spring forth into the blossom and fruit of knowledge. Although science was neither of the East, nor of the West, but international in its University, certain aspects of it gained richness of colour by reason of their place of origin. India, perhaps through its habit of synthesis, was apt to realise

instinctively the idea of unity and to see in the phenomenal world a universe instead of a multiverse. It was this tendency, the lecturer thought, which had led an Indian physicist, like himself, when studying the effect of force on matter, to find boundary lines vanishing, and to see points of contact emerge between the realms of the living and the non-living.

#### THE MASTER-DISCOVERY

Now, what is the discovery of Sir Jagadish Bose, which has created so much noise in the scientific world? It is that discovery which has conclusively proved that "there is no sharp dividing line between the nervous life of plants and animals, and in one respect it seems that the life of the plant *Mimosa* exactly reproduces the life-history of human nations."

Now, what was the prevailing theory with respect to plants in the scientific world? The universally accepted theory has been that in plants like the *Mimosa* there was no transmission of excitation analogous to the nervous transmission in the animal, the propagated effect being considered as a mere hydro-mechanical disturbance. This theory was based on the experiments successfully carried out by the famous German plant-physiologists, Pfeffer and Haberlandt. On account of the eminent position held by the

German scholars, the theory propounded by Dr. Bose before the Royal Institution about fifteen years ago, received but little acknowledgment from the other plant-physiologists of the West.

The principal points of difference are aptly noted down by Dr. J. C. Bose in a recent paper, from which we cull the following :—

“ Few things appear to stand out in such striking contrast as the life activities in the animal and in the plant. Scientific inquiries, have, indeed, been struck by the glaring differences between the two. Animals respond to a shock by movement, whereas most plants maintain under a succession of blows an attitude of passivity. Certain tissues of the animal go on beating incessantly without any apparent cause; this spontaneous activity undergoes very characteristic modifications under the specifications of different drugs. No corresponding phenomena had been suspected in the plant. Animal tissues give electric sign of irritation; ordinary plants, according to leading electro-physiologists, show no such signs of excitement. In the animal again there is an evolution of the wonderful nervous system, by which the organism is put into intimate communication with its different parts and with the environment. In the vegetal

organism, on the other hand, all authorities are unanimous in declaring that there is no such thing as a nervous impulse even in a plant admittedly so sensitive as *Mimosa Pudica*. The two streams of life, in plant and animal, would thus appear to flow side by side, under the guidance of laws which are altogether different."

But Sir Jagadish Chander's investigation has upset the hitherto universally accepted theory and has successfully demonstrated the identical nature of the nervous impulse in the plant and animal. The success of the new research is largely due to the invention of a new apparatus of extreme sensibility. It is so delicately constructed as to enable the plant to record automatically its perception of stimulus and the speed of its nervous impulse.

This new apparatus, Sir Jagadish calls the Resonant Recorder. "The principle of my Resonant Recorder," says Dr. Bose, "depends on a certain phenomenon, known in music as resonance or sympathetic vibration. We may be so tuned as to thrill to certain notes and not to others. An artificial ear can be constructed to resonate to a sound of a definite pitch. The drum of the artificial ear is made of thin soap-film; a beam of light reflected from its surface forms characteristic patterns of colour

on a screen. To various cries this ear remains deaf, but the apathy disappears as soon as the note to which the ear is tuned is sounded at a distance. On account of sympathetic vibration the artificial ear-film is thrown into wildest commotion and the hitherto quiescent colour pattern on the screen is now converted into a whirlpool of indescribably gorgeous colours of peacock green and molten gold.

“In the same manner, if the strings of two different violins are exactly tuned, then a note sounded on one will cause the other to vibrate in sympathy. We may likewise tune the vibrating writer, with a reed. Suppose the reed and the writer had both been tuned to vibrate a hundred times in a second. When the reed is sounded the writer will also begin to vibrate in sympathy. In consequence of this the writer will no longer remain in continuous contact with the recording plate, but will deliver a succession of taps, a hundred times in a second.”

With this apparatus, we get a record which consists of a series of dots, and the distance between one dot and the next represents one-hundredth part of a second. So extraordinarily delicate is this new instrument that by its means it is possible to record a time interval as short as the thousandth part of the duration of a single beat of the heart.

Sir Jagadish has these delicate instruments manufactured by Indian artisans under his direct personal supervision. Now, when his novel theories are being recognised and accepted by the celebrated scientific societies all over the world, orders are also pouring in for these purely Indian instruments.

The researches of Dr. Bose have brought to light many of the activities which we have been accustomed to associate only with animal life. Suppose we give a blow to the plant, how long will it take to perceive the blow and give an answering signal? The time has been found to be six-hundredth part of a second. This period is subject to modification as in the animal under special conditions. Thus, under fatigue, the period is considerably prolonged; after a severe shock it is said to remain dazed for a long time. Moreover, in summer, the speed of nervous impulse has been found to be about 30 millimetres per second. But it may increase under warmth and decrease under cold.

Again Dr. Bose has succeeded in arresting the nervous impulse of the plant by interposing an electric block, in a manner similar to the corresponding arrest in the animal nerve.

Intoxicating liquor produces the same effect in plants as in animals. When Dr. Bose poured out a little poison on the plant,

the record showed an astonishing result. The speed of nervous impulse instantly decreased.

Professor Bose has also proved that the trees begin to sleep at 12 P.M. and get up at 8 A.M., in the morning, like the civilized nations of the world. The illustration of the death of a plant and also the reversal of the stimulus at the time of death, was lucidly explained.

In establishing these facts with experiments, Dr. Bose has to criticise the prevailing opinions of the great German scholars and totally upset their theories. "Professor Bose strongly criticises," says a German scientific paper, "*Dutrochet's* theory that the transmission in plants is one of hydro-mechanical disturbance and not of true excitation. He urges that the capillary tubes will offer great resistance to the passage of water in case where feeble deformation of tissue had been caused by mechanical stimulation. Besides excitation is induced and transmitted by means of stimulus which causes no mechanical disturbances. As regards *Pfeffer's* experiment of transmission through chloroformed regions, Bose explains that the penetration of narcotic inside the tissue was too slight to be effective.

"Haberlandt, who scattered the tissue in all probability, failed to kill all the cells. Bose claims that transmission of excitation in the

plant is analogous to the nervous impulse in the animal. The inference of temperature and velocity supports his view."

#### THE EFFECT OF THIS DISCOVERY

Now, one may be tempted to ask:—"All these discoveries and researches are good, but what material good will it render unto the world? Will it put an end to the endless suffering of humanity?"

Let us first answer the question in the words of the great scientist Faraday. Faraday had succeeded in making a wire carrying a current move when in a magnetic field, and the visitor said, "Tell me, Professor Faraday, and of what use is this new discovery," to which the reply was,—“Sir, of what use is the new-born child?"

Really, this discovery is in its infancy, who can foretell that great results may not come from it? When the law of gravitation was discovered, its author could not even imagine that it would be productive of such immense good. But also in near future the discovery "would mean an advance," in the words of Sir J. C. Bose, "of a revolutionary character in the science of Physiology, of Medicine and of Agriculture." This opinion has been endorsed by the famous scientific journal "The Lancet," which speaks highly of the



biological importance of Professor Bose's discovery:

“The study of responsive reactions in plants must be regarded as of fundamental importance to the elucidation of various phenomena relating to the irritability of lining tissues.”

This discovery about the plants, which will in the near future throw an entirely new idea and light on agriculture, is not the only department which will, through centuries, perpetuate his lasting fame. From the beginning he devoted himself heart and soul in discovering one broad and bold principle and to the realisation of this noble object he spared no pains and worked patiently on against powerful odds—both in Europe and America. It is “the existence of similarity of phenomena in various spheres of things living or dead on their molecular basis of matter.”

#### PLANT RESPONSE

In his monumental work “Plant Response,” published in the year 1906, he has recorded a series of wonderful discoveries which evoked considerable enthusiasm and admiration in the scientific world. There we find him dealing with and proving beyond any shade of doubt, these discoveries:—

“ His experiments on root pressure and the rise of sap; those by which he seeks to demonstrate that not only sensitive plants, but all plants respond to excitation by variation of turgescence and electrical state; his comparison of the glandular structures of the sun-dew and pitcher plants with animal glands; his demonstration of Dr. Waller’s “blaze current” in a brominated lead plant and assertion that it cannot be regarded as a sign of life: his demonstration on the motile leaflets of biophytura of the anodic and cathodic effects of constant current, and the velocity of transmission of excitatory waves; his comparison retentiveness of molecular change in metals with memory.”

Reviewing the above book and the book on “Electro-physiology” published in 1907, the well-known scientific paper *Nature* observed:—

“ A biologically equipped reader will experience dazzled admiration for the logical progressive way in which the author builds up, not in words, but actually on a complete functioning plant from three simple conceptions.” The paper goes on to add:—

“ In fact the whole book abounds in interesting matter skilfully woven together, and would be recommended as of great value, if it did not continually arouse our incredulity.”

## GOVERNMENT RECOGNITION

The Government of India were at first very slow in recognising Dr. Bose's services to the cause of Science. It was only after the Royal Society honoured him that they began to help him in various little ways and in 1900 sent him up to the Congress of Science at Paris. They conferred the distinction of C. I. E. in 1903 and at the time of the Coronation in 1911 they conferred on him the title of C.S.I. When Sir J. C. Bose returned in 1916 from America the Government of Bengal arranged for a Sheriff's meeting to offer him a welcome and in 1917, the knighthood was conferred on him. A huge meeting of students was held to offer Sir J. C. Bose their congratulations on the knighthood and Dr. P. C. Ray appropriately occupied the chair. Among other things he remarked that Professor Bose must not be looked upon as a mere discoverer of scientific truth, but as a Yuga-Pravartak, *i.e.*, as one who has brought about a new epoch in scientific thought and methods and synthesis. He referred to Dr. Bose as a great man and an unselfish scientist. He said that if he had gone on with his electrical researches, in the course of which he ably "succeeded in sending wireless messages, before Marconi had done so, and if he had taken out patents for-

the apparatus and instruments which he had invented, he could have made millions by their sale." But he was a scientist pure and simple, he himself toiled on and on in spite of ridicule, opposition and lack of any recognition, leaving others to make money by his researches.

#### HIS LATEST TRIUMPHS

In the beginning of the year 1918 Dr. Bose's private laboratory was visited by His Excellency the Viceroy, Lord Chelmsford, accompanied by the former Governor of Bengal. Their Excellencies took so great an interest in his recent discoveries that they remained there for full two hours. Recently Dr. Bose succeeded in accomplishing a feat, which was so long considered utterly impossible. The Indian savant transplants trees in perfect condition. At a recent experiment in Calcutta he first rendered the trees unconscious by the action of suitable narcotics and thus saved the two trees from the shock due to uprooting. Now, as they were planted again, they are growing vigorously. Another triumph of Sir Jagadish was the High Magnification Crescograph. This is one of his unique inventions. It can magnify and record the growth of plants in as short a period as a single second. The highest power of the microscope stands dwarfed by its side

by many thousand times. This instrument will, no doubt, bring about a revolution in the scientific world, specially in the agricultural department. The high magnification attained by it varies from ten thousand to a million times. A few months ago, the peculiar date palm-tree of Faridpur, attracted the attention of Dr. Bose. This tree, it was reported, lay down in the evening when the temple bells called the people to prayer and again in the morning stood erect. He sent his pupils with his own apparatus to examine it. It is believed that the result will help him in his researches. The result will be published in the "Bose Institute Transactions."

#### THE BOSE RESEARCH INSTITUTE

The Bose Research Institute which Dr. Bose has founded will be a lasting monument of his greatness. Dr. Bose had felt from very early days the extreme difficulties due to the absence of well-equipped laboratories in India. He knew also how little research work was encouraged in our Universities. Writing in 1913 to the *Bengal Educational Review* he made some noteworthy observations. He maintains in it that there is no necessary antagonism between teaching and research. "The object of a University being the advancement of

knowledge, this must include the complementary functions of the discovery of truth and diffusion of knowledge. It may be said generally that teaching degenerates unless it be kept in touch with research ; since the constant repetition of second or third-hand knowledge leads to mere mimicry in pupils : the living touch of reality is test." He proceeds to say that the status of a university depends on the answer to these questions :

What advancement in any branch of knowledge has been made by you ? What discoveries and investigations have been brought about under your fostering care ? Is your university to be always a preparatory school for the foreign universities which have a world-status ? Will you never be able to make your work so distinguished that instead of there being a constant export of your students to other universities, there should be an interchange and that you should receive an import of foreign students attracted by the special contribution which your university has made to the general stock of knowledge ? " This is not to be regarded," he adds, " as an unrealisable dream. It has been accomplished before. The fame of Nalanda and Taxila did attract students from other lands who made long pilgrimages to the Indian shrines of learning."

Dr. Bose says in the same article that the

facilities offered by the Government are not many and that they are on highly red-tape lines. Referring to possibilities in India, he says of the Indian students :—

In my experience, there is a genuine desire among a fair number of students to undertake research work. But as regards success in such work, I think it is often forgotten that research is different from class-teaching. There are at least ten thousand workers all over the world engaged in original investigation, and we hear of comparatively few successful results. You cannot command results by merely opening classes. There must be favourable combination of circumstances for success in research. You must first have as the teacher one who after long seeking has found; who has seized boldly, as it were, the thorns that beset his own path in the hope of making it a little easier for those who should come after; who enhances the value of life and work by drawing others into the great vortex of the struggle for truth. This is the man who alone can kindle enthusiasm in his disciples. A candle can only be lighted from another burning candle. As regards the qualifications of the true student, he is one who comes seeking at all cost to know. It is knowledge itself and not the accessories of knowledge—fame, comfort, power—that should be all in all to him. The seeker after knowledge must fix his eye on the distant goal of truth itself. Under these conditions we may expect good results in researches of enduring importance. It must, however, be remembered that even out of a number of earnest students there can only be a few who can succeed in striking out a new path.

Of the future of Research Work in India, he says :—

I think, there is a great future for such work in India. First, on account of favourable conditions in the tropics, we have a wealth of biological material unavailable to the Northern laboratories. The Indian

mind is again characteristically synthetic ; it refuses to recognise artificial divisions. The greatest work for the future lies in the borderlands. Work of this description would require unremitting toil, great patience and indomitable persistence. In these qualifications some of our students will not be found wanting. At present they find little scope for the satisfaction of the nobler aspirations—not the mere gratification of personal ambition—but the service which they can render by bringing their contribution to the store of the world's knowledge.

In 1915, he foreshadowed the Research Institute in a speech delivered at Calcutta :—

“ This recognition that the advance of human knowledge will be incomplete without India's special contributions must be a source of great inspiration for future workers in India. His countrymen had the keen imagination which could extort truth out of a mass of disconnected facts and the habit of meditation without allowing the mind to dissipate itself. Inspired by his visits to the ancient Universities, at Taxila, at Nalanda and at Conjeevaram, Dr. Bose had the strongest confidence that India would soon see a revival of those glorious traditions. There will soon rise a Temple of Learning where the teacher, cut off from wordly distractions, would go on with his ceaseless pursuit after truth, and dying hand on his work to his disciples. Nothing would seem laborious in his inquiry ; never is he to lose sight of his quest, never is he to let it be obscured by any terrestrial tempta-



tions. For his is the Sanyasin spirit, and India is the only country where so far from there being a conflict between science and religion, knowledge is regarded as religion itself. Such a misuse of science as is now unfortunately in evidence in the West would be impossible here. Had the conquest of air been achieved in India, her very first impulse would be to offer worship at every temple for such a manifestation of the divinity in man."

In November 1916, however, Dr. Bose opened the Research Institute. It was done with due ceremony and the speech he delivered in dedicating it to the nation is one of the finest of his public utterances. The address bespeaks a scientific mystic carrying on his brows "the calm wisdom of his Vedic heritage." Dr. Bose is seen in it to be not merely the scientist searching truth with many a sigh, with his eye fixed on the minutest accuracies of detail but also as a dreamer and idealist. We catch a glimpse of the very soul of the East and hear the saintly accents of renunciation in words like these:—

"Not in matter but in thought, not in possessions but in ideals are to be found the seeds of immortality. Not through material acquisition but in generous diffusion of ideas and ideals can the true empire of humanity be established."

That Dr. Bose's researches are inspired by a great idea will be seen from these words of his:—

The ideal of giving, of enriching, in fine, of self-renunciation in response to the highest call of humanity is the other and complementary ideal. The motive power for this is not to be found in personal ambition but in effacement of all littlenesses, and uprooting of that ignorance which regards anything as gain which is to be purchased at others' loss. This I know, that no vision of truth can come except in the absence of all sources of distraction, and when the mind has reached the point of rest.

Speaking of the gallant band of disciples he has gathered round him, he says:—

Public life and the various professions will be the appropriate sphere of activity for many aspiring young men. But for my disciples, I call on those very few, who, realising some inner call, will devote their whole life with strengthened character and determined purpose to take part in that infinite struggle to win knowledge for its own sake and see truth face to face.

The Institute is meant for the advance of science and the diffusion of knowledge. The civic and public diffusion of language is to be "without any academic limitations, to all races and languages, to both men and women alike and for all time coming."

The lectures given here will not be mere repetitions of second-hand knowledge. They will announce, to an audience of some fifteen hundred people, the new discoveries made here, which will be demonstrated for the first time before the public. We shall thus maintain continuously the highest aim of a great seat of learning by taking active part in the advancement

and diffusion of knowledge. Through the regular publication of the transactions of the Institute, these Indian contributions will reach the whole world. The discoveries made will thus become public property. No patent will ever be taken. The spirit of our national culture demands that we should for ever be free from the deservation of utilising knowledge for personal gain. Besides the regular staff, there will be a selected number of scholars, who by their work have shown special aptitude, and who would devote their whole life to the pursuit of research. They will require personal training and their number must necessarily be limited. But it is not the quantity but quality that is of essential importance.

The Institute will not shut its doors against foreign students, as some English institutions do. For, as Dr. Bose says :—

It is my further wish, that as far as the limited accommodation would permit, the facilities should be available to workers from all countries. In this I am attempting to carry out the traditions of my country, which so far back as twenty-five centuries ago, welcomed all scholars from different parts of the world, within the precincts of its ancient seats of learning, at Nalanda and at Taxilla.

Of its future he observes :—

These are the dreams that wove a net-work round my wakeful life for many years past. The outlook is endless for the goal is at infinity. The realisation cannot be through one life or one fortune but through the co-operation of many lives and many fortunes. The possibility of a fuller expression will depend on very large endowments. But a beginning must be made, and this is the genesis of the foundation of this institute. I came with nothing and shall return as I came ; if something is accomplished in the interval, that would indeed be a privilege. What I have I will offer and one who had shared with me the struggles and hardship that had to be faced, has willed to bequeath

all that is hers for the same object. In all my struggling efforts, I have not been altogether solitary. While the world doubted there had been a few, now in the city of silence, who never wavered in their trust.

#### DR. BOSE AS A TEACHER

Dr. Bose must not be regarded as merely a scientist whose life has been spent within the chambers of study and research. He has many other interests in life and his talents are also many-sided. Prof. Sudhindra Bose, writing from America, has paid him a well-deserved tribute:—

“Prof. Bose is a clear, forceful and convincing speaker, is intoxicated with the fascination of his work and speaks therefore out of the fulness of his heart, and has no time for the gaudy acts of the professional spell-binders. He is intensely human and sees deeply that the essential brotherhood of man is a glowing reality and not a mere abstraction. His passion as a humanist is ‘India and its people.’ As a teacher and guide of young men, Dr. Bose has been remarkably successful.” What he did for them, he has himself expressed in a recent address of his to the students:—

In your congratulations for the recent honour you have overlooked a still greater that came to me a year ago, when I was gazetted as your perpetual professor so that the tie which binds me to you is never to be severed. Thirty-two years ago I sought to be your teacher. If I were to begin life anew I

could not have chosen a higher vocation. And for the trust that was imposed in me could I do anything less than place before you the highest that I knew? I never appealed to your weaknesses but your strength. I never set before you what was easy, used all the compulsion for the choice of the most difficult, and perhaps as a reward for these years of effort, I find all over India those who have been my pupils occupying position of the highest trust and responsibility in different walks of life. I do not merely count those who have won fame and success, but I also claim many others who have taken up the burden of life manfully and whose life of purity and unselfishness had brought gleams of joy into suffering lives.

On one occasion, he pointed out that the striking feature in the life of a teacher in India was the great devotion he evoked in the students. This ideal was highly valued both in England and India. In India, he said, the teacher was like the head of a family, revered by his pupils so deeply as to show itself by touching the feet of the Master. This was not a servile act, but one of respect and regard, and the teacher often reciprocated the sentiment in loving his students and by being generous to their faults. Professor Bose said he had the good fortune never to have had any trouble with his students, during his 35 years of work in the college. The real secret of success was in trying to look at things from the students' point of view and to cultivate a sense of humour.

#### OTHER INTERESTS

Dr. Bose was elected in 1911 to the chair

of the Bengal Literary Conference held at Mymensingh. Though the address deals mainly with unvoiced life, the style in which it is written as also the relation sought to be established between science and poetry indicate the wide scholarship and thought of the scientist. He said : "Both the poet and the scientific inquirer were seeking in their different ways to lift the veil from the mystery beyond. The poet, ignoring the need of rigid proof, has to use the language of imagery. The burden of his song is a perpetual "as if." The scientific inquirer on the other hand has to practise constant restraint in order to guard himself against self-deception. Even so, however, he, like the poet, comes into the regions of light invisible. To him also the opaque becomes transparent, and force and matter tend to lose their mutual distinctiveness and are fused in one. It is here, on the threshold of this realm of wonder that he may drop for a moment his accustomed self-expression, and exclaim in exultation "not 'as if'—but the thing itself." The address was delivered in Bengali, a language in which Dr. Bose is much interested.

#### PUBLIC SERVICES COMMISSION

Dr. Bose gave this evidence in 1913 before the Commission :—

Regarding the question of limitations that exist in employment of Indians in the higher service, I should like to give expression to an injustice which is very keenly felt. It is unfortunate that Indian graduates of European universities who have distinguished themselves in a remarkable manner do not for one reason or other find facilities for entering the higher educational service.

As teachers and workers it is an incontestable fact that Indian officers have distinguished themselves very highly, and anything which discriminates between Europeans and Indians in the way of pay and prospects is most undesirable. A sense of injustice is ill-calculated to bring about that harmony which is so necessary among all the members of an educational institution, Professors and students alike.

#### HIS PATRIOTISM

Dr. Bose is one of the greatest patriots India has produced. His life is a living example of the many sided character of our Renaissance. Patriotism in a country like this comes often to be identical with politics. But it is our singular good fortune that it has found its expression not only in politics but also in the sciences and the arts. The discoveries of Dr. Bose have shed lustre on his country. He has raised his hand in the estimation of the world and shown that once again the world will have to sit at the feet of India and gain knowledge. By opening the Research Institute and attracting through it the best aspirants after knowledge from all over the world, he has done more than any other to create and ensure the intellectual

hegemony of the East. The institute revives the splendour of Taxila and Nalanda, whose glorious memories fired the ambition of his youth.

If Dr. Bose has set by his life an example of high-souled patriotism, he has also given conscious expression to it in many of his speeches. In Madura he asked, "are we a living nation?" and said:—

In-travelling all over the world which I have done several times, I was struck by two great characteristics of different nations. One characteristic of certain nations is living for the future. All the modern nations are striving to win force and power from Nature. There is another class of men who live on the glory of the past. Now what is to be the future of our nation? Are we to live only in the glory of the past and die off from the face of the earth, or to show that we are worthy descendants of the glorious past and to show by our work, by our intellect and by our service that we are not a decadent nation? We have still a great and mighty future before us, a future that will justify our ancestry. In talking about ancestry do we ever realise that the only way in which we can do honour to our past is not to brag of what our ancestors have done but to carry out in the future something as great, if not greater, than they? Are we to be a living nation, to be proud of our ancestry and to try to win renown by continuous achievements? These mighty monuments that I see around me tell us what has been done till very recent times. I have travelled over some of the greatest ruins of the Universities of India, I have been to the ruins of the University of Taxila in the farthest corner of India, which attracted the people of the West and the East. I had been to the ruins of Nalanda which invited all the West to gain knowledge under its intellectual fostering. I had been all there and



seen them. I have come here also and I want to visit Conjeevaram. But are you to foster the dead or to try to bring back your University in India and drag once more from the rest of the world people who would come down and derive knowledge from India? It is in that way and that way alone we can win our self-respect, and we can make our life and the life of the nation worthy. The present era is the era of Temples of learning. In order to erect temples of learning we require all the offerings of our mighty people. We want to erect temples and *viharas*, which are so indispensable to the study of Nature and her secrets. It is a problem which appeals to every thoughtful Indian. It is by the effort of the people and by their generosity that all these mighty temples arose; and now are we to worship the dead stones or are we to enact living temples so that the knowledge that has been made in India shall be perpetuated in India? I receive requests from the different Universities in America and Germany to allow students from those countries to come and learn the science that had its birth in India. Now is this knowledge to pass beyond our boundaries, so that again in future time we have to go to the West to get back this knowledge or are we keep this flame of learning burning all time?

#### DR. BOSE A SCIENTIFIC MYSTIC

Even as a scientist Dr. Bose carries on his brows the "Calm wisdom of his Vedic heritage." He is a scientific mystic. In his investigations, he has often been reminded of the symbolic fresco in the dim caverns of Ajanta, depicting the cosmic dream of the eternal struggle of light with darkness. As he went on, however, he not only succeeded in detaching so often the real from the obscuring veil of darkness but came to find

an all-pervading unity in the universe. Every step in advance in this vast simplification—making them all appear as various rhythms and harmonies of a single fundamental sequence—only drove the question deeper :—

“Who is he that sits within striking the molecules this way and that ? Or what is he, pure, free, ever the witness? Who interprets the records of strain, using the brain as his galvanometer, and discarding alike the laboratory and its instruments when these no longer please him?”

He said in concluding his lecture at the Royal Institution on the 10th of May 1902:

“It was when I came upon the mute witness of these self-made records and perceived in them one phase of pervading unity that bears within it all things; the mote that quivers in ripples of light, the teeming life upon our earth, and the radiant suns that shine above us—it was then that I understood for the first time a little of that message proclaimed by my ancestors on the banks of the Ganges thirty centuries ago :—

“They who see but one in all the changing manifoldness of this universe, unto them belongs eternal truth, unto none else, unto none else.”

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## APPENDIX

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### THE INDIAN TEMPLE OF SCIENCE

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BY PROF. PATRICK GEDDES.

The following descriptive account of the Bose Research Institute in Calcutta, which was opened towards the close of last year, is from the pen of Prof. Patrick Geddes:—

The scientific event of the year in Calcutta is the opening of the Bose Research Institute, with its great scheme not only of continuing the researches of its founder, but of carrying on his large conceptions of the investigation of the processes of life and with help of all the resources and refinements of the physical sciences.

The Institute stands in the very centre of intellectual activity of Calcutta. The building which is meant to be a temple dedicated to science is a striking and dignified one. It is constructed of fine greyish purple sandstone, and in Indian style, of the pre-Mahomedan period, and the ornament and its details are symbolic throughout and repay study. In front is a small garden, appropriately of sensitive plants, with fountain and pool, and with sun dial and electrically controlled clock dial for mutual comparison. A vivid sign of tracing, being the Institute and its work is a

large double automatically made in two parallel curves before the eyes of the observer. One of these curves records the resultant of the essential changes of the atmospheric environments—temperature, light, etc., while the other summarises the responses of a large tree to those changing conditions for every minute of the twenty-four hours. This autograph of the tree gives striking and vivid demonstration of Sir. J. C. Bose's discovery that all plants, including even rigid trees, are fully sensitive to the changes around them. Even the passage of a drifting cloud is perceived and recorded by the tree in its own peculiar script and by an instrument invented for this purpose, a marvel of scientific ingenuity. Here then we have a conspicuous illustration of the significance of this Institute as no mere laboratory of this and that line of physical or physiological research among many, but from the first aiming at the concentration of the main resources and methods of the physical sciences, and of those to bear upon the central problem of all the biological sciences—that of the essential processes of life itself.

The spacious Entrance Hall has a long series of glass cases which at once exhibit and preserve the essential apparatus of many past years of inquiry, from physical researches on electric waves to physiological researches on life. These are arranged in sequence, that of their increasing perfection in observation and record. Step by step one thus passes from instruments direct and simple to the present, well-nigh of magical elaboration of delicacy and exactitude. Here we have Bose's

first apparatus for space signalling by which so far back as 1895 he sent at the Town Hall ether wave through a solid wall, and a line of men including the Governor, and made it displace a heavy weight, ring a bell and explode a miniature mine placed in a closed room. Recent instruments record the imperceptible pulsation in a plant, note the perception-time within the thousandth part of second, and measure ultra-microscopic movements. The significance of this Institute as a centre of new invention, of exceptional skill in the construction of the most delicate apparatus, and in the possibilities of all these to science, and ultimately to industries thus becomes apparent. For it is here worth noting that most of the great physical discoverers and inventors from—Watt and Kelvin, back Galileo and Leonardo de Vinci, or onwards to Bell and Edison and now Bose himself, have been their own instrument makers, or hand and brain thus alternately stimulate each other, to the complementary advances we call “discovery” and “invention” respectively.

Let us first pass through the great Lecture Hall, look into the actual Laboratories, where the researches, preliminary to all announcement of them, have to be made. These are partly in the main building but more largely in the annex, and indeed largely almost primarily, on the garden around, with which we may therefore best begin. Again, sensitive and other moving plants preponderate like twiners and climbers, which cover a long and shady pergola which will serve also as a college cloister, and its “Philosophers’ Way.”

The nearer ground is laid out with pleasant lawns, with fountain and tank for water-plants and with a group of trees, partly old inmates of the garden, partly lately transplanted hither, at full size, under anæsthetics. Under these trees is a variety of apparatus and above is perched an open platform for observation and thought by turns, since this alternation of keen outlook and meditative interpretation is the very process of science, the rhythm of its intellectual life.

From these beginnings of the future Biophysical Garden we may now enter the Laboratories. Here beyond the small marble entrance porch, again kept free for observation and meditation, are glass houses—white, red and blue, for the study of the growth and behaviour of plants under light from opposite ends of the spectrum, as compared with normal conditions. Beyond these are the larger laboratories, electrical and chemical, mechanical, and microscopic and physiological.

For so many enquiries the three new storeyed annex is already insufficient. Research work must thus flow back into every available room of the main building even into the long space under the gallery of the lecture hall, economically contrived for work and use. The further new building already begun, will thus soon be required.

The Institute has as yet only the beginning of a Library, at present lodged in Sir J. C. Bose's house. But additions are urgent and these on a comprehensive scale are required by this Institute as not only a laboratory of varied research, but

also more and more as a meeting place and clearing-house at once of physical and biological sciences, and these in their ever-widening relations.

A hostel for workers, of Indian simplicity yet also with something of Indian Art, and free from that too official and too often-almost prison-like character which these institutions of late years have too often been acquiring alike in East and West will also be erected, while the Director's House is intended, in the—we trust still distant—future as a further hostel.

Having thus broadly surveyed the new Institute, and seen, or foreseen, something of its working we may now enter the great Lecture Hall which is seated for some 1,500 auditors. Here the inaugural ceremonies of the Institute took place and as soon as may be thereafter, a course of lectures by Sir J. C. Bose will be given embodying the main results of his studies in physics and in physiology, both plant and animal. These will afterwards be published as a volume. After courses individual lectures will also be announced from time to time, and fresh researches described as these advance to the level of publicity.

As the laboratories and grounds of the Institute afford various fresh and vivid departures from conventional academic design, so also this great Hall, of the as yet best attainable environment for scientific exposition. And this first and foremost as a monument of simple, beautiful and efficient design, in which a large audience can at once see and hear without the visual interruption and the

acoustic defects too common in auditoria designed without the collaboration of the physicist.

The purpose of this Hall is thus neither restrictedly scientific, as its magnitude shows, nor yet simply popular. The essential idea is that of providing for the scientific exposition of new knowledge, and this at its highest appeals to the intelligent public, much as does the Royal Institution of London.

The Hall itself is decorated with symbolic meaning and this at once for scholar and artist as well as scientist. The ceiling design, with its great radiating lotus is freely adopted from one of the cathedral caverns of Ajanta, yet with the sensitive plants so specially connected with the work of the Institute, around its border. The body of the Hall is left quiet and plain, as befits its purpose of attention, but above the lantern screen, is a frieze painting, an allegoric masterpiece. "The Quest" by Nandalal Bose, a well-known member of that little group of Calcutta artists who are recovering the tradition of Indian painting, yet adapting these to modern interest and individual expression. Starting from the sacred river at dawn, strides forth the tall and keen braced figure of "Intellect" feeling the sword edge with which he has to cleave his way and companioned in his adventurous journey by his bride "Imagination" inspiring him with her magic-flute. Thus here in the institute its distinguished scientific leader will stand as thinker with the artist, the philosopher and the poet. The final and focal ornament of the Hall the great relief in bronze, silver and gold



is that of the sun-god rising in his chariot to the daily cosmic strife of light with darkness.

How this new Institute may act and react with Indian thought and life, as well as with the world's science, and how also it may advance here industry, there agriculture, there again medicine, and above all the needed emancipation and renewal of higher education, it is too soon to predict. Enough for the present that this flowering of a creative life should now fully be opened. Its fruits will ere long be maturing, and even its seeds of new activities spreading throughout India and flying over the world.

# ESSAYS AND DISCOURSES

BY

DR. PRAFULLA CHANDRA RAY, C. I. E.

This is a comprehensive collection of the writings and speeches of Dr. P. C. Ray, the well-known Indian chemist. At the request of the publishers, the papers collected for the first time in this volume have been selected and revised by Dr. Ray himself. Appropriately enough Dr. Ray's contributions on Scientific Researches and Hindu Chemistry in particular find precedence in this collection. The volume opens with a paper on "The Problem of Scientific Education in India" written as early as 1889 in the pages of the *Calcutta Review*. Among other papers in this section are "Progress of Chemistry in Bengal," "Possibilities of Chemical Industries in India," "Higher Science in the Universities," "Chemistry and Medicine" and the special lectures on "Hindu Chemistry" delivered by Dr. Ray in February last at the Madras University. This is followed by papers on Education and Industries—Dr. Ray's evidence before the Royal Commission on Public Services, on the Educational Services as also before the Indian Industrial Commission in 1917. Dr. Ray's thoughtful article on "Bengali Brain and its Misuse" which had provoked a great deal of discussion in the Indian Press in 1910, his presidential addresses to the Bengal Literary Conference and the last Social Conference at Calcutta, are also included in this volume. Then follow Dr. Ray's appreciations of the late Ananda Mohan Bose, Dadabhai Naoroji and Sir William Wedderburn. The appendix contains a complete list of the researches of Dr. Ray and his pupils. The volume is bound in Clot

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