THE BOOK WAS DRENCHED

TEXT FLY IN THIS BOOK

SIR JAGADISH CHANDER BOSE

HIS LIFE, DISCOVERIES AND WRITINGS.

"It is no easy life that lies before a scientific investigator. He has to steel his body and nerve to the utmost. There is to be for him no life of ease. It is to be one of unending struggle. Even after all this there is no assurance whatever of success to reward him for his ceaseless toil. He has to cast his life as an offering, regarding gain or loss, success or failure as one. The lure that draws heroic souls is not the success which can easily be achieved but defeat and tribulation in the pursuit of the unattainable."—Jagadish Bose.

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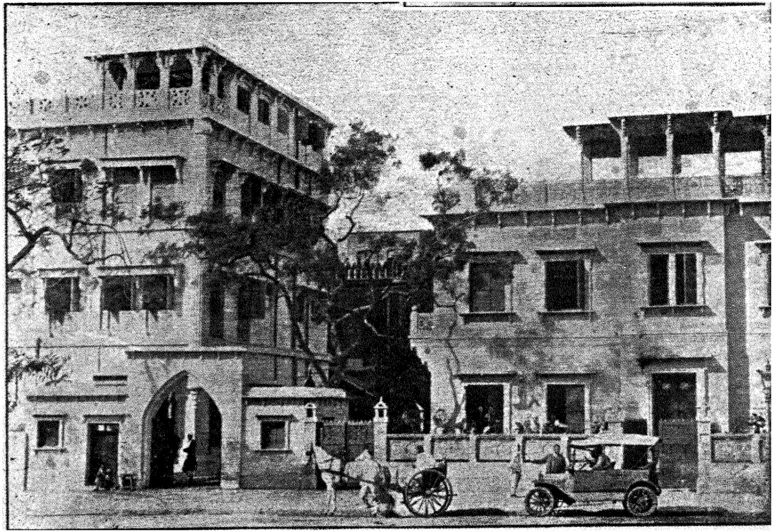
PUBLISHERS' NOTE.

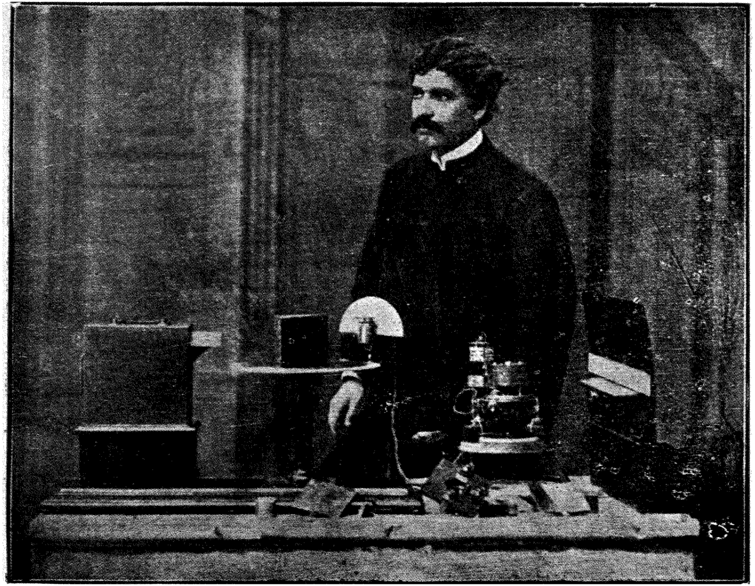
This volume opens with a brief but succinct account of Sir Jagadish Chander Bose's life and his works. It describes his early struggles, his controversies with leading European scientists and his final victory, his tours in Europe and America and the establishment of what Prof. Geddes aptly calls the "Temple of Science" in Calcutta. The sketch recounts his various experiments and discoveries and summarises his achievements in the realm of science. The life sketch is followed by an almost exhaustive collection of his writings and speeches. It begins with Sir Jagadish's educational addresses including his famous Hindu University speech and his evidence before the Calcutta University Commission. Then follow speeches on general subjects. His purely scientific lectures occupy the bulk of the book. Dr. Bose's views on other important subjects, besides those mainly scientific, will be found of absorbing interest. An interesting feature of the book is the inclusion of his addresses to students. The collection also includes a list of his Researches and Discoveries and a description of the Bose Research Institute by Prof. Geddes, his enthusiastic biographer.

CONTENTS.

Sir Jagadis Chander Bose is a fine example of the fertile union between the immemorial mysticism of Indian philosophy and the experimental methods of Western science. Whilst we in Europe were still steeped in the rude empiricism of barbaric life, the subtle Eastern had swept the whole universe into a synthesis and had seen the one in all its changing manifestations. . . He is pursuing science not only for itself but for its application to the benefit of mankind. We welcome the additions to knowledge which he has made, but most of all we welcome in him the evidence that India and Great Britain can unite their genius to mutual advantage.—"The Times."



BOSE RESEARCH INSTITUTE.



Professor J. C. Bose lecturing on his discoveries at the Royal Institution rendered famous by the works of Davy and Faraday.

SIR J. C. BOSE

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 tbe form of worship rendered by the artisans to Viswakarma, God in his 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 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 Jagadish 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 folk, 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 those who tilled 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 then follows:—

"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 IN ENGLAND

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."

But the elder Bose had no objection to his son pursuing a medical or scientific vocation. Accordingly he left for England. Of his studies in the English Universities, his biographer, Patrick Geddes, writes as follows :—

Arrived at London, his B. A. diploma served him for matriculation, and he started the usual first-year work of the medical student. The Physics and Chemistry were much what he had done before, but the Zoology course, under Ray Lankester, was interesting and wholly new; for even to this day Calcutta University excludes zoological science. Botany too, in the summer term, was congenial, so that the preliminary scientific examination was passed without difficulty. With the following autumn term began the first year of medical studies proper, with anatomy. But the fever was still as bad as ever, with even more frequent attacks, which were brought on intensely by the odours of the dissecting-room. Hence the anatomist advised young Bose to give up his medical course as hopeless. Dr. Ringer, then the most distinguished physician of the Hospital, as well as one of the best and kindliest of professors, who had already been treating him with arsenical and other injections, but all without success, concurred in this advice. Thus thrown into new perplexity, Bose decided on leaving London and taking to science at Cambridge.

He passed his B. A. examination in 1884 from-Christ College where he won the natural science scholarship. Next year he secured the B. Sc. Degree from the London University.

RETURNS TO INDIA.

But more than his studies was the inspiration he received from the leading lights in the world of science. In that excellent account of "The Life and Work of Sir Jagdish Bose" (Longmans Green & Co.)

Prof. Patrick Geddes, the enthusiastic biographer, very rightly asks:—

What better teacher could he have had for Physiology than Michael Foster, or for Embryology than Francis Balfour, then at the very height of his brilliant powers? Geology too had its interest, both from Professor Hughes and his kindly and hospitable wife; and so on. But after the middle of the second year, he settled down to regular work in Physics, Chemistry and Botany. Of Professor Liveing's chemical course, the stimulus to spectroscopy is specially remembered. Vines' lectures and laboratory of Botany were slso much appreciated, and Francis Darwin's first course of Vegetable Physiology was given before he left. And most educative and decisive for the future physicist was the teaching of Lord Rayleigh, whose admirably patient and careful experimentation. to the most scrupulous accuracy, with every factor of disturbance allowed for or compensated, and all with correspondingly clear and careful explanation, produced a profound impression, which has been lifelong.

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 have imagined that Jagadish would one day assume the position of a teacher in the land, where he earnestly sought for light, the light of science!

Bose, now twenty five, got an introduction from Prof. Fawcett, the Economist, to Lord Ripon, the then Viceroy of India.

His Labour in the Cause of Science

Though Dr. Bose got the Professorship of Physics in the Presidency College, after some difficulties, he could not obtain any facilities to carry on his researches.

And he was also the victim of race discrimination in the Department. When Bose joined service, an Indian Professor's income, even if he be in the Imperial service, was two-thirds that of a European. A further insult was offered to him by cutting down half of even this two thirds since his appointment was only officiating. But Bose was determined and strong.

With this combination of personal pride with loyalty to his countrymen and colleagues, he decided on a new form of protest, and maintained it with unprecedented definiteness and pertinacity. As his protest was disregarded, he resolved never to touch the cheque received by him monthly as his pay and continued this for three years, with what privations accordingly need not now be entered into, save with a word of appeciation for his wife's brave acceptance of them.

After three years' work both the Principal and the Director of Public Instruction came to realise the value of Bose's work and his character and become his staunchest friends.

In consequence of this change of view of the Director, Bose's appointment, by help of a special order from the Government, was not only made permanent, but this with retrospective effect. He therefore received his full pay for the last three years in a lump sum.

"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 subsidy 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. On an 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 dicovery. 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.

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 simultaneously 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 domonstrated 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. He continued his experiments on plant and animal response to stimuli. So striking was the correspondence that, when Bose showed the records to Sir Michael Foster, the veteran physiologist picked up one and said:

'Come now, Bose, what is the novelty in this curve? We have known it for at least the last half-century.' 'What do you think it is?' said Bose. 'Why, a curve of muscle response, of course.' 'Pardon me; it is the response of metallic tin.' 'What!' said Foster, jumping up—'Tin! Did you say tin?' On explanation, his wonder knew no bounds; and he hurried Bose to make a communication to the Royal Society, which he (then Secretary) offered to communicate.

On May 10, 1901, 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.

The lecture was highly appreciated and its totally unexpected revelations created wide interest in scientific circles. But then troubles were brewing to which we shall refer immediately.

After his preliminary communication Bose read his paper at the Royal Society on June 6 with full and detailed experimental demonstration. The rest of the story will be told in Prof. Geddes' words*:—

The paper seemed as well received as usual, but the blow was now to come; and this from no less than Sir John Burdon Sanderson, who was then, and for many years had been, 'the grand old man' of physiological science in England. His work, moreover, had largely lain not only in the study of the behaviour of muscle and nerve under stimulation, but very specially upon the movements of the Venus' fly-trap (Dionæa), to which Darwin had first called his attention, and to the electrical physiology of which he had devoted unsparing labours during many years. He thus stood out as a peculiar authority on the electro-physiology both of animals and plants so far as was then known; and his interest was still so keen that he had come up from Oxford for this paper. He was naturally the person to whom all looked to open the usual discussion after the paper. He began with a compliment on Bose's previous physical work; but then said it was a great pity that he should leave his own sphere of study, in which he had attained such acknowledged distinction, for other fields which properly belonged to the physiologists Professor Bose's paper was still under consideration for publication; but he might give him the advice that the title should be changed from 'The Electric Response' to 'Certain Physical Reactions,' so leaving to physiologists the use of their term 'Response,' with which physicists are not concerned; and further, as to the electric response of ordinary plants described at the end of the paper, he would say that it was absolutely impossible, since he had tried to detect it for many years past, and never could obtain any. It simply could not be!

Two other professors supported Sanderson and Bose in his reply held his ground and said that "it seemed inexplicable that the doctrine could be advocated—and in the Royal Society of all places—that knowledge should advance so far and no further; so he could, on no account, alter a word of the paper, even at the risk of refusal of publication, unless he were shown, on scientific grounds, wherein the experiments he had just shown were faulty or defective." This was too much for the learned academicians. The opposition was not based on scientific grounds.

As a physicist he was regarded as an intruder in the domain of physiology. As his English biographer finely pointed out : " As an unsophisticated man from the East, he had seriously taken the lessons preached by the West about the evils of the caste system ; but here he felt he had come against a yet worse system of caste whose etiquette he had unwittingly offended."

Thus prejudice and personal antipathy got the upper hand and Dr. Bose's paper was shelved and a bald telegram blurted out " Bose's Work and Paper are rejected by the Royal Society."

Bose, who had returned to India, now applied for an extension of the period of deputation in order that he might go again to England and justify his contentions. Thwarted in his attempts he persisted till he got his own way. Heartened by the encouragement afforded by the Secretary of State who was struck by Bose's courage, he

went to work anew at the Royal Institution Laboratory. He at first feared a cold reception, but was consoled by a brother physicist: 'You can't poach on other people's preserves without some resentment; and you've upset their apple-cart.' He settled down to work for the vacation at his London home, and then returned to the Royal Institution when it re-opened in October. Work abated depression, but did not remove it. About this time he was cheered by a letter from Professor Vines, the well-known botanist and vegetable physiologist of Oxford, who expressed interest, asked to see his experiments, and came accordingly to the Royal Institution Laboratory, bringing with him Horace Brown, another effective investigator of the process of plant-life, and Howes, who was Huxley's successor at South Kensington.

With the first application of stimulus to the plant, a wide swing of the galvanometer-mirror's light-beam along the scale demonstrated its sensitiveness. Never before had Bose seen three sober Englishmen so joyously excited: 'they were just as mad as boys.' Said Howes: 'Huxley wuuld have given years of his life to see that experiment.' Said another: 'What did you to let off steam when you discovered this? You should shout, or you will kill yourself by repressing it.' Then in business mood: 'The Royal Society has not published your paper, so you can give it to the Linnean. We are its President and Secretary this year, so we invite you to read us a full paper. Show us your experiments; and we will invite all the physiologists, and particularly, your opponents.'

But then new difficulties cropped up. It was alleged that his results were by no means new! They had already been discovered by some one else.

Results substantially similar to these obtained by Bose had been communicated to a London scientific society in November 1901 by the physiologist who had seen Bose's experiments before the Royal Society (June 1901) and had also taken part in the subsequent discussion. Bose learned of the new turn of affairs from a letter from Professor Howes, as the Secretary of the Linnean Society. A new period of depression followed, far deeper than the preceding one, but he rallied himself to reply, formally asking for an inquiry into the matter. This was at once granted. Vines and Howes, both also Fellows of the Royal Society, had fortunately seen proofs of Bose's paper there ten months before that at the Linnean, and five months before the other claimant's communication. Bose's lecture at the Royal Institution, a few days earlier than the Royal Society function, was also in print and in evidence. With all the facts before them, the committee of inquiry had no hesitation. Bose's right to absolute priority was completely established, and the paper was published accordingly.

It is useless to recount the story of his trials. Its lessons however should be borne in mind. That truth prevails in the end, that persistency wins and that even the Royal Society is not without its share of the vanity of learning!

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 scientfic 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 Societe de Phisique, the Second at the Sorbonne, the third before the Societe de Zoologique. He was elected about the year 1902 to the Council of the Societe Francaise de Phisique.

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 visualisation 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. Professors 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 Pflargen Physiologishches 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.

BACK TO INDIA.

Dr. Bose returned home on the completion of his world tour. In reply to one of the numerous addresses of welcome which were presented to him, Dr. Bose observed :—

This is 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 co-operate 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.

Though a prophet is seldom respected in his own country, Bose 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 Bengalee Professor was asked by the University of the land of the 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 interdependent, 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 such a stir 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. Bose himself in a 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 inquirers have, indeed, been struck by the glaring differences between the two. Animals respond to a shock by movement, where as 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 signs 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.

THE RESONANT RECORDER

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. It 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 had 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 the 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 living 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 to 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, bnt 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 leaflets of biophyture of the anodic and kathodic 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 went 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

Bose was to have retired in 1913, on the completion of his fifty-fifth year; but the Bengal Government, in recognition of his services to the Presidency College and of his great influence over students, extended his period of service for two years, so that he retired in November 1915. As a further acknowledgment the Government gazetted him as Professor Emeritus on full pay instead of pension—a distinction so far unique in the Educational Service of India. Thus was secured his permanent connection with the Presidency College, whose renown he has so largely enhanced. Further than this, he received a Knighthood and the Companionship of the Star of India.

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, a 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.

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 lost." 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 pligrimages 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 the 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 temptations. 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."

On the 30th November 1917 on his fifty-ninth birthday, 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 purposes 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 knowledge 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 desire 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 Taxila.

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 here 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.

Lectures in the Institute.

Since the foundation of the Institute Dr. Bose has delivered a series of thought provoking discourses on scientific subjects. Distinguished men from the Universities and public life have witnessed his remarkable instruments functioning what to the lay world appears as nothing short of miracles. In

January 1918 Dr. Bose explained under the auspices of Lord Ronaldshay, the Governor of Bengal, The Mystery of the Paying Palm Tree, when he made mention of a new instrument of his own design and make, the Cr[illegible] which was exhibited at the Institute a fortnight hence. Lecturing on the Revelations of Plant Life, he showed the working of his perfected instrument—an apparatus that gives a visual demonstration of movements far beyond the highest powers of a microscope. The end of the month saw him in Bombay lecturing on his favourite subject "The Unity of Life." The lecture was illustrated by lantern slides and an instructive exposition was given of his discoveries in plant life. Dr. Bose also explained the principle of his Resonant Recorder.

HIS LATEST TRIUMPHS

It was about this time that Dr. Bose's private laboratory was visited by His Excellency the Viceroy, Lord Chelmsford, accompained by the 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. This is the transplantation of trees in perfect condition. At an 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, especially in the agricultural department. The high magnification attained by it varies from ten thousand to a million times. Some time ago, the peculiar date palm-tree of Faridpur, attracted the attention of Dr. Bose. This tree lay down in the evening when the temple bells called the people to prayer and again, in the morning, stood erect.

Dr. Bose began to investigate this peculiar phenomenon and the result was surprising. He first obtained photographs of the tree in different positions which proved the phenomenon to be real. He then devised a special apparatus to record continuously the movement of the tree day and night. The records showed that the Palm Tree fell with the rise of temperature and rose with the fall. He then tried the apparatus on other trees and the records " brought out the extraordinary and unsuspected fact that all trees are moving—such movements being in response to changes in environment."

In January, next year, Dr. Bose dealt with the mysterious phenomenon of the recurrent opening and closure of flowers. This discourse was entitled " The

Night Watch of Nymphæa." This was followed in February with a discourse on "Wounded Plants."

Dr. Bose subsequently left for an extensive tour in Europe where he was received and honoured by the various Universities. He lectured in London, Paris, Berlin, Vienna and several places and his demonstrations were witnessed by the leading scientists and distinguished men of all vocations. He returned to India in May 1920 when he was presented with numerous addresses of welcome. Our readers will remember how he was attacked by interested scientists in England on the eve of his lecture before the Royal Society nearly 20 years ago. During his tour in 1920 he was not spared either. This time it was Dr. Waller who attacked him. Dr. Bose explained the circumstances in his speech at the Bengal Society at Calcutta to which we draw special attention. Early in 1921 Dr. Bose began another series of lectures in his Institute which attracted wide attention. Speaking on the "Surge of Life" on the 4th February he showed some striking demonstrations with the Recording Crescograph. He spoke in successive sittings on "Science and Research," "Sense Organs of Plants" and other subjects. On April 12, 1921 he was entertained by the members of the Rotary Club of which he was unanimously elected an honorary member.

In August Dr. Bose addressed the students of the Dacca University when he gave a lucid description of his experiments relating to plants. He summarised the results of his investigations in plant and animal life and said :—

If he were asked what was the outcome of his recent work, he would say that it was the establishment of the great generalisation that the story of the simplest life was symbolic of all life in its diverse manifestations of growth and decay, of perception and reaction and even of conduct and behaviour. He found that an organism derived its strength from the soil which nourished its body, and the environment which by its multitudinous shocks stirred it up from that lethargy which was akin to death. It is its perception and quick adjustment to change, its inherited memory of the past that called forth all its nascent powers so that in all its struggles it rose victorieus above the most adverse circumstances.

Laymen often ask, of what avail are these theoretical and abstract truths ? Dr. Bose has always held that the advance of knowledge and its practical application are not of conflicting interest but complementary to each other. He illustrated this with an example from his own experiences.

Twenty-seven years ago he was working with a very inadequate means in investigations of an abstruse character—the properties of electric waves. He was then constantly questioned about their utility. In 1895, he succeeded in perfecting an apparatus by which wireless messages could be sent and detected with the utmost certainty. But it evoked not even a flutter of interest, either in the official or non-official circles. He had his higher reward of obtaining through these investigations the first glimpse of that universal responsiveness which characterises all matter, living and non-living. It was no metaphysical speculation, but the challenge of the unknown that urged him to try to unravel some of the baffling mysteries which surround life. About this work also it had been constantly questioned :—What earthly use could there be of his investigations on plant life ? And it was not till last year that some of the leading scientific bodies of the West realised that these investigations might lead to the increase of earth's food-supply.

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 positions 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 lite manfully and whose life of purity and unselfishness had brought gleams of joy unto 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.

BENGAL LITERARY CONFERENCE

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 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 practice 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 evidence before this Commission. We give a short extract below ;—

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 land 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 chracteristics 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 to 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 the 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 to 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 harmonics 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 discording 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 the universe, unto them belongs eternal truth, unto none else, unto none else."

I. Educational

TEACHING OR RESEARCH

[Professor J. C. Bose writing in the columns of the Bengal Educational Journal for September 1913, discussed the comparative values of Teaching and Research, the two primary functions of a University.]

I do not think there is necessarily any 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 lost. Hence the importance of the encouragement of originality and research in an University, even from the point of view of the teacher.

And the power of a University to encourage research will depend on the world-status which that University has created for itself. What is the worth of its degree and what is the value of the honours conferred by it in the estimation of the world? This estimation and this world-status can by no manner of means be created artificially.

For the question will be asked 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 always to be a preparatory school for the foreign Universities which have a high 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 as an unrealisable dream. It has been accomplished before. The fame of Nalanda and Taxila did attract students from other lands who made long [illegible] to the Indian shrines of learning.

It is well known that those who have come in close contact with great scientific workers and worked under them, have carried away a great impulse, and have afterwards become centres of great intellectual activity. Those who are in touch with scientific activity in England know how much of this is due to the pupils of Kelvin and Rayleigh, of J. J. Thompson and Ramsay. It would be invidious to mention specific names, but I shall be disappointed indeed if the present activities of scientific men in India do not bear fruit in the near future.

FACILITIES FOR RESEARCH.

It would serve no good purpose to draw attention to the relative absence of facilities for research in India compared to those in foreign countries. I have found it not at all an unusual thing for Universities in America to spend a million dollars in the equipment of a laboratory. Envy at the good fortune of others leads to no productive results. It has to be remembered that there are two factors for successful investigation—one, external, demanding lavish expenditure of money—the other, internal, which requires intense mental application. Perhaps in this power of concentration, Indians possess an asset of no mean value. In spite of difficulties work has been done here which has found recognition in the great intellectual centres in the West. It is obvious that with better facilities much more can be done; it is a matter which should not present insuperable difficulties to our Universities.

FACILITIES IN CALCUTTA.

My experience has been in connection with encouragement of research offered by the Government. Sir John Woodburn, the late Lieutenant-Governor of Bengal, was much interested by the dovotion shown by some of my pupils in the research work carried on under me, in appreciation of which he instituted a research scholarship of Rs. 100 a month. The object of this excellent institution is frequently vitiated by red-tape; for example, the maximum duration of the tenure of a scholarship, is three years. It generally happens that only in the third year of his tenure a scholar's training is sufficiently advanced to enable him to begin original work on his own account, and at this critical period his scholarship is withdrawn. It is highly desirable that these scholarships should be continued in specific cases where exceptional promise has been shown. It is moreover desirable that their special training should find scope, and their services utilised in the Department of Education for the cause of education itself.

THE KEENNESS OF 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 a 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 costs 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.

THE FUTURE OF RESEARCH IN INDIA.

I think there is a great future for such work. 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 undoubtedly in the border lands which, at present, divide one department of science from another, and in such work alone do we look for scientific generalisation of supreme importance. 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 [illegible]

EVIDENCE BEFORE THE PUBLIC SERVICES COMMISSION

The following is the full text of the evidence tendered by Dr. J. C. Bose, C, S. I., C. I. E., on the 18th December, 1913, before the Royal Commission on the Public Services in India. Dr. Bose's evidence was confined to the Education Services. Dr. Bose was then Professor of Physics in the Presidency College, Calcutta.

WRITTEN STATEMENT.

83, 627 (I) *Method of recruitment.*—The first question on which I have been asked to give my opinion is as regards the method of recuitment. I think that a high standard of scholarship should be the only qualification insisted on. Graduates of well-known Universities, distinguished for a particular line of study, should be given the preference. I think the prospects of the Indian Educational Service are sufficiently high to attract the very best material. In Colonial Universities they manage to get very distinguished men without any extravagantly high pay. Possibly the present departmental method of election does not admit of sufficiently wide publicity of notice to attract the best candidates.

83, 628 (II) *System of training and probation.*—As regards probation and training, Educational officers should first win a reputation as good teachers before the appointment is confirmed as they are transferred to important colleges.

83, 629 (IV) *Conditions of Salary.*—As regards conditions of salary, the pay should be moderately high, but not extravagant, and settled once for all under some simple and well-defined rules. It is not only very humiliating but degrading to a true scholar to be scrambling for money. The difference between the pay of the higher and lower services should be minimised.

83, 630 (VI) *Conditions of pension.*—With reference to pension, I think it is very unfair that more favourable terms are offered, when the pensioner elects to retire in England.

83, 631 (VII) *Such limitations as exist in the employment of non-Europeans.*—Passing on to the question of limitations that exist in the 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.

83, 632 (VIII) *Relations of the service with the Indian Civil Service and with other services*—As regards the relations with the Indian Civil Service, I am under the impression that they are somewhat strained, but of this I have no personal experience.

83, 633 (IX) *Other points.*—I have endeavoured to give my opinion on the definite questions which have been asked. There is another aspect of educational work in India which I think is of the highest importance, though I am not exactly sure whether it falls within the terms of reference to the Royal Commission. I think that all the machinery to improve the higher education in India would be altogether ineffectual unless India enters the world-movement of the advancement of knowledge. And for that it is absolutely necessary to touch the imagination of the people so as to rouse them to give their best energies to the work of research and discovery, in which all the nations of the world are now engaged. To aim at anything less will only end in a lifeless and mechanical system from which the soul or reality has passed away. On this subject I could have said much, but I will confine myself to one point which I think at the present juncture to be of importance. The Government of Bengal has been foremost in a tentative way in encouraging research. What is necessary is the extension and continuity of this enlightened policy.

83,634. *Supplementary Note.*—I would like to add a few remarks to make the meaning of paragraphs 83,627 and 83,631 in my note more explicit.

At presnt recruitment in the Indian Educational Service is made in England and is practically confined to Englishmen. Such racial preference is, in my opinion, prejudicial to the interest of education. The best man available, English or Indian should be selected impartially, and high scholarship should be the only test.

It has been said that the present standard of Indian Universities is not as high as that of British Universities, and that the work done by the former is more like that of a sixth form of public schools in England. It is therefore urged that what is required for an Educational officer is the capacity to manage classes rather than high scholarship. I do not agree with these views: (1) there are Universities in Great Britain whose standards are not higher than ours; I do not think that the Pass Degree even of Oxford or Cambridge is higher than the corresponding degree here; (2) the standard of the Indian Universities is being steadily raised; (3) the standard will depend upon what the men entrusted with educational work will make it. For these reasons it is necessary that the level of scholarship represented by the Indian Educational Service be maintained very high.

In paragraph 83,631 I have stated that even those Indians who have distinguished themselves in European Universities have little chance of entering the higher Educational Service. I should like to add that these highly qualified Indians need only opportunities to render service which would greatly advance the cause of higher education. As regards graduates of Indian Universities, I have known men among them whose works have been highly appreciated. If promising Indian graduates are given the opportunity of visiting foreign Universities, I have no doubt that they would stand comparison with the best recruits that can be obtained from the West.

ORAL EVIDENCE.

83,635. (Chairman). The witness favoured an arrangement by which Indians would enter the higher ranks of the service, either through the Provincial Service or by direct recruitment in India. The latter class of officers, after completing their education in India, should ordinarily go to Europe with a view to widening their experience. By this he did not wish to decry the training given in the Indian Universities, which produced some of the very best men, and he would not make the rule absolute. It was not necessary for men of exceptional ability to go to England in order to occupy a high chair. Unfortunately, on account of there being no openings for men of genius in the Educational Service, distinguished men were driven to the profession of Law. In the present condition of India a larger number of distinguished men were needed to give their lives to the education of the people.

83,636. The witness himself had spent part of his career in Europe, and looking back he could say that this had been of great profit to him, not so much on account of the training he got, as by being brought into personal contact with eminent men whose influence extorted his admiration, and create in him a feeling of emulation. In this way he owed a great deal to Lord Rayleigh under whom he worked, but he did not see why that advantage should not eventually be secured by Indians in India under an Indian Lord Rayleigh.

83,637. There should be only one Educational Service, but men who were distinguished in any subject should not start from its very lowest rung but should be placed somewhere in the middle of it.

83,638. There were men in the Provincial Service who were very distinguished; it was all a question of genius. The Educational Service ought to be regarded not as a profession, but as a calling. Some men were born to be teachers. It was not a question of race, of course; in order to have an efficient educational system, there must be an efficient organisation, but this should not be allowed to become fossilised, and thus stand in the way of healthy growth.

83,639. In the Presidency College a young man fresh from an English University was at once appointed a Professor regardless of his lack of experience, whereas an Indian who passed the highest examination with honours in India was appointed as an Assistant Professor. This grounding often made him more efficient as a teacher than the Professor recruited from England. There were now several Professors in the College, in the Provincial Service who were highly qualified, and who lectured to the highest classes with very great success.

83,640. In the Physics Deparment he had under his direction several Assistants who were so well qualified that they were allowed to give lectures to several classes. These Assistants, after their exprience at the Presidency College, would be best fitted to become Professors in the mofussil at Colleges. He would like to see them promoted to the higher service after they had had experience. But before he gave them the highest positions, he would make it compulsory for them to go to Europe.

83 641. A proportion of Europeans in the service was needed, but only as experts and not as ordinary teachers. Only the very best men should be obtained from Europe, and for exceptional cases. The general educational work should be done entirely by Indians, who understood the difficulties of the country much better than any outsider.

83,642. He advocated the direct recruitment of Indians in India by the local government in consultation with the Secretary of State, rather than by the Secretary of State alone. Indians were under a great difficulty, in that they could not remain indefinitely in England after taking their degress and being away from the place of recruitment their claims were overlooked.

83,643. There was no reason why a European should be paid a higher rate of salary than an Indian on account of the distance he came. An Indian felt a sense of inferiority if a difference was made as regards pay. The very slight saving which government made by differentiating between the two did not compensate for the feeling of wrong done. This feeling would remain even if the pay was the same, but an additional grant in the shape of a foreign service allowance was made to Europeans. All workers in the field of education should feel a sense of solidarity, because they were all serving one great cause, namely, education.

83,644. The term "professor", as at present used in India, was undoubtedly a comprehensive one, but it was equally comprehensive in the West.

83,645. (Sir Murray Hammick). The witness did not wish to recruit definite proportions of the service in England and in India respectively. He would for various reasons prefer a large number of Indians engaged in education.

83,646. Even in Calcutta he would not make any difference between the pay of the Indian and the pay of the European.

83,647, (Sir Valentine Chirol). The witness attached great value to the influence of the teacher upon the student in the earlier stages of his education, and it was in these stages that that influence could best be exercised. At the same time he desired to limit the appointment of non-Indians to men of very great distinction.

83,648. If a foreign professor would not come and serve in India for the same remuneration as he obtained in his own country the witness would certainly not force him to come.

83,649. (Mr. Abdur Rahim). Recruitment for the Educational Service should be made in the first place in India, if suitable men were available; but if not then he would allow the best outsiders to be brought in. In the present state of the country it would be very easy to fill up many of the chairs by selecting the best men in India.

83,650. The aim of the universities should be to promote two classes of work—first, research; and secondly, an all-round sound education. Men of different types would be required for these two duties.

83,651. (Mr. Madge). Any idea that the educational system of India was so far inferior to that of England, that Indians, who had made their mark, had done so, not because of the educational system of the country, but in spite of it, was quite unfounded. The standard of education prevailing in India was quite up to the mark of several British Universities. It was as true of any other country in the world as of India that education was valued as a means for passing examinations, and not only for itself, and there was no more cramming in India than elsewhere.

83,652. The West certainly brought to the East a modern spirit, which was very valuable, but it would be dearly purchased by the loss of an honorable career for competent Indians in their own country.

83,653. The educational system in India had in the past been too mechanical, but a turn for the better was now taking place and the universities were recognising the importance of research work, and were willing to give their highest degrees to encourage it.

83,654. (Mr. Macdonald). The witness did not think it was necessary to have a non-Indian element in the service in order to stiffen it up, but he accepted the principle that there should be a certain small proportion of non-Indians.

83,655. The title of professor at a college or University should carry with it dignity and honour, and ought not to be so freely used as at present. All he asked was that it should not be abolished at the expense of such Indians as were doing as good work as their European colleagues.

83,656. If the Calcutta University continued to develop its teaching side, there would be no objection to recruiting University Professors from aided colleges. This would have certain advantages.

83,657. (Mr. Fisher) The witness desired to secure for India Europeans who had European reputations in their different branches of study. If it was necessary to go outside India or England to procure good men, he would prefer to go to Germany. This was the practice in America where they were [illegible] all the great intellects of Europe.

83,658. The witness would like to see India entering the world movement in the advance and march of [illegible]. It was of the highest importance that there should be an intellectual atmosphere in India. It would be of advantage if there were many Indians in the Educational Service. For they came more in contact with the people, and influenced their intellectual activity. Besides, on retirement they would live in India and their life experience would be at their countrymen's service.

83,659. There was very little in the complaint made in certain quarters that the work of the Professors in the colleges in India was hampered by the Government regulations as to curricula. A good teacher was not troubled by such matters.

83,660. (Mr. Sly). There was no scope for the employment of non-Indians in the high schools as apart from the colleges. It was in the professorial line that more help from the West was required.

83,661. (Mr. Gokhale). The witness knew of three instances in which the colonies had secured distinguished men on salaries which were lower than those given to officers of the Indian Educational Service. One was at Toronto, another was in New Zealand, and the third at Yale University. The salaries on the two latter cases were £ 600 and £ 500 a year. The same held good as regards Japan. The facts there had been stated in a Government of India publication as follows: "Subsequent to 1895 there were 67 Professors recruited in Europe and America. Of those, 20 came from Germany, 16 from England and 16 from the United States. The average pay was £384. In the highest Imperial University the average pay is £684. As soon as Japanese could be found to do the work, even tolerably well, the foreigner was dropped."

83,662. When the witness first started work in India, he found that there was no physical laboratory, or any grant made for a practical experimental course. He had to construct instruments with the help of local mechanics, whom he had to train. All this took him ten years. He then undertook original investigation at his own expense. The Royal Society became specially interested in his work and desired to give him a Parliamentary grant for its continuation. It was after this that the Government of Bengal came forward and offered him facilities for research.

83,663. In the Educational Service he would take men of achievement from anywhere; but men of promise he would take from his own country.

83,664. (Mr. Chaubal). He did not know whether the salaries he had mentioned as having been paid in Japan, New Zealand and Yale were on an incremental scale or not.

83665. There was a difference of kind between the way in which students were taught in schools and the way in which they were taught in colleges. He did not agree with the witnesses who had said that during the first year or two years at college the instruction given was similar to that given in a school. It was very difficult to disprove or to prove such statements. There would be no advantage in keeping boys to a school course up to the intermediate standard and making the colleges deal with only those students who had passed the intermediate examination.

83,666. (Sir Theodore Morison). There should be one scale of pay for all persons in the higher educational department. The rate of salary, Rs. 200 rising to Rs. 1,500 per month, was suitable, subject to the proviso that the man of great distinction, instead of beginning at the lowest rate of pay, should start somewhere in the middle of the list, say, at Rs. 400 or Rs. 500. He would make no reference in regard to Europeans or Indians in that respect. In effect this no doubt amounted to making Indians eligible for higher educational posts both by direct recruitment and by promotion.

83,667. He would not favour the handing over of all the Government institutions in Bengal to private agencies; there must be one or two Government colleges in order to keep up the standard. He should be sorry to see the Government dissociating itself from one of its primary duties, which was education.

83,668. Privately managed Colleges paid less in salary than the Government Colleges. They paid about the same as was given in the Provincial Service, and they obtained fairly good men. It would not be right for a great Government to grant a minimum pay to Indian Professors and an extravagantly high pay to their European [illegible] for doing the same kind of work.

83,669. At the Presidency College the facilities for scientific work were now greater than in many institutions in England. India was now becoming a great country for Biological research. Again, the Physical and Chemical Laboratories at the Presidency College were finer than many in England. If young men of science in England thought they obtained better opportunities in pursuing their subjects in New Zealand and Toronto than in India, the India office ought to remove that impression at once.

83,670. (Lord Ronaldshay). When an Indian graduate under the witness's scheme was appointed direct to the higher service in India he would not compel him to go to England for a period of training. The person who would be appointed in India directly from the Indian Universities would have to have previously served with distinction in subordinate positions; a visit to Europe would be an advantage but not absolutely necessary.

83,671. (Mr. Biss). The cost of living in Calcutta to an Indian Professor or Lecturer would all depend as the style in which he lived. In each service there is always a standard of living to which every member is expected to conform. An Indian Professor had to go to Europe from time to time to keep himself in touch with the developments of his subject. An Indian officer had to support a large number of relations. The question of a man's private expenses should not be raised in fixing his pay. One might as well inquire whether the candidate for admission to the service was a bachelor or married, or as to how many children he had. He had known Europeans who had led a simple life, and had been all the better for it.

83,672. He could not understand why men went to Japan and Canada instead of coming to India on better terms. It was a mystery to him. He thought it was either sheer ignorance or the spread of the commercial spirit.

83,673. All the students coming to his side of the University, were, as a rule, keen and anxious to learn; he could not wish for better students.

83,674. (Mr. Gupta). He desired one service, because he thought it was most degrading that certain men, although they were doing the same work, should be classed in a Provincial Service, while others should be classed in an Imperial Service. The prospect of the members of the Provincial Service were not at all what they ought to be, and that was the reason why the best men were not attracted to it.

EDUCATION IN THE WEST AND EAST

An entertainment in honour of Dr. J. C. Bose was given on the 16th December 1915, in the precincts of the Calcutta Presidency College. Dr. Bose, who had just returned from a successful tour through Europe, America and Japan, made a speech recounting his experiences in the West. The speech as printed in the " Presidency College Magazine" was as follows:—

It was his rare good fortune to have been amply rewarded for the hardships and struggles that he had gone through by the generous and friendly feelings of his colleagues and the love and trust of his pupils. He would say a few words regarding his experience in the Presidency College for more than three decades, which he hoped would serve to bring all who loved the Presidency College—present and past pupils and their teachers—in closer bonds of union. He would speak to them what he had learnt after years of patient labour, that the impossible became possible by persistent and determined efforts and adherence to duty and entire selflessness. The greatest obstacle often arises out of foolish misunderstanding of each other's ideals, such as the differing points of view, first of the Indian teacher, then of his Western colleagues, and last but not least, the point of view of the Indian pupils themselves. In all these respects his experience had been wide and varied. He had both been an undergraduate and a graduate of the Calcutta University with vivid realization of an Indian student's aspirations; he had then become a student of conservative Cambridge and democratic London. And during his frequent visits to Europe and America he had become acquainted with the inner working of the chief Universities of the world. Finally he had the unique privilege of being connected with the Presidency College for thirty-one years, from which no temptation could sever him. He had the deepest sense of the sacred vocation of the teacher. They may well be proud of a consecrated life—consecrated to what? To the guidance of young lives, to the making of men, to the shaping and determining of souls in the dawn of their existence, with their dreams yet to be realised.

Education in the West and in the East showed how different customs and ways might yet express a common ideal. In India the teacher was, like the head of a family, reverenced by his pupils so deeply as to show itself by touching the feet of their master. This is no servile act if we come to think of it; since it is the expression of the pupil's desire for his master's blessings, called down from heaven in an almost religious communion of souls. This consecration is renewed every day, calling forth patient foresight of the teacher. As the father shows no special favour, but lets his love and compassion go out to the weakest, so it is with the Indian teacher and his pupil. There is the relation something very human, something very ennobling. He would say it was essentially human rather than distinctively Eastern. For do we not find something very like it in Mediæval Europe? There too before the coming of the modern era with its lack of leisure and its adherence to system and machinery, there was a bond as sacred between the master and his pupils. Luther used to salute his class every morning with lifted hat, "I bow to you, great men of the future, famous administrators yet to be, men of learning, men of character who will take on themselves the burden of the world." Such is the prophetic vision given to the greatest of teachers. The modern teacher from England will set before him an ideal not less exalted —regarding his pupils as his comrades; he, as an Englishman, will instil into them greater virility and a greater public spirit. This will be his special contribution to the forming of our Indian youths.

Turning to the Indian students he could say that it was his good fortune never to have had the harmonious relation between teacher and pupils in any way ruffled during his long connection with them for more than three decades. The real secret of success was in trying at times to see things from the student's point of view and to cultivate a sense of humour enabling him to enjoy the splendid self-assurance of youth with a feeling not unmixed with envy. In essential matters, however, one could not wish to meet a better type or one more quickly susceptible to finer appeals to right conduct and duty as Indian students. Their faults are rather of omission than of commission, since, in his experience, he found that the moment they realised their teachers to be their friends, they responded instantly and did not flinch from any test, however severe, that could be laid on them.

ADDRESS TO THE HINDU UNIVERSITY.

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Invited to address the Benares Hindu University in connection with its inauguration in March 1916, Dr. Bose delivered the following discourse.

"FROM THE VOICED TO THE UNVOICED."

In tracing the characteristic phenomenon of life—from simple beginnings in that vast region which may be called Unvoiced, as exemplified in the world of plants, to its highest expression in the animal kingdom one is repeatedly struck by one dominant fact, that in order to maintain an organism to the height of its efficiency, something more than a mechanical perfection of its structure is necessary. Every living organism, in order to maintain its life and growth, must be in free communion with all the forces of the universe about it. Further it must not only constantly receive stimulus from without, but must also give out something from within. And the healthy life of the organism will depend on these twofold activities of inflow and outflow. When there is any interference with these activities, then morbid symptoms appear, which ultimately must end in disaster and death. This is equally true of the intellectual life of a nation. When, through narrow conceit, a nation regards itself self-sufficient and cuts itself from the stimulus of the outside world, then intellectual decay must inevitably follow. So far as regards the receptive function. Then there is another function in the intellectual life of a nation—that of spontaneous outflow—that giving out of its life by which the world is enriched. When the nation has lost this power, when it merely receives but cannot give out, then its healthy life is over and it sinks to a degenerate existence which is purely parasitic.

THE FUNCTION OF A NATIONAL UNIVERSITY.

How can our nation give out of the fulness of the life that is in it and how can a new Indian University help in the realisation of this object. It is clear that its power of directing and inspiring will depend on its world status. This can be secured to it by no artificial means; nor can any charter assure it. This world-status can only be won by the intrinsic value of the great contributions to be made by its own Indian scholars for the advancement of world's knowledge. To be organic and vital our new University must stand primarily for self-expression and for winning for India a place she has lost.

Knowledge is never the exclusive possession of any particular race nor does it recognise geographical limitations. The whole world is interdependent and a constant stream of thought had been carried out throughout the ages enriching the common heritage of mankind. Although science was neither of the

East nor of the West, but international in its universality, certain aspects of it gained richness by reason of their place of origin. Has India then any great contributions to offer for the advance of human knowledge? And we have also to realise in this connection: What has been her strength in the past and what is the weakness that has been paralysing her activities?

CONDITIONS FOR SCIENTIFIC SUCCESS.

For the accomplishment of any great scientific work there must be two different elements and these must be evenly balanced; any excess of the one at the expense of the other would be highly detrimental to the discovery of truth and advancement of knowledge. These elements are: first, a great imaginative faculty, and second: a due regulation of that faculty in pursuance of rigid demonstration. An aimless experimentation can lead to no results, while an unrestrained imagination will lead to the wildest speculation, which is subversive of intellectual sanity. A true inquirer has, therefore, to guard against being self-deceived; he has, at every step, to compare his own thought with the external fact; he has remorselessly to abandon all in which these are not agreed. Thus what he slowly gathers is certain, forming a sure foundation of what is to come. Even in this path of self-restraint and verification, he is making for a region of surpassing wonder. When the visible light ends he still follows the invisible. Where the note of the audible reaches the unheard, even then he gathers the tremulous message.

How have these wonderful feats been rendered possible? First, by the recognition of man's own limitations and then, undaunted by these, in setting about the creation of artificial organs, which would require great genius for invention and extraordinary skill in construction. Indian inquirers had even at an early stage clearly understood our physical limitations. They recognised that there are *infra*-sensible phenomena, which exist but cannot be detected on account of the imperfection of our senses. For want of finer instruments—which are in reality artificial means for extending the range of our perception—the progress of knowledge was arrested. The cause of our scientific ill success has been just this want of a true recognition of the experimental side. This may have been due to decline of national life, however brought about, or to the general distraction consequent on the unsettled condition of the country. No great experimental work can be carried out unless the mind of the inquirer remains undisturbed, unless he be connected with an institution having great and inspiring traditions where constructive skill of great mechanicians has been handed down from generation to generation. Whatever the reason might be, the mind gradually drifted from the irksome curb of slow experimental verification to the fascination of unrestrained speculation. What could be more enchanting than that delightful story in the Arabian

Nights when the prince presses a pin in the neck of a mechanical horse and the machine flies through space! To confuse romance with reality is but one step. It is by the contact of the hand with real things, that the brain receives a constant stream of stimulating message; and the answering impulse of the brain gives the hand its cunning. Without action, the mind must lose its vigour and will succumb at last. It will begin to think that great achievements in science may perhaps be won by some lucky chance or by certain feats of jugglery. I cannot think anything so deadening to progress as this attitude of mental degeneracy.

LIFE OF AN INVESTIGATOR.

It is no easy life that lies before a scientific investigator. He has to steel his body and nerve to the utmost. There is to be for him no life of ease. It is to be one of unending struggle. Even after all this there is no assurance whatever of success to reward him for his ceaseless toil. He has to cast his life as an offering, [illegible] gain or loss, success or failure, as one. This will perhaps be better realised when I recount the real history of the conquest of air. I had the unusual opportunity of coming in close contact with the work of the man to whom this great achievement is ultimately due. Many lives had previously been sacrificed in various ineffective attempts till the investigation on the supporting power of moving surfaces was scientifically taken up by Langley in America. After many years of patient experimentation new data were obtained which were contrary to all previously accepted theories of aerodynamics. Then the question of light motors presented insuperable difficulties. After these had been overcome, Langley took up the question of flying machines and a small model of the automatic flying machine ascended the air on the 6th of May 1896, for the first time and after describing a series of special curves in the air safely descended on the Potomac river, having accomplished the length of flight of over 3,000 ft. I had this recounted to me by his friend, Graham Bell, the inventor of the telephone who watched this flight. Great interest was aroused, and the American nation keenly watched for the occasion when a larger machine was to make its flight before the public. In this public demonstration a small screw was left loose by the carelessness of a workman, with the result that the machine instead of rising was precipitated into the river. A chorus of derision arose which was magnified by the Press, and Langley died of a broken heart.

This has often been the fate of great inventors and discoverers. But the lure that draws heroic souls is not the success which can easily be achieved but defeat and tribulation in the pursuit of the unattainable. I have seen at the Smithsonian Institution this machine failed at the first experiment. But after Langley's death the experiment was repeated, and the aeroplane rose into the air like a bird that has been set free after a long period of imprisonment.

THE MENTAL FACTOR.

I spoke in some detail of the source of the weakness that had so long arrested our scientific advance. This was our neglect of the experimental factor. I shall show later how this defect can be remedied if we once realise and face it. I shall now take up the other factor, the mental, in which fortunately we do possess certain advantages. It is to be remembered that every experiment has to be carried out first in the inner region of the mind. To keep the mental vision clear great struggles have to be undergone, for the clearness of the inner vision is lost too easily. The greatest wealth of external appliances is of no avail, where there is not a concentrated pursuit of a great object. Those whose minds rush hither and thither, those who hunger for public applause or personal gain instead of truth, by them the quest is never won. In pursuit of knowledge an Indian inquirer has the burning imagination which could extort truth out of a mass of disconnected facts, a habit of meditation without allowing the mind to dissipate itself. If he caught with his scientific imagination a glimpse of a wonder-working ray as yet unknown to man, and believed that experiment would reveal its properties and potentialities, he would go on working ceaselessly through a long life and dying hand on his task to his disciples.

POWER OF DETACHMENT.

And what about the fruit of knowledge that has been acquired and its applications. It is well-known that a moving machinery in increasing its unrestrained pace is rushing towards destruction, unless it has a self-checking governor to restrain it before the danger limit is reached. In the West there has been no check or limit to the competition for personal gain and lust for power in exploiting the application of knowledge not so much for saving as for causing destruction. And on account of the absence of this restraining force, Western civilisation is trembling to-day in an unstable poise on the brink of ruin.

Let us now look at the innate restraining power that governs Indian life and culture. We may call it the force of detachment or for want of a better phrase, the impulse of spirituality. Let us see how this common heritage reacts on the Indian mind. As an extreme case let us see how one of the greatest of warrior kings became suddenly transformed under its dominating influence even at the moment of his greatest victory. In the ninth year of his reign his arms were successful and the extensive territories of Kalinga were incorporated with his Empire. This is what the Emperor Asoka writes on imperishable stone as the record of his triumph:

"His Majesty feels remorse on account of the conquest of the Kalingas, because during the subjugation of a country, slaughter, death and taking away captive of people necessarily occur. And for this His Majesty feels profound sorrow. Although, a man should do him injury, he holds that it must be patiently borne. His Majesty desires for all security, peace of mind and joyousness."

And the chiefest conquest is through righteousness. So much about the man of the sword. As regards the other man who truly dedicates his life or quest of knowledge in our country, any longing for personal gain or misuse of his knowledge would be worse than sacrilege. Poised as he is between the infinity of the past and the infinity of the future, between universes of worlds and universes of atoms —can anything be worth his while for so sorry a prize? Can his mind be satisfied with anything less sublime than to be merged in the rhythmic sweep of the world-spirit itself.

SYNTHESIS OF SCIENCES

The excessive specialisation in the West has led to the danger of our losing sight of the fundamental truth that there are not sciences but a single science that includes all. India is, perhaps through her habit of mind, better fitted to realise a wider synthesis. One of the greatest contributions in the realm of science would undoubtedly be the establishment of a great generalisation, not merely speculative, but based on actual demonstration of an underlying unity amidst bewildering diversity.

Shall this great glory be for India to win? In my investigations on the action of forces on matter, I was amazed to find boundary lines vanishing and to discover points of contact emerging between the Living and the non-Living. My first work in the region of invisible lights made me fully realise how in the midst of a luminous ocean we stood almost blind. But out of the very imperfection of his senses, man has dared in science to build for himself a raft of thought by which to make daring adventures into the great seas of the unknown.

Life Unvoiced

Just as in following light from visible to the invisible our range of investigation transcends our physical sight, so also the problem of the great mystery of Life and Death is brought a little nearer solution, when, in the realm of the living, we pass from the Voiced to the Unvoiced. Is there any possible relation between our own life and that of the plant world? The question is not one of dreamy speculation but of actual demonstration by some method that is unimpeachable. This means that we should abandon all our pre-conceptions, most of which are afterwards found to be absolutely groundless and contrary to facts. The final appeal must be made to the plant itself, and no evidence should be accepted unless it bears the plant's own signature. This means first the discovery of some compulsive force which would make the plant give some answering signal; then instrumental means have to be supplied for the automatic conversion of these signals into an intelligent script; and last of all we have ourselves to learn the nature of the hieroglyphic.

The Inner History of Plant Life

It was to be the discovery of the Inner History of the plant hidden under a placid exterior, the detection of the subtle impress left on by storm and sunshine, by the warmth of summer and frost of winter, by a passing breeze or a drifting cloud. It can easily be imagined how extraordinarily delicate the instruments must be which would detect all these and reveal the secrets of the unvoiced and hidden life. It has to measure the twitching throb under a shock, the time it takes the plant to perceive it, and measure the rate of impulse with which the message is being sent along the conducting path of the plant. It has to measure its living pulsation and the stupor that comes under the action of narcotics and signal the exact moment of death under the action of poisons.

I said that the slur against Indian competence in science has chiefly lain in regard to lack of the experimental skill and the power of invention and construction of apparatus of extreme delicacy. To this the sufficient answer is, that the instruments just described have all been devised in India and constructed by Indian mechanicians. Their great perfection and extreme delicacy may be gauged from the fact that, though these instruments have been widely exhibited in all the scientific centres of the West and though America boasts the possession of the greatest mechanicians of the world, yet even in America they found it impossible to repeat these instruments. And requests have, in consequence, been made by the different Universities in Europe and America for the supply of duplicates of instruments from my Laboratory these being regarded of essential importance for furthering the new investigations relating to life.

It will thus be seen that, when we put our whole strength into the accomplishment of any object, all difficulties vanish and the impossible becomes possible. But this cannot be the outcome of easy complacency. For twelve years a single man had to bear the brunt of the fight against the whole scientific world and after years of drudgery and many failures success came to me at last.

You may ask whether dreamy speculations have been of any help to me. Twenty years ago I had to write a magazine article on the life of plants. It was written in one hour under the free play of an unrestrained imagination. It told of wonderful things, and it is not at all surprising that some of them did come out true; but the rest of the speculation was quite wrong. It is not the likelihood of something coming out right that is of the least importance in science. What really counts is the absolute certainty of demonstrated fact which is true for all time; and on this sure foundation alone can great superstructures be raised. How necessary it is to observe extreme caution in being misled by speculation will be obvious when we realise that we may be led astray by appearances which we accept as well-ascertained facts. All of us, for instance, have regarded 'Mimosa' as delicately sensitive, shrinking from touch, while most of the ordinary plants were supposed to be devoid of all sensibility. My investigations show that the so-called sensitive plants are really paralysed, this motor paralysis being confined to one side; while many of the so-called insensitive plants are far more sensitive than the much-vaunted Mimosa. Again who has not been struck by the closing of the leaflets of certain plants at the onset of darkness, this being unhesitatingly regarded as the sleep of plants? In reality, closure of leaflets has nothing whatever to do with true sleep; my investigations show that plants, generally speaking, do not go to sleep in the evening but keep wide awake nearly all night long and fall asleep only about six in the morning! This will show how necessary it is for the discovery of truth to maintain a spirit of absolute detachment and perfect freedom of mind from all preconceived bias. The hardest struggle is to protect oneself from being self-deceived, and one has to guard against it and keep vigilant all the time.

THE WIDE VISTA

It was after repeating every one of the innumerable tests by which animal life is usually differentiated that I was able to prove that the phenomenon of life with all its multiplex variations are identical in plant and in animal. In other words, all life is One. This identity has been proved to be so real that after discovering some new reactions in plants, I have been able to predict its occurrence, hitherto unsuspected, in the animal, and my predictions have come out invariably true. The unexpected revelations in the life of plants have opened out vast fields of inquiry in physiology, in medicine, and even in psychology. Many problems long regarded as insoluble have been brought within the region of experimental investigation. In physiology the new inquiry is concerned in the determination of the characteristics of life and death, and in unravelling the mystery of automatism. In medicine it deals with the fundamental reaction of drugs on protoplasm itself, by which its practice is raised from empiricism to science. It tries to solve the anomaly of an identical drug inducing two opposite effects on different individuals. In [illegible] a new chapter has been opened out by the discovery of nervous impulse in plants. Certain new phenomenon discovered in plant-nerve shows that the intensity of the nervous impulse which colours our sensation, as pleasure or pain, is not solely determined by the intensity of the external blow, but that the character of the sensation is capable of modification according to the predisposition which can be imparted to the vehicle that carries the sense-bearing message.

These are but a few of the many-sided inquiries which have had their birth in India, and which cannot but affect many branches of science. Shall these remain the offering of an individual worker to come to an end with him, or shall there rise a school of science to hold the need of recognition which has been so hardly won and maintained a continuous and living tradition of India's gift to the world in the realm of science?

HOPE FOR THE FUTURE.

In any case if India has to make any contribution to the world, it should be as great as the hope we cherish for her. Let us not talk of the glories of the past till we have secured for her her true place among the intellectual nations of the world. Let us find out how she has fallen from her high estate, and ruthlessly put an end to all that self-satisfied, little-minded vanity which has been the cause of our fatal weakness. What is it that stands in her way? Is her mind paralysed by weak superstitious fears? Not so; for her great thinkers, the Rishis, always stood for freedom of intellect, and while Galileo was imprisoned and Bruno burnt for his opinions, they boldly declared that even the Vedas are to be rejected if they do not conform with truth. They urged in favour of persistent efforts for the discovery of physical causes yet unknown, since to them nothing was extra-physical but merely mysterious, because of the hitherto unascertained cause. Were they afraid that the march of knowledge was a danger to true faith? Not so; for to them knowledge and religion are one. Do they now lack devotion to a life consecrated to knowledge? Not so; for they have still the *sanyasin* spirit which utterly controls the body and can meditate or inquire endlessly while life remains, never for a moment losing sight of the object, never for a moment let it be obscured by any terrestrial temptation.

These are the hopes that animate us. For there is something in the Hindu culture which is possessed of extraordinary talents and strength, by which is resisted the ravages of time and the destructive changes which have swept over the earth. And indeed a capacity to endure through infinite transformations must be innate, in that mighty civilisation which has seen the intellectual culture of the Nile, the Valley of Assyria, and of Babylon, wax and wane and disappear, and which to-day gazes on the future with the same invincible faith with which it met the past.

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ADDRESS TO STUDENTS.

[*Sir Jagadis Chandra Bose delivered the following Address, on the 25th February 1917, to the students of the Presidency College, Calcutta, on receiving their congratulations on the occasion of his knighthood.*]

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. For the trust that you imposed on 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 that was easy but 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 now occupying positions 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 has brought gleams of joy in suffering lives.

The Law Universal.

Through science I was able to teach you how the seeming veils the real; how though the garish lights dazzle and blind us, there are lights invisible, which glow persistently after the brief flare burns out. One came to realise how all matter was one, how unified all life was. In the various expressions of life even in the realm of thought the same Universal law prevails. There was no such thing as brute matter, but that spirit suffused matter in which it was enshrined. One also realised dimly a mysterious Cyclic Law of Change, seen not merely in inorganic matter but also in organised life and its highest manifestations. One saw how inertness passes into the climax of activity and how that climax is perilously near its antithetic decline. This basic change puzzles us by its seeming caprice not merely in our physical instruments but also in the cycle of individual life and death and in the great cycle of the life and death of nations. We fail to see things in their totality and we erect barriers that keep kindreds apart. Even science which attempts to rise above common limitations, has not escaped the doom which limited vision imposes. We have caste in science as in religion and in politics, which divides one into conflicting many. The law of Cyclic change follows us relentlessly even in the realm of thought. When we have raised ourselves to the highest pinnacle, through 'some oversight' we fall over the precipice. Men have offered their lives for the establishment of truth. A climax is reached after which the custodians of knowledge themselves bar further advance. Men who have fought for liberty impose on themselves and on others the bond of slavery. Through centuries have men striven to erect a mighty edifice in which Humanity might be enshrined; through want of vigilance the structure crumbled into dust. Many cycles must yet be run and defeats must yet be borne before man will establish a destiny which is above change.

And through science I was able to teach you to seek for truth and help to discover it yourself. This attitude of detachment may possess some advantage in the proper understanding of your duties. You will have, besides, the heritage of great ideals that have been handed down to you. The question which you have to decide is duty to yourself, to the king and to your country. I shall speak to you of the ideals which we cherish about these duties.

Duty to Self.

As regards duty to self, can there be anything so inclusive as being true to your manhood? Stand upright and do not be either cringing or vulgarly self-assertive. Be righteous. Let your words and deeds correspond. Lead no double life. Proclaim what you think right.

Ideal of Kingship.

The Indian ideal of kingship will be clear to you if I recite the invocation with which we crowned our kings from the Vedic Times:

"Be with us. We have chosen thee
Let all the people wish for thee
Stand steadfast and immovable
Be like a mountain unremoved
And hold thy kingship in thy grasp."

We have chosen thee, our prayers have consecrated thee, for all the wishes of the people went with thee. Thou art to stand as mountain unremoved, for thy throne is planted secure on the hearts of thy people. Stand steadfast then, for we have endowed thee with power irresistible. Fall therefore not away; but let thy sceptre be held firmly in thy grasp.

Which is more potent, Matter or Spirit? Is the power with which the people endow their king identical with the power of wealth with which we enrich him by paying him his Royal dues? We make him irresistible not by wealth but by the strength of our lives, the strength of our mind, may, we have to pay him more according to our ancient Law givers, as much as the eighth part of our deeds and virtues, and the merit we have ourselves acquired. We can only make him irresistible by the strength of our lives, the strength of our minds, and the strength that comes out of righteousness.

Duty to Our Country.

And lastly, what are our duties to our country? These are essentially to win honour for it and also win for it security and peace. As regards winning honour for our country, it is true that while India has offered from the earliest times welcome and hospitality to all peoples and nationalities her children have been subjected to intolerable humiliations in other countries even under the flag of our king.

There can be no question of the fundamental duty of every Indian to stand up and uphold the honour of his country and strove for the removal of wrong.

The general task of redressing wrong is not a problem of India alone, but one in which the righteous men are interested the world over. For wrong cries for redress everywhere, in the clashing interests of the rich and poor, between capital and labour, between those who hold the power and those from whom it has been withheld,—in a word, in the struggle of the Disinherited.

When any man is rendered unable to uphold his manhood and self-respect and woman are deprived of the chivalrous protection and consideration of men and subjected to degradation, the general level of manhood or womanhood in the world is lowered. It then becomes an outrage to humanity and a challenge to all men to safeguard the sacredness of our common human nature.

What is the machinery which sets agoing a world movement for the redress of wrong ? For this I need not cite instances from the history of other countries but take one which is known to you and in which the living actors are still among us. In the midst of the degradation of his countrymen in South

Africa, there stood up a man himself nurtured in luxury, to take up the burden of the disinherited. His wife too stood by him, a lady of gentle birth. We all know who that man is—he is Gandhi,—and what humiliations and suffering he went through! Do you think he suffered in vain and that his voice remained unheard? It was not so, for, in the great vortex of passion for justice, there were caught others—men like Polak and Andrews. Are they your countrymen? Not in the narrow sense of the word, but truly in a larger sense, that these who choose to bear and suffer belong to one clan, the clan from which Kshatriya Chivalry is recruited. The removal of suffering and of the cause of suffering is the Dharma of the strong Kshatriya. The earth is the wide and universal theatre of man's woeful pageant. The question is who is to suffer more than his share. Is the burden to fall on the weak or the strong? Is it to be under hopeless compulsion or of voluntary acceptance?

DEFENCE OF HOMELAND.

In your services for your country there is none higher at the present moment than to ensure for her security and peace. We have so long enjoyed the security of peace without being called upon to maintain it. But this is no longer so.

At no time within the recent history of India has there been so quick a readjustment and appreciation as regards proper understanding of the aspiration of the Indian people. This has been due to what

India has been able to offer not merely in the regions of thought but also in the fields of battle.

MASS-RESPONSE.

And remember that when the world is in conflagration, this corner which has hitherto escaped it, will not evade the peril which threatens it. The march of disaster will then be terribly rapid. You have soon to prepare yourself against any hostile sides. You can only withstand it if the whole people realise the imminent danger. You can by your thought and by your action awaken and influence the multitude. Do not have any misgivings about the want of long previous preparations. Have you not already seen how mind triumphs over matter and have not some of you with only a few months' preparation stood fearless at your post in Mesopotamia and won recognition by your calm collectedness and true heroism? They may say that you are but a small handful, what of the vast illiterate millions? Illiterate in what sense? Have not the ballads of these illiterates, rendered into English by our Poet, touched profoundly the hearts of the very elect of the West? Have not the stories of their common life appealed to the common kinship of humanity? If you still have some doubts about the power of the multitude to respond instantly to the call of duty, I shall relate an incident which came within my own personal experience. I had gone on a scientific expedition to the borders of the Himalayan Terrai of Kumaun; a narrow ravine was between me and the plateau on the other side. Terror prevailed among the villagers on the other side of the ravine; for a tigress had come down from the forest. And numerous had been the toll in human lives exacted. Petitions had been sent up to the Government and questions had been asked in Parliament. A reward of Rs. 500 had been offered. Various captains in the army with battery of guns came many a time, but the reward remained unclaimed. The murderess of the forest would come out even in broad day-light and leisurely take her victims from away their companions. Nothing could circumvent her demoniac cunning. When all hopes had nearly vanished, the villagers went to Kaloo Singh, who possessed an old matchlock. At the special sanction of the Magistrate he was allowed to buy a quantity of gunpowder; the bullets he himself made by melting bits of lead. With his primitive weapon with the entreaties of his villagers ringing in his ears Kaloo Singh started on his perilous journey. At midday I was startled by the groanings of some animals in pain. The tigress had sprung among a herd of buffalo and with successive strokes of its mighty paws had killed two buffaloes and left them in the field. Kaloo Singh waited there for the return of the tigress to the kill. There was not a tree near by; only there was a low bush behind which he lay crouched. After hours of waiting as the sun was going down he was taken aback by the sudden apparition of the tigress which stood within six feet of him. His limbs had become half paralysed from cold and his crouching position. Trying to raise his gun he could take no aim as his arm was shaking with involuntary fear. Kaloo Singh explained to me afterwards how he succeeded in shaking off his mortal terror. "I quietly said to myself. Kaloo Singh, who sent you here? Did not the villagers put their trust on you! I could then no longer lie in hiding, and I stood up and something strange and invigorating crept up strength into my body. All the trembling went and I became as hard as steel. The tigress had seen me and with eyes blazing crouched for the spring lashing its tail. Only six feet lay between. She sprang and my gun also went off at the same time and she missed her aim and fell dead close to me." That was how a common villager went off to meet death at the call of something for which he could give no name, and the mother and wife of Kaloo Singh had also bidden him go. There are millions of Kaloo Singhs with mother and sisters and wife to send them forth. And you too have many loved ones who would themselves bid you arm for the defence of your homes.

DIFFERENCE OF TEMPERAMENT.

The issue is clear, and immediate action is imperative. But action is delayed by misunderstanding arising out of temperamental differences between the Governing Class and the People. Curiously enough the respective responsive characteristics of the Anglo-Saxon and the Indians are paralleled by the two types of responses seen in all living matter. In the one type the response is slow but proportionate to the stimulus that excites it. The response grows with the strength of external force. In the other it is quite different,—here it is on all-or-none-principle. It either responds to the utmost or nothing at all. This is also illustrated in the different racial characteristics. The Anglo-Saxon has won his rights by [illegible] . step by step. The insignificant little has, by accumulation, become large, and what has been gained, has been gained for all time. But in the Indian the ideal and the emotional are the only effective stimulus. The ideal of his King is Rama, who renounced his kingdom and even his beloved for an idea. One day a king and another day a bare-footed wanderer in the forest! Who cares? All or nothing!

The concessions made by a modern form of Government [illegible] by necessary limitations may appear almost as grudging gifts. The Indian wants something which comes with unhesitating frankness and warmth and strikes his ideality and [illegible]. But ancient and modern kingship are sometimes at one in direct and spontaneous pronouncement of the royal sympathy. Such was the Proclamation of Queen Victoria which stirred to its depths the popular heart.

"In the Prosperity of Our subjects will be our strength, in their contentment Our security, in their Gratitude Our best Reward."

That there are increasingly frequent reflexes in our Government to popular needs and wishes is happily illustrated at a most opportune moment from the statements in the recent *Gazette of India* and cables received from London. In the former we find that the Viceroy and his council had recommended the abolition of the system of indentured labour. In the telegram from London Mr. Chamberlain states that the Viceroy has informed him that Indians will be eligible for commissions in the new Defence of India Army.

MARCH OF WORLD TRAGEDY.

In the meantime the Embodiment of World Tragedy is marching with giant strides. Brief will be his hesitation whether he will choose to step first to the East or to the West. Already across the Atlantic, they are preparing for the dreaded visitation. In the farthest East they have long been prepared. We alone are not ready. Pity for our helplessness will not stay the impending disaster, rather provoke it. When that comes, as assuredly it will, unless we are prepared to resist, havoc will be let loose and horrors prepetrated before which the imagination quails back in dismay.

I have tried to lay before you, as dispassionately as I could, the issues involved. But some of you may cry out and say, we cannot live in cold scientific and philosophic abstractions. Emotion is more to us than pure reasoning. We cannot stay in this indecision which is paralysing our wills and crushing the soul out of us. The world is offering their best and behold them marching to be immolated so that by the supreme offering of death they might win safety and and honor for their motherland. There is no time for wavering. We too will throw in our lot with those who are fighting. They say that, by our lives, we shall win for our birthland an honoured place in their federation. We shall trust them. We shall stand by their side and fight for our home and homeland. And let Providence shape the Issue.

EVIDENCE BEFORE THE CALCUTTA UNIVERSITY COMMISSION.

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Sir J. C. Bose, as an educationist and professor of repute, was among those selected to give evidence before the Sadler Commission of 1917-19. His evidence classified under different heads is reproduced from the Report.

DEFECTS OF THE EXISTING SYSTEM OF UNIVERSITY EDUCATION.

The existing system does not give young Indians full opportunity of obtaining the highest training. The defects may be remedied by placing students under personal guidance and training of teachers of high personal character and recognised international standing. The teacher can exert no influence on his pupils unless, by his own example, he is able to inspire in them a devotion for high ideals and love for knowledge.

Under the present system no encouragement for investigation on new advances of knowledge is possible because :—

(*a*) Such branches of knowledge are not now represented in the curricula.

(*b*) There is no examining body competent to appraise the value of research.

These defects may be remedied by recognising publication by the highest scientific societies, such as the Royal Society, entitling students for a degree of the University, or by recognising the recommendations of a teacher of acknowledged authority on the work carried out by his pupils. The publication of the results, together with the name of the teacher on whose recommendation the degree is conferred, will serve as a check on possible abuse.

CALCUTTA, AS A SEAT OF LEARNING.

Such resources exist in Calcutta, among which may be mentioned the Research Institute which I have founded. This institute is intended not only to advance science, but also to foster intellectual curiosity among students. Progress of knowledge is impossible without a fresh outlook and the awakening of a keen love of nature. The present system of examination in vogue at the Calcutta University deadens this faculty. The services of an institute like the one mentioned may be of considerable importance to the University in advancing learning provided the free and spontaneous growth of the institute is not marred by external interference. With such safeguards the co-operation of my institute will be at the disposal of the University. In connection with this I would urge the importance of giving colleges and institutions affiliated to the University full liberty for individual development. Some of the important colleges have done much in the past to advance higher education, each in a particular branch of knowledge. Each has thus established a tradition of the highest value. The University can, by the fullest recognition of the services rendered by each, secure their active co-operation for building up the great University of the future. Unfortunately, certain new regulations, hastily carried, in spite of strong opposition from leading educationists, are likely to deal a serious blow to the harmonious relations which should exist between the University and its affiliated institutions. This new departure places the University in the unfavourable light of a rival to its affiliated institutions. The unfairness of this rivalry is accentuated by the fact that professors from affiliated institutions have been induced to transfer their services to the University by offers of higher pay without consulting the college authorities and thus placing them at a serious disadvantage. The University, it need hardly be urged, should be raised above such a compromising position by the discontinuance and dis-avowal of this policy.

UNIVERSITY COURSES IN APPLIED SCIENCE AND TECHNOLOGY.

(i) I should strongly support such a course.

(ii) There is no reason why there should be segregation of higher technological training from other branches of higher education. Segregation in the present state of finance will make higher technological training an impossibility.

(iii) (*a*) A student in applied science should receive adequate training only in the particular branch of pure science of which he is learning the application.

CONDITIONS OF ADMISSION TO THE UNIVERSITY.

Perhaps improvement is possible by introducing a wider variety of more interesting subjects for matriculation, such as are included in the Cambridge local examination. But this must be undertaken by the University itself, without making it in any way departmental. The record of good class work done by students, in the case of illness during examination time, should entitle a candidate to favourable consideration.

UNIVERSITY EXAMINATIONS AND PUBLIC SERVICE.

Considering the high ideal placed by the Commission before themselves, and expecting its realisation, one would be justified that the products of the University would be best fitted for the public services. I cannot think of a body better qualified to train and test the qualifications of aspirants to office than the Calcutta University of the immediate future. If further discrimination be needed this may be secured by open competition among the graduates.

CONDITIONS OF STUDENT LIFE IN BENGAL.

As regards the moral level of the Indian students as compared with those of other countries, I am in a position to judge from my experiences of English and American university life, and my long connection with the student community in Bengal. I think the Bengali students have suffered from misrepresentation, perhaps unintentional I am in a position to state that they will in no way suffer by comparison with their brethren of the West. I find that they are highly susceptible to good influences and promptly responsive to any appeal to their idealism. They labour, however, under the di[illegible] that they have not sufficient opportunity of coming in contact with, and under the influence of, those who are fitted to mould the lives of our youth. The well-known services which they have rendered on such occasions as famine and flood, show the great potentiality which very often becomes atrophied for lack of scope.

While there is thus not enough of elevating influence brought to bear on their plastic minds, influences of a different character, calculated to impair their idealism are more in evidence. I may refer, for example, to the importation into the temple of knowledge of methods, which are not considered honourable even in the arena of politics, where whatever is not clearly illegal is considered sufficiently moral.

It is easy to see that, under such circumstances, appeals to higher motives and idealism of students have produced the growing cynicism which is observed among certain sections of the student community. Those of us who are anxious to promote a reverential attitude and growing belief in goodness among students ought to consider what conditions favour such a consummation.

MESSAGE TO THE SCHOLARS OF THE BOSE INSTITUTE.

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On his return from Europe in January 1921, Sir J. C. Bose delivered an address to the Scholars of his Institute in Calcutta. He said that the world was going through a period of transformation and re-adjustment and continued :—

"Nature shows no mercy to the effete and the decadent. The parasite, who is allowed to exist by the labour of others, will surely disappear. How is India to meet this crisis? It is only by securing the strength of body, of mind and soul. You cannot afford to weaken the one without weakening the others. The law of life and all its activities is one. It is not cotton-wool protection, but the shock of adversity that strengthens every fibre of true manhood. Thus will you learn to stand upright and despise to be either cringing or vulgarly self-assertive. You will then lead no double life, and your word and deed will correspond. Rather will your deed exceed your word: for, the sum total of energy is constant, and when all the strength is wasted in word, there will be nothing left to build your character. Even a speck of protoplasm has a faculty of choice. It accepts or rejects the multifarious stimuli of its environment. Have you made your choice of what life is to mean to you? Your destiny is to be determined not by outside, but by you and you alone. Are you to be satisfied by mere parrot's training—process akin to passive osmosis? The result of it is that even the greatest message that came to us from the past is merely repeated by rote, without its being regarded as an injunction which is to transform our life. There is thus a tendency to lay down law for others, whereas the only law which it is given us to enforce is on ourselves. Why are we so inefficient? Because we have not the daring to leave the beaten track and go out in great adventures. The more difficult is the quest the greater is the challenge. And I firmly believe that when one has gained the vision of a purpose to which one can and must dedicate himself wholly, the closed doors shall be opened and the seemingly impossible become attainable. I hear it constantly said that had we been given the opportunity we might have accomplished great things. Opportunities are never given; but man has the divine power to create; he can, if he wills it, create the necessary condition and determine his destiny.

II. General

LITERATURE AND SCIENCE.

The following is the substance of the Address delivered in Bengali by Prof. J. C. Bose, on the 14th April 1911, as the President of the Bengal Literary Conference, which met in the Easter of 1911 at Mymensing.

IN this Literary Congress it would appear that you have interpreted Letters in no exclusive sense. We are not met to discuss the place that literature is to hold in the gospel of beauty. Rather are we set upon conceiving of her in larger ways. To us to-day literature is no mere ornament, no mere amusement. Instead of this, we desire to bring beneath her shadow all the highest efforts of our minds. In this great communion of learning, this is not the first time that a scientific man has officiated as priest. The chair which I now occupy has already been held by one whom I love and honour as friend and colleague and glory in our countryman, Praphulla Chandra Ray. In honouring him, your Society has not only done homage to merit, but has also placed before our people a lofty and inclusive ideal of literature.

You are aware that, in the West, the prevailing tendency at the moment is, after a period of synthesis, to return upon the excessive sub-division of learning. The result of this specialisation is rather to accentuate the distinctiveness of the various sciences, so that, for a while, the great unity of all tends perhaps to be obscured. Such a caste-system in scholarship, undoubtedly helps at first, in the gathering and classification of new material. But if followed too exclusively, it ends by limiting the comprehensiveness of truth. The search is endless. Realisation evades us.

The Eastern aim has been rather the opposite, namely that, in the multiplicity of phenomena, we should never miss their underlying unity. After generations of this quest, the idea of unity comes to us almost spontaneously, and we apprehend no insuperable obstacle in grasping it.

I feel that, here in this Literary Congress, this characteristic idea of unity has worked unconsciously. We have never thought of narrowing the bounds of literature by a jealous definition of its limits. On the contrary, we have allowed its empire to extend. And you have felt that this could be adequately done only, if, in one place, you could gather together all that we are seeking, all that we are thinking, all that we are examining. And for this you have to-day invited those who sing along with those who meditate, and those who experiment. And this is why, though my own life has been given to the pursuit of science, I had yet no hesitation in accepting the honour of your invitation.

POETRY AND SCIENCE.

The poet, seeing by the heart, realises the inexpressible and strive to give it expression. His imagination soars, where the sight of others fails, and his news of realm unknown finds voice in ryhme and metre. The path of the scientific man may be different, yet there is some likeness between the two pursuits. Where visible light ends, he still follows the invisible. Where the note of the audible reaches the unheard, even there he gathers the tremulous message. That mystery which lies behind the expressed, is the object of his questioning also; and he, in his scientific way, attempts to render its abstruse discoveries into human speech.

This vast abode of nature is built in many wings, each with its own portal. The physicist, the chemist, and the biologist entering by different doors, each one his own department of knowledge, comes to think that this is his special domain, unconnected with that of any other. Hence has arisen our present rigid division of phenomena, into the worlds of the inorganic, vegetal, and sentinent. But that this attitude of mind is philosophical, may be denied. We must remember that all enquiries have, as their goal, the attainment of knowledge in its entirety. The partition walls between the cells in the great laboratory are only erected for a time to aid this search. Only at that point where all lines of inv[illegible] meet, can the whole truth be found.

Both poet and scientific worker have set out for the same goal, to find a unity in the bewildering diversity. The difference is that the poet thinks little of the path, whereas, the scientific man must not neglect. The imagination of the poet has to be unrestricted. The intuitions of emotion cannot be established by rigid proof. He has, therefore, to use the language of imagery, adding constantly the words 'as if.'

The road that the scientific man has to tread is, on the other hand, very rugged, and in his pursuit of demonstration he must pay a severe restraint on his imagination. His constant anxiety is lest he should be self-deceived. He has, therefore, at every step to compare his own thought with the external fact. He has remorselessly to abandon all in which these are not agreed. His reward is that he gets, however little is certain, forming a strong foundation for what is yet to come. Even by this path of self-restraint and verification, however, he is making for a region surpassing wonder. In the range of that invisible light, gross objects cease to be a barrier, and force and matter become less aesthetic. When the veil is suddenly lifted, upon the vision hitherto unsuspected, he may for a moment lose his accustomed self-restraint and, exclaim "not 'as if'—but the thing itself!"

Invisible Light.

In illustration of this sense of wonder which links together poetry and science, let me allude briefly to a few matters that belong to my own small corner in the great universe of [illegible] . that of light invisible and of life unvoiced. Can anything appeal more to the imagination than the fact that we can detect the peculiarities in the internal molecular structure of an opaque body by means of light that is itself invisible? Could anything have been more unexpected than to find that a sphere of China-clay focusses invisible light more perfectly than a sphere of glass focusses the visible; that in fact, the refractive power of this clay to electric radiation is at least as great as that of the most costly diamond to light? From amongst the innumerable octaves of light, there is only one octave, with power to excite the human eye. In reality, we stand, in the midst of a luminous ocean, almost blind! The little that we can see is nothing, compared to the vastness of that which we cannot. But it may be said that out of the very imperfection of his senses man has been able, in science, to build for himself a raft of thought by which to make daring adventure on the great seas of the unknown.

UNVOICED LIFE.

Again, just as, in following up light from visible to invisible, our range of investigation transcends our physical sight, so also does our power of sympathy become extended, when we pass from the voiced to the unvoiced, in the study of life: Is there then any possible relation between our own life and that of the plant-world? That there may be such a relation, some of the foremost of scientific men have denied. So distinguished a leader as the late Burdon-Sanderson declared that the majority of plants were not capable of giving any answer, by either mechanical or electrical excitement, to an outside shock. Pleffer, again, and his distinguished followers, have insisted that the plants have neither a nervous system, nor anything analogous to the nervous impulse of the animal. According to such a view, the two streams of life, in plant and animal, flow side by side, but under the guidance of different laws. The problems of vegetable life are, it must be said, extremely obscure, and for the penetrating of that darkness we have long had to wait for instruments of a superlative sensitiveness. This has been the principal reason for our long clinging to mere theory, instead of looking for the demonstration of facts. But to learn the truth we have to put aside theories, and rely only on direct experiment. We have to abandon all our preconceptions, and put our questions direct, insisting that the only evidence we can accept is that which bears the plant's own signature.

How are we to know what unseen changes take place within the plant? If it be excited or depressed by some special circumstance, how are we, on the outside, to be made aware of this? The only conceivable way would be, if that were possible, to detect and measure the actual response of the organism to a definite external blow. When an animal receives an external shock it may answer in various ways; if it has voice, by a cry; if it be dumb, by the movement of its limbs. The external shock is a stimulus; the answer of the organism is the response. If we can find out the relation between this stimulus and the response, we shall be able to determine the vitality of the plant at that moment. In an excitable condition, the feeblest stimulus will evoke an extraordinarily large response: in a depressed state, even a strong stimulus evokes only a feeble response; and lastly, when death has overcome life, there is an abrupt end of the power to answer at all.

We might therefore have detected the internal condition of the plant, if, by some inducement, we could have made it write down its own responses. If we could once succeed in this apparently impossible task we should still have to learn the new language and the new script. In a world of so many different scripts, it is certainly undesirable to introduce a new one! I fear the Uniform Script Association will cherish a grievance against us for this. It is fortunate, however, that the plant-script bears, after all, a certain resemblance to the D[illegible]—inasmuch as it is totally unintelligible to any but the very learned!

But there are two serious difficulties in our path; first, to make the plant itself consent to give its evidence; second, through plant and instrument combined, to induce it to give it in writing. It is comparatively easy to make a rebellious child obey: to extort answers from plants is indeed a problem! By many years of close contiguity, however, I have come to have some understanding of their ways. I take this opportunity to make public confession of various acts of cruelty which I have, from time to time, perpetrated on unoffending plants, in order to compel them to give me answers. For this purpose, I have devised various forms of torment,—pinches, simple and revolving, pricks with needles, and burns with acids. But let this pass. I now understand that replies so forced are unnatural, and of no value. Evidence so obtained is not to be trusted. Vivisection, for instance, cannot furnish unimpugnable results, for excessive shock tends of itself to make the response of a tissue abnormal. The experimental organism must therefore be subjected only to moderate stimulation. Again, one has to choose for one's experiment a favourable movement. Amongst plants, as with ourselves, there is, very early in the morning, especially after a cold night, a certain sluggishness. The answers, then, are a little indistinct. In the excessive heat of mid-day, again, though the first few answers are very distinct, yet fatigue soon sets in. On a stormy day, the plant remains obstinately silent. Barring all these sources of aberration, however, if we choose our time wisely, we may succeed in obtaining clear answers, which persist without interruption.

It is our object, then, to gather the whole history of the plant, during every moment between its birth and its death. Through how many cycles of experience it has to pass! The effects on it of recurring light and darkness; the pull of the earth, and the blow of the storm; how complex is the concatenation of circumstances, how various are the shocks, and how multiplex are the replies which we have to analyse; In this vegetal life which appears so placid and so stationary, how manifold are the subtle internal reactions! Then how are we to make this invisible visible?

THE DIARY OF THE PLANT.

The little seedling we know to be growing, but the rate of its growth is far below anything we can directly perceive. How are we to magnify this so as to make it instantly measurable? What are the variations in this infinitesimal growth under external shock? What changes are induced by the action of drugs or poisons? Will the action of poison change with the dose? Is it possible to counteract the effect of one by another?

Supposing that the plant does not give answers to external shock, what time elapses between the shock and the reply? Does this latent period undergo any variation with external conditions? Is it possible to make the plant itself write down this excessively minute time-interval?

Next, does the effect of the blow given outside reach the interior of the plant? If so, is there anything analogous to the nerve of the animal? If so, again, at what rate does the nervous impulse travel in the plant? By what favourable circumstances will this rate of transmission become enhanced, and by what will it be retarded or arrested? Is it possible to make the plant itself record this rate and its variations? Is there any resemblance between the nervous impulse in plants and animals? In the animal there are certain automatically pulsating tissues like the heart. Are there any such spontaneously beating tissues in a plant? What is the meaning of spontaneity? And lastly, when by the blow of death, life itself is finally extinguished, will it be possible to detect the critical moment? And does the plant then exert itself to make one over-whelming reply, after which response ceases altogether? Its autobiography can only be regarded as complete, if, with the help of efficient instruments, all these questions can be answered by it, so as to form the different chapters.

"If the plant could have been made thus to keep its own diary, then the whole of its history might have been recovered!" But words like these are born of day-dreams merely. Vague imaginings of this kind may furnish much gratification to an idle life. When, awaking from these pleasant dreams of science, we seek to actualise the conditions imposed by them, we find ourselves face to face with a dead wall. For the doorway of nature's court is barred with iron, and through it can penetrate no mere cry of childish petulance. It is only by the gathered force of many years of concentration, that the gate can be opened, and the seeker enter to explore the secrets that have baffled him so long.

DIFFICULTIES OF RESEARCH IN INDIA.

We often hear that, without a properly equipped laboratory, higher research in this country is an absolute impossibility. But while there is a good deal in this, it is not, by any means, the whole truth. If it were all, then, from these countries where millions have been spent on costly laboratories, we should have had daily accounts of new discoveries. Such news we do not hear. It is true that here we suffer from many difficulties, but how does it help us, to envy the good fortune of others? Rise from your depression! Cast off your weakness! Let us think, "In whatever condition we are placed, that is the true starting-point for us." India is our working place, and all our duties are to be accomplished here, and nowhere else. Only he who has lost his manhood need repine.

In carrying out research, there are other difficulties, besides the want of well-equipped laboratories. We often forget that the real laboratory is one's own mind. The room and the instruments only externalise that. Every experiment has first to be carried out in that inner region. To keep the mental vision clear, great struggles have to be undergone. For its clearness is lost, only too easily. The greatest wealth of external appliances is of no avail, where there is not a concentrated pursuit, utterly detached from personal gain. Those whose minds rush hither and thither, those who hunger for public applause instead of truth itself, by them the quest is not won. To those, on the other hand, who do long for knowledge itself, the want of favourable conditions does not seem the principal obstacle.

In the first place, we have to realise that knowledge for the sake of knowledge is our aim, and that the world's common standard of utility has no place in it. The enquirer must follow where he is led, holding the quiet faith that things which appear to-day to be of no use may be of the highest interest to-morrow. No height can be climbed, without the hewing of many an unremembered step! It is necessary, then, that the enquirer and his disciples should work on ceaselessly, undeterred by years of failure, and undistracted by the thunder of public applause. We may, one day, come to realise that India in the past has shared her knowledge with the world, and we may ask ourselves, is that destiny now ended for us? Are we of to-day to be debtors only? Perhaps when we have once felt this, a new Nalanda may arise.

THE PHYTOGRAPH.

I was speaking of the need of various delicate instruments—phytographs, as I shall call them—for the automatic record of the plant's responses. What was, ten years ago, a mere aspiration, has now, after so many years of effort, become actual fact. It is unnecessary to tell here of many a fruitless and despairing attempt. Nor shall I trouble you with any account of intricate mechanism. I need only say that with the aid of different types of apparatus, it is now possible for all the responsive activities of the plant to be written down. For instance, we can make an instantaneous record of the growth and its variations, moment by moment. Scripts can be obtained of its spontaneous movement. And a recording arm will demarcate the line of life from that of death. The extreme delicacy of one of these instruments will be understood, when it is said that it measures and records a time-interval so short as one-thousandth part of a second!

It has been supposed that instruments for research of this delicacy and precision, were only possible of construction in the best scientific manufactories of Europe. It will, therefore, be regarded as interesting and encouraging to know that every one of these has been executed entirely in India, by Indian workmen and mechanicians.

With perfect instruments at our disposal, we may proceed to describe a few amongst the many phenomena which now stand revealed. But before this, it is necessary to deal briefly with the superstition that has led to the division of plants into sensitive and insensitive. By the electrical mode of investigation, it can be shown that not only Mimosa and the like, but all plants of all kinds are sensitive, and give definite replies to impinging stimuli. Ordinary plants, it is true, are unable to give any conspicuous mechanical indication of excitement. But this is not because of any insensitiveness, but because of equal and antagonistic reactions which neutralise each other. It is possible, however, by employing appropriate means to show that even ordinary plants give mechanical replies to stimulus.

The Determination of the Latent Period.

When an animal is struck by a blow, it does not respond at once. A certain short interval elapses between the incidence of the blow, and the beginning of the reply. This lost time is known as the latent period. In the leg of a frog, the latent period, according to Helmholtz, is about one-hundredth of a second. This latent period, however, undergoes appropriate variation with changing external conditions. With feeble stimulus, it has a definite value, which, with an excessive blow, is much shortened. In the cold season, it is relatively long. Again, when we are tired, our perception-time, as we may call it, may be greatly prolonged. Every one of these observations is equally applicable to the perception-time of the plant. In Mimosa, in a vigorous condition, the latent period is six one-hundredths of a second, that is to say, only six times its value in an energetic frog! Another curious thing is that a stoutish tree will give its response in a slow and lordly fashion, whereas a thin one attains the acme of its excitement in an incredibly short time! Perhaps some of us can tell, from our own experience, whether similar differences obtain amongst human kind or not? The plant's latent period in our cold weather may be almost doubled. Ordinarily speaking it takes *Mimosa* about fifteen minutes to recover from a blow. If a second blow be given, before the full recovery of its equanimity, then the plant becomes fatigued, and its latent period is lengthened. When over-fatigued, it may temporarily lose its power of perception altogether, what this condition is like, my audience is only too likely to realise, at the end of my long address!

THE RELATION BETWEEN STIMULUS AND RESPONSE.

According to varying circumstances, the same blow will evoke responses of different amplitudes. Early in the morning, after the prolonged inactivity of a cold night, we find the plant inclined to be lethargic, and its first answers correspondingly small. But, as blow after blow is delivered, this lethargy passes off, and the replies become stronger and stronger. A good way to remove this lethargy quickly, is to give the plant a warm bath. In the heat of the midday, this state of things is reversed. That is to say, after giving vigorous replies, the plant becomes fatigued, and its responses grow smaller. This fatigue passes off, however, on allowing it a period of rest. On increasing the intensity of the impinging stimulus, the response also increases. But a limit is attained, beyond which response can no longer be enhanced. Again, just as the pain of a blow persists longer with ourselves, in winter than in summer, so the same holds good of the reaction of the plant also. For instance, in summer it takes *Mimosa* ten to fifteen minutes to recover from a blow, whereas in winter the same thing would take over half an hour. In all this, you will recognise the similarity between human response and that of the plant.

SPONTANEOUS PULSATION.

In certain tissues, a very curious phenomenon is observed. In man and other animals, there are tissues which beat, as we say, spontaneously. As long as life lasts, so long does the heart continue to pulsate. There is no effect without a cause. How then was it that these pulsations became spontaneous? To this query, no fully satisfactory answer has been forthcoming. We find, however, that similar spontaneous movements are also observable in plant tissues, and by their investigation the secret of automatism in the animal may perhaps be unravelled.

P[illegible], in order to know the heart of man, play with those of the frog and tortoise. "To know the heart," be it understood, is here meant in a purely physical, and not in a poetic sense. For this it is not always convenient to employ the whole of the frog. The heart is, therefore, cut out, and made the subject of experiments, as to what conditions accelerate, and what retard, the rate and amplitude of its beat. When thus isolated, the heart tends of itself to come to a standstill, but if, by means of fine tubing, it be then subjected to internal blood pressure, its beating will be resumed, and will continue uninterrupted for a long time. By the influence of warmth, the frequency of the pulsation may be increased, but its amplitude diminished. Exactly the reverse is the effect of cold. The natural rhythm and the amplitude of the pulse undergo appropriate changes, again, under the action of different drugs.

Under either, the heart may come to a standstill, but, on blowing this off, the beat is renewed. The action of chloroform is more dangerous, any excess in the dose inducing permanent arrest. Besides these, there are poisons also which arrest the heart beat, and a very noticeable fact, in this connection, is, that some stop in a contracted, and others in a relaxed condition. Knowing these opposed effects, it is sometimes possible to counteract the effect of one poison by administering another.

I have thus briefly stated some of the most important phenomena in connection with spontaneous movements in animal tissues. Is it possible that in plants also any parallel phenomena might be observed? In answer to this question, I may say that I have found numerous instances of automatic movements in plants.

RHYTHMIC PULSATIONS IN DESMODIUM.

The existence of such spontaneous movements can easily be demonstrated, by means of our Indian *Bon charal*, the telegraph plant, or Desmodium gyrans, whose small leaflets dance continually. The popular belief that they dance in response to the clapping of the hands is quite untrue. From readings of the scripts made by this plant, I am in a position to state that the automatic movements of both plants and animals are guided by laws which are identical.

Firstly, when, for convenience of experiment, we cut off the leaflet, its spontaneous movements, like those of the heart, come to a stop. But if we now subject the isolated leaflet, by means of a fine tube, to an added internal pressure of the plant's sap, its pulsations are renewed, and continue uninterrupted for a very long time. It is found again that the pulsation frequency is increased under the action of warmth, and lessened under cold, increased frequency being attended by diminution of amplitude and *vice versa*. Under either, there is temporary arrest, revival being possible when the vapour is blown off. More fatal is the effect of chloroform. The most extra-ordinary parallelism, however, lies in the fact that those poisons which arrest the beat of the heart in a particular way, arrest the plant-pulsation also in a corresponding manner. I have thus been able to revive a leaflet poisoned by the application of one, with a dose of a counteracting poison.

Let us now enquire into the causes of these automatic movements so called. In experimenting with certain types of plant-tissues, I find that an external stimulus may not always evoke an immediate reply. What happens, then, to the incident energy? It is not really lost, for these particular plant-tissues have the power of storage. In this way, energy derived in various ways from without—as light, warmth, food, and so on—is constantly being accumulated, when a certain point is reached, there is an overflow, and we call this overflow spontaneous movement. Thus what we call automatic is really an overflow of what has previously been stored up. When this accumulated energy is exhausted, then there is also an end of spontaneous movements. By abstracting its stored-up heat—through the application of cold water—we can bring to a stop the automatic pulsations of Desmodium. But, on allowing a first accession of heat from outside, these pulsations are gradually restored.

In the matter of these so-called spontaneous activities of the plant, I find that there are two distinct types. In one, the overflow is initiated with very little storage, but here the unusual display of activity soon comes to a stop. To maintain such specimens in the rhythmic condition, constant stimulation from outside is necessary. Plants of this type are extremely dependent on outside influences, and when such sources of stimulus are removed, they speedily come to an inglorious stop. *Kamranga* or *Averrhoa* is an example of this kind. In the second type of automatic plant-activity I find that long continued storage is required, before an overflow can begin. But, in this case, the spontaneous outburst is persistent and of long duration, even when the plant is deprived of any immediately exciting cause. These, therefore, are not so obviously dependent as the others on the sunshine of the world. Our telegraph plant, *Desmodium* or *Tencharal*, is an example of this.

It appears to me that we have here a suggestive parallel to certain phenomena with which this audience will surely prove more familiar than I, namely, the facts of literary inspiration. For the attainment of this exalted condition, also, is it not necessary to have previous storage, with a consequent bubbling overflow ? Certain indications incline me to suspect that, perhaps, in this also, we have an example of so called spontaneity, or automatic responsiveness. If this be so, aspirants to the condition might well be asked to decide in whose footsteps they will choose to tread—those of *Kamranga*, with its dependence on outside influences, and inevitably ephemeral activity, or those of *Bon charol*, with its characteristic of patient, long enduring, accumulation of forces, to find uninterrupted and sustained expression.

THE PLANT'S RESPONSE TO THE SHOCK OF DEATH.

A time comes when, after one answer to a supreme shock, there is a sudden end of the plant's power to give any response. This supreme shock is the shock of death. Even in this crisis, there is no immediate change in the placid appearance of the plant. Drooping and withering are events that occur long after death itself. How does the plant, then, give this last answer ? In man, at the critical moment, a spasm passes through the whole body, and similarly in the plant, I find that a great contractile spasm takes place. This is accompanied by an electrical spasm also. In the script of the Morograph, or Death Recorder, the line that, up to this point, was being drawn, becomes suddenly reversed, and then ends. This is the last answer of the plant.

These mute companions, silently growing beside our door, have now told us the tale of their life—tremulousness and their death spasm, in script that is as inarticulate as they. May it not be said that this, their story has a pathos of its own, beyond any that the poets have conceived?

THE HISTORY OF A FAILURE THAT WAS GREAT.

[At the invitation of the President and the Committee of the Faridpore Industrial Exhibition, Dr. Bose gave a lecture on the life of his father, Bhagaban Chunder Bose who founded the Exhibition at Faridpore, where he was the Sub-Divisional Officer over fifty years ago. The address was published in the "Modern Review" for February 1917. In the course of his address Dr. Bose said:—]

It is the obvious, the insistent, the blatant that often blinds us to the essential. And in solving the mystery that underlies life, the enlightenment will come not by the study of the complex man, but through the simpler plant. It is the unsuspected forces, hidden to the eyes of men,—the forces imprisoned in the soil and the stimuli of alternating flash of light and the gloomings of darkness,—these and many others will be found to maintain the ceaseless activity which we know as the fullness of throbbing life.

This is likewise true of the congeries of life which we call a society or a nation. The energy which moves this great mass in ceaseless effort to realise some common aspiration, often has its origin in the unknown solitudes of a village life. And thus the history of some efforts, now forgotten, which emanated from Faridpore, may be found not unconnected with others with which India is now meeting her problems to-day. How did these problems first dawn in the minds of some men who forecast themselves by half a century? How fared their hopes, how did their dreams become buried in oblivion? Where lies the secret of that potency which makes certain efforts apparently doomed to failure, rise renewed from beneath the smouldering ashes? Are these dead failures, so utterly unrelated to some great success that we may acclaim to-day? When we look deeper we shall find that this is not so, that as inevitable as is the sequence of cause and effect, so unrelenting must be the sequence of failure and success. We shall find that the failure must be the antecedent power to lie dormant for the long subsequent dynamic expression in what we call success. It is then and then only that we shall begin to question ourselves, which is the greater of the two, a noble failure or a vulgar success.

As a concrete example, I shall relate the history of a noble failure which had its setting in this little corner of the earth. And if some of the audience thought that the speaker has been blessed with life that has been unusually fruitful, they will soon realise that the power and strength that nerved me to meet the shocks of life were, in reality, derived at this very place, where I witnessed the struggle which over-powered a far greater life.

CONTACT WITH WESTERN CULTURE.

An impulse from the outside reacts on impressionable bodies in two different ways, depending on whether the recipient is inert or fully alive. The inert is fashioned after the pattern of the impression made on it, and this in infinite repetition of one mechanical stamp. But when an organism is fully alive, the answering reaction is often of an altogether different character to the impinging stimulus. The outside shocks stir up the organism to answer feebly or to the utmost in ways as multitudinous and varied as life itself. So 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. It is the release of some giant force which lay for long time dormant. My father was one of the earliest to receive the impetus characteristic of the modern epoch as derived from the West. And in his case it came to pass that the stimulus evoked the latent potentialities of his race for evolving modes of expression demanded by the period of transition in which he was placed. They found expression in great constructive work, in the restoration of quiet amidst disorder, in the earliest effort to spread education both among men and women, in questions of social welfare, in industrial efforts, in the establishment of people's banks and in the foundation of industrial and technical schools. And behind all these efforts lay a burning love for his country and its noble traditions.

MATTERS EDUCATIONAL.

In educational matters he had very definite ideas which are now becoming more fully appreciated.

English schools were, at that time, regarded as the only efficient media 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 tilled the ground and made the land blossom with green verdure and ripening corn, and the sons of the 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. 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. I now realise 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. This I realised more particularly when later I wished to go to Europe 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.

A FAILURE THAT WAS GREAT.

There has been some complaint that the experiment of meeting out cut and dried moral texts as a part of school routine has not proved to be so effective as was expected by their promulgators. The moral education which we received in our childhood was very indirect and came from listening to stories recited by the 'kathaks' on various incidents connected with our great epics. Their effect on our minds was very great; this may be because our racial memory makes us more prone to respond to certain ideals that have been impressed on the consciousness of the nation. These early appeals to our emotions have remained persistent; the only difference is that what was then taken as a narrative of incidents more or less historical, is now realised as eternally true, being an allegory of the unending struggle of the human soul in its choice between what is material and that other [illegible] which transcends it. The only pictures now in my study are a few frescoes done for me by Abanindra Nath Tagore and Nanda Lal Bose. The first fresco represents Her, who is the Sustainer of the Universe. She stands pedestalled on the lotus of our heart. The World was at peace; but a change has come. And She under whose Veil of Compassion we had been protected so long, suddenly flings us to the world of conflict. Our great epic, the Mahabharata, deals with this great conflict, and the few frescoes delineate some of the fundamental incidents. The coming of the discord is signalled by the rattle of dice, thrown by Yudhisthira, the pawn at stake being the crown. Two hostile arrays are set in motion, the mighty Kaurava armaments meeting in shock of battle the Pandava host with Arjuna as the leader, and Krishna as his Divine Charioteer. At the supreme moment Arjuna had flung down his earthly weapon, Gandiva. It was then that the eternal conflict between matter and spirit was decided. The next panel shows the outward or the material aspect of victory. Behind a foreground of waving flags is seen the battle-field of Kurukshetra with the procession of white-clad mourning women seen by fitful lights of funeral pyres. In the last panel is seen Yudhisthira renouncing the fruits of his victory setting out on his last Journey. In front of him lies the vast and sombre plain and mountain peaks, faintly visible by gleams of unearthly light, unlocalised but playing here and there. His wife and his brothers had fallen behind and dropped one by one. There is to be no human companion in his last journey. The only thing that stood by him and from which he had never been really separated is Dharma or the Spirit of Righteousness.

LIFE OF ACTION.

Faridpore at that time enjoyed the notoriety of being the stronghold of desperate characters, decoits by land and water. My father had captured single-handed one of the principal leaders, whom he sentenced to a long term of imprisonment. After release he came to my father and demanded some new occupation, since the particular vocation in which he had specialised was now rendered impossible. My father took the unusual course 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. Nemerous were the decorations he bore. The most conspicuous was an ugly mark on his breast left by an arrow and a hole on the thigh caused by a spear thrust. The trust imposed on this marauder proved to be not altogether ill placed for once in a river journey we were pursued by several long boats filled with armed dacoits. When these boats came too near for us to effect an escape 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.

INDUSTRIAL EFFORTS.

I come now to another period of his life, fifty years from now, when he foresaw the economic danger that threatened his country. This Agricultural and Industrial Exhibition was one of the first means he thought of to avert the threatened danger. Here also he attempted to bring together other activities. Evening entertainments were given by the performance of "Jatras," which have been the expression of our national drama and which have constantly enriched our Bengali literature by the contributions of village bards and composers. There were athletic tournaments also and display of physical strength and endurance. He also established here the people's bank, which is now in a most flourishing condition. He established industrial and technical schools, and it was there 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 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 some Great Design.

In practical agriculture my father was, among Indians, one of the first to start a tea industry in Assam, now regarded as one of the most flourishing. He gave practically everything to the starting of some weaving mills. He stood by this and many other efforts in industrial developments. The success of which I spoke did not come till long after—too late for him to see it. He had come before the country was ready, and it happened to him as it must happen to all pioneers. Every one of his efforts failed and the crash came. And a great burden fell on us which was only lifted by our united efforts just before his work here was over.

A failure? Yes, but not ignoble or altogether futile. Since it was through the witnessing of this struggle that the son learned to look on success or failure as one, to realise that some defeat was greater than victory. And if my life in any way proved to be fruitful, then that came through the realisation of this lesson.

To me his life had been one of blessing and daily thanksgiving. Nevertheless every one had said that he had wrecked his life which was meant for far greater things. Few realise that out of the skeletons of myriad lives have been built vast continents. And it is on the wreck of a life like his and of many such lives that will be built the Greater India yet to be. We do not know why it should be so, but we do know that the Earth Mother is hungry for sacrifice.

INAUGURATION OF THE BOSE INSTITUTE

The following is the text of the address delivered by Sir J. C. Bose at the opening ceremony of his Research Institute at Calcutta on Nov. 30, 1917:—

I dedicate to-day this Institute—not merely a Laboratory but a Temple. The power of physical methods applies for the establishment of that truth which can be realized directly through our senses, or through the vast expansion of the perceptive range by means of artificially created organs. We still gather the tremulous message when the note of the audible reaches the unheard. When human sight fails, we continue to explore the region of the invisible. The little that we can see is as nothing compared to the vastness of that which we cannot. Out of the very imperfection of his senses man has built himself a raft of thought by which he makes daring adventures on the great seas of the unknown. But there are other truths which will remain beyond even the supersensitive methods known to science. For these we require faith, tested not in a few years but by an entire life. And a temple is erected as a fit memorial for the establisment of that truth for which faith was needed. The personal, yet general, truth and faith whose establishment this Institute commemorates is this: that when one dedicates himself wholly for a great object, the closed doors shall open, and the seemingly impossible will become visible for him.

Thirty-two years ago I chose teaching of science as my vocation. It was held that by its very peculiar constitution, the Indian mind would always turn away from the study of Nature to metaphysical speculations. Even had the capacity for inquiry and accurate observation been assumed present, there were no opportunities for their employment; there were no well-equipped laboratories nor skilled mechanicians. This was all too true. It is for man not to quarrel with circumstances but bravely accept them; and we belong to that race and dynasty who had accomplished great things with simple means.

This day twenty-three years ago, I resolved that as far as the whole-hearted devotion and faith of one man counted, that would not be wanting and within six months it came about that some of the most difficult problems connected with Electric Waves found their solution in my Laboratory, and received high appreciation from Lord Kelvin, Lord Rayleigh and other leading physicists. The Royal Society honoured me by publishing my discoveries and offering, of their own accord, an appropriation from the special Parliamentary Grant for the advancement of knowledge. That day the closed gates suddenly opened and I hoped that the torch that was then lighted would continue to burn brighter and brighter.

But man's faith and hope require repeated testing. For five years after this the progress was interrupted; yet when the most generous and wide appreciation of my work had reached almost the highest point there came a sudden and unexpected change.

In the pursuit of my investigations I was unconsciously led into the border region of physics and physiology and was amazed to find boundary lines vanishing and points of contact emerge between the realms of the Living and Non-living. Inorganic matter was found anything but inert; it also was a thrill under the action of multitudinous forces that played on it. A universal reaction seemed to bring together metal, plant and animal under a common law. They all exhibited essentially the same phenomena of fatigue and depression, together with possibilities of recovery and of exaltation, yet also that of permanent irresponsiveness which is associated with death. I was filled with awe at this stupendous generalisation; and it was with great hope that I announced my results before the Royal Society,—results demonstrated by experiments. But the physiologists present advised me, after my address, to confine myself to physical investigations in which my success had been assured, rather than encroached on their preserve. I had thus unwittingly strayed into the domain of a new and unfamiliar caste system and so offended its etiquette. An unconscious theological bias was also present which confounds ignorance with faith. It is forgotten that He, who surrounded us with this ever-evolving mystery of creation the ineffable wonder that lies hidden in the microcosm of the dust particle, enclosing within the intricacies of its atomic form all the mystery of the cosmos has also implanted in us the desire to question and understand. To the theological bias was added the misgivings about the inherent bent of the Indian mind towards mysticism and uncheered imagination. But in India this burning [illegible] which can extort new order out of a mass of apparently contradictory facts, is also held in check by the habit of meditation- It is this restraint which confers the power to hold the mind in pursuit of truth, in infinite patience to wait, and reconsider, to experimentally test and repeatedly verify.

It is but natural that there should be prejudice, even in science, against all innovations; and I was prepared to wait till the first incredulity could be overcome by further cumulative evidence. Unfortunately there were other incidents and misrepresentations which it was impossible to remove from this insolating distance. Thus no conditions could have been more desperately hopeless than those which confronted me for the next twelve years. It is necessary to make this brief reference to this period of my life; for one who would devote himself to the search of truth must realise that for him there awaits no easy life, but one of [illegible] struggle. It is for him to cast his life as an offering, regarding gain and loss, success and failure, as one. Yet in my case this long persisting gloom was suddenly lifted. My scientific deputation in 1914, from the Government of India, gave the opportunity of giving demonstrations of my discoveries before the leading scientific societies of the world. This led to the acceptance of my theories and results, and the recognition of the importance of the Indian contribution to the advancement of the world's science. My own experince told me how heavy, sometimes even crushing, are the difficulties which confront an inquirer here in India; yet it made me stronger in my determination that I shall make the path of those who are to follow me less arduous, and that India is never to relinquish what has been won for her after years of struggle.

THE TWO IDEALS.

What is it that India is to win and maintain? Can anything small or circumscribed ever satisfy the mind of India? Has her own history and the teaching of the past prepared her for some temporary and quite subordinate gain? There are at this moment two complementary and not antagonistic ideals before the country. India is drawn into the vortex of international competition. She has to become efficient in every way,—through spread of education, through performance of civic duties and responsibilities, through activities both industrial and commercial. Neglect of these essentials of national duty will imperil her very existence; and sufficient stimulus for these will be found in success and satisfaction of personal ambition.

But these alone do not ensure the life of a nation. Such material activities have brought in the West their fruit, in accession of power and wealth. There has been a feverish rush even in the realm of science, for exploiting applications of knowledge, not so often for saving as for destruction. In the absence of some power of restraint, civilisation is [illegible] in an unstable poise on the brink of ruin. Some complementary ideal there must be to save man from that mad rush which must end in disaster. He has followed the lure and excitement of some insatiable ambition, never pausing for a moment to think of the ultimate object for which success was to serve as a temporary incentive. He forgot that far more potent than competition was mutual help and co-operation in the scheme of life. And in this country through millenniums, there always have been some, who, beyond the immediate and absorbing prize of the hour, sought for the realisation of the highest ideal of life—not through passive renunciation, but through active struggle. The weakling who has refused the conflict, having acquired nothing has nothing to renounce. He alone who has striven and won can enrich the world by giving away the fruits of his victorious experience. In India such examples of constant realisation of ideals through work have resulted in the formation of a continuous living tradition. And by her latent power of rejuvenescence she has readjusted herself through infinite transformations. Thus while the soul of Babylon and the Nile Valley have transmigrated, ours still remains vital and with capacity of absorbing what time has brought, and making it one with itself.

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 the effacement of all littleness, 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.

Public life and the various professions will be the appropriate spheres of activity for many aspiring young men. But for my disciples, I call on those very few, who, realising 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.

ADVANCEMENT AND DIFFUSION OF KNOWLEDGE.

The work already carried out in my laboratory on the response of matter, and the unexpected revelations in plant life, foreshadowing the wonders of the highest animal life, have opened out very extended regions of inquiry in Physics, in Physiology, in Medicine, in Agriculture and even in Psychology. Problems, hitherto regarded as insoluble, have now been brought within the sphere of experimental investigation. These inquiries are obviously more extensive than those customary either among physicists or physiologists, since demanding interests and aptitudes hitherto more or less divided between them. In the study of Nature, there is a necessity of the dual view point, this alternating yet rhythmically unified interaction of biological thought with physical studies, and physical thought with biological studies. The future worker with his freshened grasp of Physics, his fuller conception of the inorganic world, as indeed thrilling with "the promise and potency of life" will redouble his former energies of work and thought. Thus he will be in a position to winnow the old knowledge with finer seives, to re-search it with new enthusiasm and subtler instruments. And thus with thought and toil and time he may hope to bring fresher views into the old problems. His handling of these will be at once more vital and more kinetic, more comprehensive and unified.

The further and fuller investigation of the many and ever-opening problems of the nascent science which includes both Life and Non-Life are among the main purposes of the Institute I am opening to-day; in these fields I am already fortunate in having a devoted band of disciples, whom I have been training for the last ten years. Their number is very limited, but means may perhaps be forthcoming in the future to increase them. An enlarging field of young ability may thus be available, from which will emerge, with time and labour, individual originality of research, productive invention and some day even creative genius.

But high success is not to be obtained without corresponding experimental exactitude, and this is needed to-day more than ever, and to-morrow yet more again. Hence the long battery of super-sensitive instruments and apparatus, designed here, which stand before in their cases in our entrance hall. They will tell you of the protracted struggle to get behind the deceptive seeming into the reality that remained unseen,—of the continuous toil and persistence and of ingenuity called forth for overcoming human limitations. In these directions through the ever-increasing ingenuity of device for advancing science, I see at no distant future an advance of skill and of invention among our workers; and if this skill be assured, practical applications will not fail to follow in many fields of human activity.

The advance of science is the principal object of this Institute and also the diffusion of knowledge. We are here in the largest of all the many chambers of this House of Knowledge—its Lecture Room. In adding this feature, and on a scale hitherto unprecedented in a Research Institute, I have sought permanently to associate the advancement of knowledge with the widest possible civic and public diffusion of it; and this without any academic limitations, henceforth to all races and languages, to both men and women alike, and for all time coming.

The lectures given here will not be mere reptitions of secondhand 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 patents will ever be taken. The spirit of our national culture demands that we should for ever be free from the desecration 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.

It is my further wish that, as far as the limited accommodation would permit, the facilities of this Institute 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.

The Surge of Life.

With this widened outlook, we shall not only maintain the highest traditions of the past but also serve the world in nobler ways. We shall be at one with it in feeling the common surgings of life, the common love for the good, the true and the beautiful. In this Institute, this Study and Garden of Life, the claim of art has not been forgotten, for the artist has been working with us, from foundation to pinnacle, and from floor to ceiling of this very Hall. And beyond that arch, the Laboratory merges imperceptibly into the garden, which is the true laboratory for the study of Life. There the creepers, the plants and the trees are played upon by their natural environments, sunlight and wind, and the chill at midnight under the vault of starry space. There are other surroundings also, where they will be subjected to chromatic action of different lights, the invisible rays, to electrified ground or thundercharged atmosphere. Everywhere they will transcribe in their own script the history of their experience. From this lofty point of observation, sheltered by the trees, the student will watch this panorama of life. Isolated from all distractions, he will learn to attune himself with Nature; the obscuring veil will be lifted and he will gradually come to see how community throughout the great ocean of life outweighs apparent dissimilarity. Out of discord he will realise the great harmony.

THE OUTLOOK.

These are the dreams that wove a network 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 expansion 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 hardships that had to be faced, has wished 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.

Till a few weeks ago it seemed that I shall have to look to the future for securing the necessary expansion of scope and for permanence of the Institute. But response is being awakened in answer to the need. The Government have most generously intimated their desire to sanction grants towards placing the Institute on a permanent basis the extent of which will be porportionate to the public interest in this national undertaking. Out of many who would feel an interest in securing adequate Endowment, the very first donations have come from two of the merchant princes of Bombay, to whom I had been personally unknown.

A note that touched me deeply came from some girl-students of the Western Province, enclosing their little contribution "for the service of our common mother-land." It is only the instinctive mother-heart that can truly realise the bond that draws together the nurselings of the common home-land. There can be no real misgiving for the future when at the country's call man offers the strength of his life and woman her active devotion, she most of all, who has the greater insight and larger faith because of the life of austerity and self-abnegation. Even a solitary wayfarer in the Himalayas has remembered to send me message of cheer and good hope. What is it that has bridged over the distance and blotted out all differences? That I will come gradually to know; till then it will remain enshrined as a feeling. And I go forward to my appointed task, undismayed by difficulties, companioned by the kind thoughts of my well-wishers, both for and near.

INDIA'S SPECIAL APTITUDES.

The excessive specialisation of modern science in the West has led to the danger of losing sight of the fundamental fact that there can be but one truth one science which includes all the branches of knowledge. How chaotic appear the happenings in Nature? Is nature a Cosmos in which the human mind is some day to realise the uniform march of sequence, order and law? India through her habit of mind is peculiarly fitted to realise the idea of unity, and to see in the phenomenal world an orderly universe. This trend of thought led me unconsciously to the dividing frontiers of different sciences and shaped the course of my work in its constant alternations between the theoretical and the practical, from the investigation of the inorganic world to that of organised life and its multifarious activities of growth, of movement, and even of sensation. On looking over a hundred and fifty different lines of investigation carried on during the last twenty-three years, I now discover in them a natural sequence. The study of Electric Waves led to the devising of methods for the production of the shortest electric waves known and these bridged over the gulf between visible and invisible light; from this followed accurate investigation on the optical properties of invisible waves, the determination of the refractive powers of various opaque substances, the discovery of effect of air film on total reflection and the polarising properties of strained rocks and of electric tourmalines. The invention of a new type of self-recovering electric receiver made of galena was the fore-runner of application of crystal detectors for extending the range of wireless signals. In Physical Chemistry the detection of molecular change in matter under electric stimulation, led to a new theory of photographic action. The fruitful theory of stereochemistry was strengthened by the production of two kinds of artificial molecules, which like the two kinds of sugar, rotated the polarised electric wave either to the right or to the left. Again the 'fatigue' of my receivers led to the discovery of universal sensitiveness inherent in matter as shown by its electric response. It was next possible to study this response in its modification under changing environments of which its exaltation under stimulants and its abolition under poisons are among the most [illegible] outward manifestations. And as a single example of the many applications of this fruitful discovery, the characteristics of an artificial retina gave a clue to the unexpected discovery of "binocular alternation of vision" in man :—each eye thus supplements its fellow by turns, instead of acting as a continuously yoked pair, as hitherto believed.

Plant Life and Animal Life.

In natural sequence to the investigations of the response in 'inorganic' matter, has followed a prolonged study of the activities of plant-life as compared with the corresponding functioning of animal life. But since plants for the most part seem motionless and passive, and are indeed limited in their range of movement, special apparatus of extreme delicacy had to be invented, which should magnify the tremor of excitation and also measure the perception period of a plant to a thousandth part of a second. Ultra-microscopic movements were measured and recorded; the length measured being often smaller than a fraction of a single wave-length of light. The secret of plant life was thus for the first time revealed by the autographs of the plant itself. This evidence of the plant's own script removed the longstanding error which divided the vegetable world into sensitive and insensitive. The remarkable performance of the Praying Palm Tree of Faridpore, which bows, as if to prostrate itself, every evening, is only one of the latest instances which show that the supposed insensibility of plants and still more of rigid tree is to be ascribed to wrong theory and defective observation. My investigations show that all plants, even the trees, are fully alive to changes of environment; they respond visibly to all stimuli, even to the slight fluctuations of light caused by a drifting cloud. This series of investigations has completely established the fundamental identity of life reactions in plant and animal, as seen in a similar periodic insensibility in both, corresponding to what we call sleep; as seen in the death spasm, which takes place in the plant as in the animal. This unity in organic life is also exhibited in that spontaneous pulsation which in the animal is heart-beat; it appears in the identical effects of stimulants, anaesthetics and of poisons in vegetable and animal tissues. This physiological identity in the effect of drugs is regarded by leading physicians as of great significance in the scientific advance of Medicine; since here we have a means of testing the effect of drugs under conditions far simpler than those presented by the patient far subtler too, as well as more humane than those of experiments on animals.

Growth of plants and its variations under different treatment is instantly recorded by my Crescograph. Authorities expect this method of investigation wi advance practical agriculture; since for the first time we are able to analyse and study separately the conditions which modify the rate of growth. Experiments which would have taken months and their results vitiated by unknown changes, can now be carried out in a few minutes.

Returning to pure science, no phenomena in plant life are so extremely varied or have yet been more incapable of generalisation than the "trophic" movements, such as the twining of tendrils, the heliotropic movements of some towards and of others away from light, and the opposite geotropic movements of the root and shoot, in the direction of gravitation or away from it. My latest investigations recently communicated to the Royal Society have established a single fundamental reaction which underlies all these effects so extrèmely diverse.

Finally, I may say a word of that other new and unexpected chapter which is opening out from my demonstration of nervous impulse in plants. The speed with which the nervous impulse courses through the plant has been determined; its nervous excitability and the variation of that excitability have likewise been measured. The nervous impulse in plant and in man is found exalted or inhibited under identical conditions. We may even follow this parallelism in what may seem extreme cases. A plant carefully protected under glass from outside shocks, looks sleek and flourishing; but its higher nervous function is then found to be atrophied. But when a succession of blows is rained on this effete and bloated specimen, the shocks themselves create nervous channels and arouse anew the deteriorated nature. And is it not shocks of adversity, and not cotton-wool protection, that evolve true manhood?

A question long perplexing physiologists and psychologists alike is that concerned with the great mystery that underlies memory. But now through certain experiments I have carried out, it is possible to trace "memory impressions" backwards even in inorganic matter, such latent impressions being capable of subsequent revival. Again the tone of our sensation is determined by the intensity of nervous excitation that reaches the central perceiving organ. It would theoretically be possible to change the tone or quality of our sensation, if means could be discovered by which the nervous impulse would become modified during transit. Investigation on nervous impulse in plants has led to the discovery of a controlling method, which was found equally effective in regard to the nervous impulse in animal.

Thus the lines of Physics, of Physiology and of Psychology converge and meet. And here will assemble those who would seek oneness amidst the manifold. Here it is that the genius of India should find its true blossoming.

The thrill in matter, the throb of life, the pulse of growth, the impulse coursing through the nerve and the resulting sensations, how diverse are these and yet how unified! How strange it is that the tremor of excitation in nervous matter should not merely be transmitted but transmuted and reflected like the image on a mirror, from a different plane of life, in sensation and in affection, in thought and in emotion. Of these which is more real, the material body or the image which is independent of it? Which of these is undecaying, and which of these is beyond the reach of death?

It was a woman in the Vedic times, who when asked to take her choice of the wealth that would be hers for the asking, inquired whether that would win for her deathlessness. What would she do with it, if it did not raise her above death? This has always been the cry of the soul of India, not for addition of material bondage, but to work out through struggle her self-chosen destiny and win immortality.. Many a nation had risen in the past and won the empire of the world. A few buried fragments are all that remain as memorials of the great dynasties that wielded the temporal power. There is, however, another element which find its incarnation in matter, yet transcends its transmutation and apparent destruction: that is the burning flame born of thought which has been handed down through fleeting generations.

Not in matter, but in thought, not in possessions or even in attainments but in ideals, are to be found the seed of immortality. Not through material acquisition but in generous diffusion of ideas and ideals can the true empire of humanity be established. Thus to Asoka to whom belonged this vast empire, bounded by the inviolate seas, after he had tried to ransom the world by giving away to the utmost, there came a time when he had nothing more to give, except one half of an *Amlaki* fruit. This was his last possession and his anguished cry was that since he had nothing more to give, let the half of the *Amlaki* be accepted as his final gift.

Asoka'. emblem of the *Amlaki* will be seen on the cornices of the Institute, and towering above all is the symbol of the thunderbolt. It was the Rishi Dadhichi, the pure and blameless, who offered his life that the divine weapon, the thunderbolt, might be fashioned out of his bones to smite evil and exalt righteousness. It is but half of the *Amlaki* that we can offer now. But the past shall be reborn in a yet nobler future. We stand here to-day and resume work to-morrow so that by the efforts of our lives and our unshaken faith in the future we may all help to build the greater India yet to be.

REPLY TO CALCUTTA CITIZENS' ADDRESS.

On the requisition of a number of influential citizens of Calcutta, Dr. Chunilal Bose, the Sheriff of Calcutta, convened a public meeting on Jan. 25, 1921 at the Town Hall, for the purpose of presenting an address to Sir J. C. Bose, F. R. S. The Reception was a most impressive one and attended by leading members of the Indian community. After the Sheriff declared the meeting open the Maharaja of Kassimbazaar proposed the Hon. Sir Abdur Rahim to the chair. Sir A. Chaudhuri then read the address on behalf of the citizens of Calcutta. The presentation of the address was in pure Indian style. The address was inscribed on palm-leaves—the leaves being made of gold. The cover was an embossed cross thunderbolt in gold which is the emblem of the Bose Institute. It was presented on a silver tray made by an Indian. On it was placed a silk chaddar, unhusked rice, the tiny bunch of the evergreen "dub", sandal paste in a small silver cup and also a reel pen made of gold. Sir J. C. Bose then replied as follows:—

It is the resonance of strings woven of memory that affects us deeply, and I am greatly touched by your kindness. This city has been the place of my work and struggles for more than a third of a century. It is the watching of a roadside weed in

Calcutta that turned the entire trend of my thought from the study of the inorganic to that of organised life; it was while turning round a lane near College Square that I had a distinct mental image of a ring suspended against the sky leading to the solution of the problem of my Resonant Recorder, which had baffled me for many years. The efflorescence of life is the supreme gift of a place and its associations. Who could be so base as to be untrue to his salt and the soil that nourished him? Among the citizens, that I see round me, there are some who came from distant corners of the earth and found here the place of their work and their home. The ever [illegible] civic spirit is the manifestation of the unseen power that presides over the city's destiny. And a mightier spirit is guiding the onward march of the children of this great land, inspiring them with a burning faith in the renewal of India's ancient greatness.

You have referred to the endless difficulties that lay in my path and the oppositions that had to be surmounted. I had been silent about them all these years and would have preferred to bury them in oblivion. But a controversy in the English press was started by an opponent and the matter assumed great prominence. I took no part in that controversy; I do not know how it came about that the entire English press commented in the strongest term about the unfair attempt that has been made in suppression of my discoveries. An important journal could discover no other reason for my being kept out of the Fellowship of the Royal Society for so many years except prejudice against foreigners. Another leading paper gave expression to the bitter reflection that Bose might have come to his own sooner and done even greater service to the world, if there had been a little generosity of response. There are certain facts that make one more than a little ashamed. I would do anything to remove the bitterness that has been roused and to do this I have to relate a few facts concerning my scientific efforts for the last 25 years. Yo will then realise that there is a silver lining to the darkest cloud and the apparent evil might be the precursor of the highest good.

THE CONFLICT.

What has caused the greatest bitterness roused here was the unprovoked attack made on my work last year. A belief obtained currency that my opponent represented the general attitude of the scientific men in England. The conflict which reached its climax last year orginated 20 years ago, the unaccountable behaviours of my wireless receiver which showed signs of depression under fatigue and exalted sensibility under stimulants led to the discovery of universal sensitiveness of matter; it also led to the further discovery that life reactions of plants were similar to those of animals. These results I demonstrated before the Royal Society in 1901. My physicist friends were puzzled by my incursion into the field with which they were less familiar, and the physiologists present resented my intrusion into their preserve. I had evidently offended the etiquette of an unfamiliar caste system, and I was roundly told to keep to my trade. The result was that my communication was for the first time refused publication by the Royal Society. One of my physiological opponents, whom I had shown my experiments afterwards repeated them and found to his astonishment that what I had said was too true. So impressed was he by these new results of far reaching consequence that in his excitement he came to regard them as his own discovery and published them accordingly. In extenue ation of this it must be said that he thought I was in India, and the question of priority subsequently raised by the Linnæan Society came to him as a very unpleasant surprise. After investigating the matter the Linnæan Society decided in my favour and published my work in their journal insisting that I should append a note about the glaring attempt at misappropriation. I roused considerable anger of my English friends by attenuating the statement so as to cause the least hurt. I was warned that this Oriental courtesy was misplaced and would lead to infinite trouble in future—a prophesy which unfortunately turned out to be too true. But I may truly say that if I had to go through the experience over again my course of conduct would not be different. For those who seek truth must pursue it through infinite patience, through forbearance, and thorough unfailing courtesy.

This attitude of mine suggests a phlegmatic temperament of a rare philosophic spirit. My intimate friends have reasons to think differently—they rightly impute to me an impassioned and an unphilosophic fiery temperament. An incident occurred, however, which left the deepest impression. I had been living on the banks of the Ganges and a stranger came and asked to be allowed to live in one of the outhouses. He used to subject himself to severe penances "Did you expect to win merit by tormenting your body ?" I asked. " No" he answered. " But my mind is like a wild horse always running hither and thither, and it is only through these practices that I can curb it to obedience." Alas ! it is only through daily anguish and through severe discipline that I could at all subdue the wild horse to my will.

To resume. I had incurred the undying hostility of one who held a very influential position and was also a reference in the Committee of Publication of the Royal Society. And it came to pass that one by one seven successive papers of mine were buried in the archives. And their rejection came to be reported to the India Government in proof of the dubiousness of my pretensions as an investigator. The few opportunities I had in the pursuit of research were gradually withdrawn. The atmosphere of doubt began to spread and affect even my own countrymen I was repeatedly asked to offer an explanation of my not being elected a Fellow of the Royal Society. I had none to offer. Those who knew the inner history urged me to take the world into confidence and tell all the facts. But controversy would have only led to bitterness and it would have been impossible to keep the vision clear. Some day, perhaps, the veil would be lifted, but a doubting voice would cry out that it would not be in my life time. But I could also hear another voice : " You and they will pass away ; Nations will disappear. Truth alone would persist, for it is eternal."

The Fellowship of the Royal Society.

I may now say a few words about the delayed official recognition by the Royal Society which was in no way due to my being a foreigner. I came recently to know from my friends that, so far back as twenty years ago, Lord Kelvin in recognition of my physical [illegible] on Electric Waves which he regarded as very important, wished to propose me for a Fellowship of the Royal Society. But I upset all his plans by leaving my true fold and making a daring incursion in the preserve of plant physiologists : their irritation became converted into an appreciation in the course of five years with the result that they wished to propose me for the Fellowship. But by some perversity inherent in my nature, I upset their plans also this time by intruding into the domains of animal physiology. I had to pay for my temerity for the last 15 years as no one had the courage to stand sponsor for me.

As regards the supposed crushing effect of years of cold neglect, I say it deliberately that the very adverse circumstances which seemed to overwhelm me for twenty years were the most needed stimulus for my own growth. Undisturbed by success, I learnt in these years of isolation to concentrate my mind to the solution of the baffling problems which challenged me at every step. It was then and then only could I see truth face to face.

After years of struggle success came unexpectedly. It was only the turning of the last corner. I have no time to speak of the events of the last year—of the anxieties that beset me every day in carrying from place to place the fragile instrument, on whose working everything depended. The sensitiveness of my apparatus and its power to reveal the invisible were regarded as theoretically impossible. This would be understood from the astonished exclamation of a distinguished French physicist, who saw the instrument at work, "Monsieur, I see it, but my heart still refuses to believe!" The leading physiologist in England told me after my demonstration at the Royal Society, "We thought that Oriental imagination must have misled you, for you have transcended what we regarded as scientifically possible. We realise now that you have always been in the right and we have always been in the wrong!" What response could have been more generous than this?

PHYSIOLOGICAL INSTITUTE BERLIN.

I will mention only one more incident, perhaps most momentous. They all told me that my work had found acceptance in England, in Scandinavia and in France, but had I the courage to face the German physiologists, some of whose conclusions my work had upset? My stay in Europe was drawing to a close and I had less than a week to spare. I therefore went to Berlin without notice and drove directly to the celebrated Physiological Institute at Dalhem, presided over by the eminent and veteran physiologist Haberlandt. I was received with marked coldness and suspicion as having come from the Allied countries; the anti-foreign feeling was then at its highest. I only asked for fairplay. Let all the leading scientists be invited and I would be ready to meet the shock of hostile criticisms. A lecture was organised and a miracle happened, for in less than 15 minutes the whole audience gave expression of their warmest appreciation. So complete was the conversion from scepticism that, in his subsequent address, Prof. Haderlandt declared that it was no mere accident that it should have been an Indian investigator who had in so high a degree perfected the new method of inquiry and exhibited such an extraordinary developed faculty for experimentation. The visit of their Indian guest, he added, would be a source of abiding inspiration to scientific investigators in Germany. I had expected nothing but persistent hostility, but there is a spirit of chivalry in all who truly seek after truth. And after the contest my opponents came to acclaim me as their honoured friend and colleague. Conflicts may some times be inevitable, but blessed be that contest which ends in deeper mutual appreciation and a common determination for the firmer establishment of the kingdom of righteousness.

THE RESEARCH INSTITUTE.

Early in my life I came to realise that it is not for man to complain of circumstances, but bravely to accept, to confront and to overcome them. I had the abiding faith that, when one has gained the vision of a purpose to which he can and must dedicate himself, then the closed doors will open and the seemingly impossible become fully attainable. My faith has been justified. For within three years of the foundation of my Institute, it has obtained recognition as one of the important scientific centres of the world. Advanced scholars from the West have applied for enrolment as pupils in my Institute to be trained in the new methods of investigation. The hope I cherished about the revival of our ancient Universities of Taxila and Nalanda is no longer an unattainable dream. I have dedicated my Institute to the Nation and I have done all that lay in my power. It now remains with my countrymen to determine its fuller expansion, so that within its precincts may be gathered seekers after truth from all parts of the world.

THE UNIVERSAL CALL.

My work has been interrupted by the necessary foreign visit. I now return to it and shall try with my disciples to probe into the deeper mysteries that surround life. We have but answered the call which has been echoing through the ages, the call which compels men to choose a life of unending struggle for extending the boundary of human knowledge; thus may human [illegible] be alleviated and the earth rendered productive so that two ears of corn might grow in the place of one which grew before. In this respect Science is a Divine Gift and here in India knowledge is regarded as one with religion. And no injunction could be more imperative on us than the ancient royal edict of Asoka incribed on imperishable stone twenty-two centuries ago :

"Go forth and intermingle and bring them to knowledge. Go forth among the terrible and powerful, both here and in foreign countries in kindred ties even of brotherhood and sisterhood—go everywhere."

III. Science

RESPONSE IN THE LIVING & NON-LIVING

I

[*Dr. Bose read a paper on the Response of Inorganic and Living Matter before the Paris International Congress of Physicists in August 1900. In this paper, Bose for the first time in science compares and parallelises the responses of the excitation of living tissues with those of inorganic matter. Dr. Bose says in the course of this essay*:]

A muscle-curve registers the history of the molecular change produced by excitation in a living tissue, exactly as the curve of molecular reaction registers an analogous change in an inorganic substance. The two represent the same thing; in the latter the molecular deformation is evidenced by the change of conductivity; in the other the same deformation is manifested by the change of form. We have thus means of study of the molecular reaction produced by stimulus, of varying frequency, intensity and duration. An abyss separates the phenomena of living matter from those of inanimate matter. But if we are ever to understand the hidden mechanism of the animal machine it is necessary to face numerous difficulties which at present seem formidable.

II

[*In his discourse to the Royal Society, on May 10, 1901, Dr. Bose marshalled the results of his observation of stimulating action on plant and animal life and demonstrated each of these by a comprehensive series of experiments. In concluding his demonstrations, he said.*—]

I have shown you this evening autographic records of the history of stress and strain in the living and non-living. How similar are the writings! So similar indeed that you cannot tell one apart from the other. We have watched the responsive pulse wax and wane in the one as in the other. We have seen response sinking under fatigue, becoming exalted under stimulants, and being killed by poisons, in the non-living as in the living.

Amongst such phenomena, how can we draw a line of demarcation, and say, here the physical ends, and there the physiological begins? Such absolute barriers do not exist.

Do not these records tell us of some property of matter common and persistent? Do they not show us that the responsive processes, seen in life, have been fore-shadowed in non-life?—that the physiological is related to the physico-chemical?—that there is no abrupt break, but a uniform and continuous march of law?

If it be so, we shall but turn with renewed courage to the investigation of mysteries, which have too long eluded us. For every step of science has been made by the inclusion of what seemed contradictory or capricious in a new and harmonious simplicity. Her advances have been always towards a clearer preception of underlying unity in apparent diversity.

It was when I came upon the mute witness of these self-made records, and perceived in them one phase of a 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!'

AUTOMATISM IN PLANT AND ANIMAL.

[*Dr. J. C. Bose contributed the following article to the 'Modern Review,' in 1908.*]

One of the most characteristic signs of the presence of life is the power to give a reply, of one kind or another, to stimulus. Each one of us lives in the midst of an environment which is constantly impinging upon him, in the form of stimuli, or blows. The ray of light, falling upon the retina, is really striking a blow, giving it a shock. This constitutes a stimulus. In this way, we may receive many shocks. We are struck by air-waves, for instance, and perceive sound. Or we may receive a physical blow, small or great.

As long as we are alive, in one way or another, we *respond* to these stimuli. Stimulus, falling on matter, causes a molecular upset, and this upset is exhibited in various ways, according to the instrument of expression. Let us look for a moment at the diverse effects which may be produced by the same electrical current, acting on different instruments. Acting on one form of recorder, it produces movement. On another, say an electrical bell, it causes sound. On still another, a flash of light results. In like fashion stimulus acting on living tissues, may cause mechanical movement, as when a drop of scalding water falls on the hand, and by a twitch of the muscle we draw the hand away. The same thing is seen, again in the *Mimosa*, or sensitive plant, when the excited leaf suddenly falls down. Or, similarly, under the excitation of touch, the open *Drosera* leaf closes on the fly, its prey. Instead of this mechanical movement, again we may have an electrical movement, in response to stimulus, and a suitable instrument, the galvanometer G, shows an electrical twitch, each time the living tissue is excited. And lastly, amongst forms of response, we have sensation itself. Sight is the characteristic response of the eye, hearing of the ear, and so on. Thus, in sensation, different parts of the brain act as the responding organs. For purposes of investigation, we might, in the laboratory, take a retina with its attached optical nerve, and put it in connection with the galvanometer instead of with the brain. It will then be found that each time a flash of light falls on the retina, the galvanometer responds by a twitch, just as the brain formerly responded by a passing sensation.

If we watch a *Mimosa* leaf after the application of a stimulus, we see that it first responds by a fall, and afterwards exhibits recovery. That is to say, it gradually rises to the position it originally held. Similarly a muscle which has contracted under stimulus, recovers from the contraction. This response and recovery may be recorded by means of a writing lever, and the result will be an up-curve followed by a down-curve, which may, as a whole, be called a pulse of response. Taking a number of such records, we find that a single moderate stimulus induces a single such response and recovery.

These response-records, further, constitute a measure of the livingness of the tissue. If the tissue be subjected to poison, and stimulus then applied, the pulses of response grow feebler and feebler, till, at death, they disappear. It would here seem as if there were some growing obstruction to the free occurrence of that molecular upset which constitutes excitation. Death is, in fact, the supervening of molecular rigidity, in place of molecular mobility. At death, then, it is as if the molecular machinery became suddenly interlocked. In a certain curve of life and death, which I succeeded in obtaining, the plant was placed in a bath with rising temperature and the record it first gave was of a growing expansion, suggestive of that feeling of relaxation which comes to us in a hot bath. The bath continued to rise uniformly in temperature, but, at a certain point, corresponding to the death temperature, the molecular interlocking of death took place abruptly, and this death-spasm was shown by a sudden reversal of the curve. When this happens, the plant is found to have lost its responsiveness. It is, in fact, dead. Thus responsiveness is life, and cessation of responsiveness death. We have here a glimpse, then, into the mechanical condition essential to life. As a machine converts energy from one form into another, so we find the machinery of the living organism transforming antecedent stimulus into subsequent response.

The phenomenon of life is associated, however, with many characteristics apparently more mysterious than this, inasmuch as we observe in them the occurrence of effects seemingly without a cause, I refer to what are known as automatic or spontoneous movements. For instance, it would seem that the heart beats of its own accord. A sudden contraction is followed by expansion, and this rhythm is maintained, continuously and spontaneously, throughout the duration of life. In the animal body, then, the heart furnishes us with a perfect example of an automatically-responding rhythmic tissue.

But such rhythmic tissues are not found only in the animal. They occur also in the plant. as witness the oscillating leaflets of the telegraph plant, or *Desmodium Gigrans (Ban Charral* in Bengali). We have here leaves, of which each consists of one large terminal, and two smaller lateral leaflet. Of these the two lateral leaflets are in a state of constant vibration, moving up and down. The mechanics of the movement consist of a sudden contraction, by which the leaflet is made to fall, followed by a slow expansion, bringing about recovery. I was fortunate enough to be able to make a continuous record of these pulsatory movements during 12 hours, and it was found that during that period there were nearly 200 pulsations.

We have here, then, a vegetable example of a rhythmic tissue, whose spontaneity of action is strongly suggestive of the animal heart. In this merely a superficial resemblance, or is it something deeper? If it extends to identity, then we must be able to prove the fact, by showing that under parallel conditions, parallel changes are seen in both forms of pulsation, and that the action of a given agent will have the same effect on the two. With regard to the beating of the heart, it is known that the prolonged application of an anæsthetic like ether will arrest it. Will the same drug have the same effect on the puisation of *Desmodium*? On making the experiment, the records obtained are almost indistinguishable. We find in both that, after a certain number of spasmodic flutterings, the pulsation suddenly comes to a stop. Poisoning by carbonic acid similarly affects both in the same way.

Another remarkable effect is that obtained by rise of temperature. We all know that, on suddenly entering a heated room, the heart begins to beat faster, but at the same time the extent or amplitude of each single beat is less. Comparing two records of the heart-beat of a frog, under warmth and cold respectively, we find that while at the higher temperature the heart in a given time exhibits five pulsations, at the lower it gives little more than two. On the other hand, the height of pulsation at the lower temperature is very much greater than at the higher. Precisely the same thing occurs in the pulsation of *Desmodium*.

Such parallelisms, extending as they do into detail, are striking enough. The most extraordinary thing, however, is the identity of the effects seen, when we observe the action of given drugs on the two kinds of pulsation. Poisonous acids, for example, arrest the pulsation of the heart. But this particular arrest always takes place during expansion. Now alkaline poisons also arrest the beating of the heart but in an antagonistic manner, that is to say, during contraction. That the actions of these two poisons are antagonistic, is further seen in the fact that when the heart-beat is arrested by one, it can be revived under the application of the other. Here is a curious instance of one poison acting as the antidote of another.

In *Desmodium* pulsation, likewise, it is wonderful to see that exactly the same thing takes place. Poisonous acids arrest the pulsation, but always when the leaflet is in its expanded, or highest erect position. Alkaline poisons, on the other hand, arrest the pulsation, in the contracted or depressed position of the leaflet. And finally, the arrest induced by either of these can be counteracted by the other.

These experiments conclusively prove the identical reactions of rhythmic tissue in plant and animal. But the question still remains, what is the cause of these automatic movements?

We saw at the outset that living tissues might be divided into two classes, one in which a single stimulus evokes a single response, and another in which response appears to take place without antecedent application of stimulus. To the latter of these belong rhythmic tissues in general. I shall now show, however, that there is no hard and fast line of demarcation between these classes, and in order to demonstrate this fact, we shall take a plant which is intermediate between the two types, namely, *Biophytum semitrosum*. This is a weed which grows commonly about Calcutta. Its leaflets are arranged on the leafstalk in two long rows, and show excitation by twitching or rippling movements. Ordinarily speaking, the leaves lie open, with the leaflets stationary, and excitatory movements take place only under definite stimulation. Each responding leaflet, then, when excited by an electric shock, a shock of heat, a ray of light, or a mechanical blow, responds by a fall, followed by recovery or erection, Under moderate stimulation, a single stimulus induces a single response, as in the leaf of *Mimosa* or an excited muscle. Let the stimulus, however, be excessively strong, and we find that a single twitching of the leaflets is not sufficient to express the whole of the leaf's responsive energy. Instead of this, the leaflets continue to pulsate for a longer or a shorter time accordingly as the impinging stimulus was more or less strong. The response thus echoes, as it were, or reverberates. We have here an analogy to the swing of a pendulum, or the vibrations of a tuning-fork. When the pendulum is very gently struck, it swings once, or a few times only. But when the intensity of the stimulus—or the energy of the blow is very great the pulsation persists. The tuning-fork similarly when gently struck, vibrates and emits sound for a short time, but when strongly excited gives a more lasting or persistent note.

It is thus seen that *this echoing or multiple response is an after-effect of superfluity of energy absorbed.* Reverting to the case of *Biophytum,* we find that, if we apply a strong stimulus of any description, it gives rise to multiple responses. This is true of a strong electrical shock, a heat-shock, the stimulus of strong light, and the stimulating action of chemical substances equally. If now we watch the *Biophytum* growing normally in the open, we find it ordinarily quiescent. But if the day should be particularly warm, the sunlight bright, and the specimen itself vigorous and well-fed, then we shall find, under the cumulative action of all these excesses of stimulus, that the leaflets are in a constant state of rhythmic vibration which passes like ripples along the length of the leaf. It is no definite individual blow that causes these movements, but the superfluity of energy which has been absorbed from the environmental stimuli as a whole, and is stored up in the plant, till it bubbles over in this rhythmic expression, to appear as seemingly spontaneous movements. It was our own lack of knowledge and want of sufficiently penetrative analysis, that gave rise to the assumption that these movements were self-caused.

It must thus be excess of energy which converts an ordinarily responding into an automatically responding plant. But if this is so, then it should follow that an automatically responding plant, conversely, should be convertible, through lack of energy, into an ordinarily responding plant. This also I have been able to demonstrate.

For this purpose, we must return to *Desmodium*, the telegraph plant, whose pulsation goes on perpetually, like that of the heart. If it be true that this automatism is due to the plant's store of superfluous energy, then depletion of this store ought to bring it to an end. The pulsating leaflet should then come to a state of standstill. I took a plant of *Desmodium* and deliberately starved it, cutting off its supply of food and light. Its autonomous movements, as I had expected, were thus arrested. Curiously enough, in this state of standstill, it was further found to have been converted into an ordinarily-responding plant, for a single stimulus now evoked from it a single response, while a stronger stimulus induced multiple responses. On now again placing the plant under favourable conditions of light, warmth, and food, it was found that in a short time the autonomous pulsations was duly resumed.

We have thus seen that excess of energy finds expression in multiple response, and I believe that this fact casts a flood of light on various activities at present deemed irrational. One notices the same phenomenon in any healthy baby, after it has been fed. From a state of quiescence before feeding, it will afterwards throw out its limbs again and again in a rhythmic manner, expressive of overflowing energy. This is also seen in children of a larger growth, when an intensely pleasurable stimulation will cause them to 'dance for joy,' a form *par excellence* of rhythmic activity. One has often, again, been struck by the long series of zigzag flourishes characteristic of certain signatures. This multiple rhythmic response is not improbably the expression of an overflowing self-esteem or egotism!

We have thus seen that a strong or a long-continued stimulus gives rise to multiple response, and that autonomous activities, so called, are merely an extension of this. Now are there no other autonomous activities in life, besides such conspicuous movements as those of the *Desmodium* leaflets, or the animal heart?

Let us confine ourselves for a moment to the plant and consider the process by which it derives nourishment from the soil. This depends, as we know, on a stream of fluid charged with food materials, which passes constantly through it, from below to above, a phenomenon known as the ascent of sap, and regarded, up to the present, as one of the enigmas of Botany. Various explanations have been offered, but all to be pronounced unsatisfactory. It might be thought, for example, that evaporation from the leaves produced a vaccum, on account of which the liquid is forced up from below, by atmospheric pressure. But this could hardly be true, since the ascent of sap will take place in trees a hundred feet h'gh, wh e only a 34 feet column of liquid can be lifted by barometric pressure.

Once possessed, however, of the fact that plant tissues respond to stimulus, we are able to envisage this problem in a much simpler fashion. Fine rootlets in contact with the soul, are stimulated by friction and the presence of chemical substances. The cells thus undergo a sudden contraction, forcing their liquid contents into others higher up. By the impact of this water, however, the cells above are excited and contract in turn, with the result that the fluid is forced higher still. When this wave of contraction has passed on, the terminal cells in contact with the soil recover. During this expansion they suck up fresh fluid from the soil, are once more excited and the wave of contraction is initiated again. Thus by a chain of minute pumps, as it were, placed one above another, the liquid food is forced upwards through the whole height of the plant. There is no more difficulty in understanding this process in the plant, though maintained in opposition to the attracting power of gravity, than in understanding the peristatic action in the animal body. We may thus regard the channels of the ascent of sap in the plant as a sort of diffuse heart.

That the ascent of sap is really a phenomenon initiated by excitation, is proved when we find that any circumstance or condition which depresses or augments excitation, will also retard or accelerate the rise of water in the plant. For instance, if chloroform be applied to the root, the cells become numb, and the water-movement ceases. Similarly an application of ice-cold water will arrest the ascent, which may, moreover, be renewed with greater vigour than before on the application of warm water.

It is thus seen that the constant supply of food to the plant by which it is kept alive, is maintained by the autonomus rhythmic activity of certain tissues; while autonomous rhythmic activity, as we have seen, is the result of the presence in the tissue of a superfluity of energy absorbed from its environment. Now to prove that this is so,we have only to keep the plant for a length of time with its roots in water, in a cold room, in the dark. Sooner or later, under these conditions, suction will come to an end. But if now we apply a strong shock to the root of the plant, this suctional activity will at once renew itself just as the motile activity was found to be renewed in*Desmodium* leaflets, in a state of standstill.

But the mystery of growth is even greater than that of the ascent of sap. And by means of suitable apparatus it can be shown that this also is a phenomenon of multiple activity. If we take a growing plant and attach a recording-lever to its free end, the growth-elongation wiil be described by this recording-lever, as a series of pulsations. Starve the plant, or apply cold to it, and the growth-record will come to a stop. If now, in this condition of growth-standstill, we give it the stimulus of food or warmth, there is an immediate renewal of growth-pulsation, as in the cases of the multiple mechanical and suctional response.

But this phenomenon of multiple response is not merely characteristic of the grosser responsive movements of living matter: it is equally true even in the subtler realm of sensation.

Let us think for a moment of the effect of a strong stimulus of light on the retina. We may, for example, stare a moment or two at a bright light, and then close the eyes. We now find that, even after the cessation of stimulus, the after-effect of the light persists, as a series of a strong visual impressions. This means that the intense stimulus of light has evoked in the retina multiple responsive sensations.

The same is true, in like manner, of all forms of mental stimulation. Such, when very intense, is always apt to repeat itself and become persistent. And it is in vain that we seek to escape from its recurrence. We are dogged by our own thoughts, and even in our dreams they return to us. Like other forms of living matter, further, nervous tissue is tuned to added responsiveness by the very stimulus that impinges upon it. The nerve unstimulated lies passive and inert. The nerve already subjected to stimulus has been energised by it, and its sensibility enormously exalted. Thus every moment of our present is coloured by the store of our latent memories. Stimulation by thought actually increases our power of thought. It is by the accumulation of such stimulus and our own directive activity, that nervous matter ultimately becomes automatic or autonomous, a phase which is seen in many steps, from the birth of thought to inspiration.

Thus we have traced out the continuity of response, from simple, through multiple to autonomous, in plant and animal alike. A moderate stimulus evokes a simple response, whether this be mechanical, or electrical, or even by sensation or thought. Strong stimulus, on the other hand, gives rise to multiple responses, in all their various forms. Excess of absorbed energy, derived from the sum of various environmental stimuli, bubbles over, as it were, and shows itself in rhythmic autonomous response. This phenomenon we see variously manifested, now in the beating of the heart, again in the pulsation of *Desmodium* leaflets, elsewhere in the ascent of sap, or pulsating growth, and even in echoing sensation and persistent thought.

Thus we see that, in one sense, the living organism is simply a machine. That is to say, all its parts have to be maintained in a state of mobility. Molecular rigidity, or the arrest of this machine, means death. This view may appear to some of us as extremely materialistic. But in order to keep the machine at work, in all those wonderful and complex ways of which it is capable, from mechanical movement, through throbbing sensation, to spontaneous thought, something more than mere mechanical perfection is necessary. We have seen that the most perfect type of organism when isolated soon ceases its activity. In order, then, to maintain it in spontaneity, or livingness, the in-pouring of energy is necessary from without. Every living organism, in order to maintain its life, must stand in constant free communion with all the forces of the universe about it.

Is this in truth materialism? Or is it spirituality? May it not be that we dispute these terms, because each of us is viewing a single fact from a different standpoint?

DEATH SPASM IN PLANTS.

Under the presidency of the Hon'ble Mr. P. C. Lyon, a meeting was held at the University Institute, Calcutta, on Thursday, the 5th February, 1914, when Dr. J. C. Bose delivered a very interesting lecture on " Death Spasm in Plants" before an appreciative audience. In the course of his lecture, Dr. Bose said :—

A living organism is living so long as it is responsive to the forces of its environment; it throbs in reply to each shock that it receives. Immediately after a blow, the organism becomes dazed or is irresponsive,—it regains its sensitiveness after a definite period for full recovery. Activity and insensibility,—tokens of life and death—are thus alternate. Recovery becomes protracted with increased intensity of excitation; under excessive stimulus the line of recovery becomes projected to infinity. Death is thus an extreme case of excitation.

In throbbing organisms, animal and vegetable, the rhythmic pulsations come to a stop at the moment of death.

Experiment was shown where a long pointer inscribed, in lines of light, the pulse-records and their arrest at the moment of death. Dr. Bose proceeded :—

The difference between the conditions of a tissue, living and dead, is one of molecular transformation from a state of mobility to one of interlocked rigidity. At the crucial moment, particles of the living tissue are swinging in their unstable poise, and then the molecular mechanism is interlocked in death. If we could trace the history of the molecular conflict, then and then only, could we expect to gain an insight into the secrets of life and death. For this we have to call to our aid senses we do not ourselves possess. We must have the struggle between life and death recorded automatically by the dying organism, and we must also learn to read their hieroglyphics.

SLEEP AND DEATH.

There are plants which do not exhibit any conspicuous throbbing. They can, however, be made to record questioning shocks, of slight and varying intensity and the amplitude of the responsive twitch gives a measure of the vitality of the organism. As the life-activity wanes, the answering records become smaller and smaller till, at the moment of death, it completely disappears. Sleep is a phenomenon which mimics death.

The lecturer explained the apparatus which he had invented in which the scripts made by the plant showed periodic waking and sleeping of the plant.

Contrary to current views the plant was awake till early in the morning; it remained in deepest sleep from

6 to 9 in the morning. In sleep the loss of excitability was periodic and temporary, but in death it was permanent. There was common error in regarding ordinary plants as insensitive. Experiments were shown which demonstrated that each shock provoked in every plant a spasmodic movement. Under the torture of continuous electric shocks the [illegible] of the plant were terrible to witness; this only came to an end with death by electrocution.

MORTOGRAPH.

Continuing Dr. Bose said :—

Death, whose symptoms have been considered, was brought about by abrupt and violent means. Is there any sign by which, as life gradually ebbs away, the moment of transition is determined with precision? The specimen is placed in a bath, whose temperature is continuously raised till the irreversible death-change occurs.

The lecturer's Mortograph or Death Recorder, traces a curve which determines accurately the death-point. In the script the line that, up to this point, was being drawn, becomes suddenly reversed.

This is the last answer of the plant. The death-point is very definite under normal conditions, but becomes dislocated under the action of fatigue and of drugs. Characteristically different are the death-records of the young and old. In the former the death-spasm is violent whereas in the latter it becomes less abrupt; with extreme age life is seem to merge imperceptibly into death without any struggle.

TRANSIENT FLASH OF MEMORY.

In the sensitive surface of the brain some molecular impress is left of past stimulation and experience. These remain latent till under the impulsive shock of the will, they become revived. A strong and diffuse stimulation thrown on the impressioned surface may thus revive dormant images.

The lecturer had heard from reliable witnesses revived from drowning of the flash of memory, which renewed the pictures of the past before what might have been the last moment of struggle.

An experiment was next shown which demonstrated that, at the death struggle, an intense electric discharge passes through the organism.

It is thus seen, the Doctor continued, that it is quite possible for this strong and diffuse stimulation—now involuntary—to crowd into one brief flash, a panoramic succession of all the memory images latent in the organism.

THE PRAYING PALM TREE.

In January 1918, Sir J. C. Bose delivered at the Bose Institute an interesting lecture explaining the Mystery of the Praying Palm Tree; there was a large and distinguished gathering. His Excellency Lord Ronaldshay, who presided, made a brief speech eulogising the services of the great scientist. Sir J. C. Bose then delivered his lecture which was illustrated by a series of striking experiments. He said:—

" In the dim caverns of Ajanta there is a symbolic fresco, depicting the Cosmic drama of the eternal struggle of light with darkness. The reproduction of that fresco in metal is seen in this very Hall. Out of seething chaos are rising vapours which form themselves into two apparitions, in deadly conflict. One of these represents the spirit of light, the other of darkness. As the sun of [illegible] rises on his chariot, the power of evil or darkness is being overpowered. That conflict which the ancient fresco depicted fifteen centuries ago is still raging, and men and nationalities have ranged themselves in battle array now in a struggle of right against might as they did thirty centuries ago, when Arjuna with the divine message still ringing in his cars awaited, in the fields of Kurukhetra, the hostile shock of the mighty Kaurava host. The same conflict is raging in other fields, the conflict of knowledge with ignorance. Not even the realm of science is free from this eternal struggle.

And this is inevitable, for owing to the limitations of our mind and the imperfection of our senses, the real is hidden under an obscuring veil of darkness. We are baffled at every point in our course of inquiry. In seeking for some universal law we meet with numerous contradictions: this is specially so in the study of the phenomenon of life. Turning to the simplest type of life as exhibited by plants, we hardly find a single fact which is not contradicted by something directly opposite. Thus certain leaves turn towards light, others away from it. Roots bend down in response to gravity; shoots on the other hand, rise in opposition to gravity. Thus there appears no fixity of law in nature; things appear to happen as if by chance or through caprice.

But in reality this is not so; if we are consumed with a passion for truth, and if we have infinite patience, we shall gradually find that the contradictions are apparent and not real; we shall then realise a great underlying unity behind the bewildering diversity.

THE PRAYING TREE.

Perhaps no phenomenon is so remarkable and shrouded with greater mystery as the performances of a particular palm tree near Faridpore. In the evening while the temple bells ring calling upon people to prayer, this tree bows down as if to prostrate itself.

It erects its head again in the morning, and this process is repeated every day during the year. This extraordinary phenomenon has been regarded as miraculous, and pilgrims have been attracted in great numbers. It is alleged that offerings made to the tree, that is to say to the custodian of the tree, have been the means of effecting marvellous cures. It is not necessary to pronounce any opinion on the subject; these cures may be taken as effective as other faith cures now so fashionable in the West.

I first obtained photographs of the two positions which proved the phenomenon to be real. The next thing was to devise special apparatus to record continuously the movement of the tree day and night. But difficulties were encountered in getting the consent of the proprietor to attach foreign instruments to the sacred tree. His misgivings were however removed when it was explained that the instruments were pure Swadeshi, being made in my Laboratory. The records of the Palm Tree showed that it fell with the rise of temperature, and rose with the fall. Records obtained with other trees brought out the extraordinary and unsuspected fact that all trees are moving—such movements being in response to changes in their environment.

SENSITIVE OR INSENSITIVE.

That not a "Mimosa" alone, but all plants are sensitive was demonstrated by some striking experiments. A spiral tendril, under electric shock was shown to writhe imitating the contortions of a tortured worm. In ordinary plants, all sides being equally sensitive, contraction takes place on all directions with resulting neutral effect. Another striking experiment was to show how ordinary plants could be made sensitive by the mere process of amputation of the balancing half? Further experiments were shown demonstrating the effects of light, of warmth and other stimuli on the plant. Warmth worked antagonistically to light. The numerous permutations brought about by two changing variations were shown by a mechanical hand, which traced most complicated curves. In actual life the number of changing factors are very numerous, hence the intricasy involved in the manifestations of life.

The experiments that have been shown will help the audience to realise in some measure that the world we live in is not a theatre of caprice or chance, but that an all pervading law holds and regulates its destiny. We have seen that the vast expanse of life which is unvoiced, seemingly so impassive, is instinct with sensibility. Thus the whole of the vegetable world, including rigid trees perceive the changes in their enviroment and respond to them by unmistakable signals. They thrill under light and become depressed by darkness: the warmth of summer and frost of winter, drought and rain, these and many other happenings leave a subtile impress on the life of the plant. By invention of apparatus of extreme delicacy, it is possible to make the plant itself write down the history of its own experience in a hieroglyphic which it is possible to decipher. From these pages, taken from the diary of the plant, it will perhaps be possible some day to get an insight into the great mystery that surrounds life itself. For I shall, in the course of lectures given here, show how the life of plants is a mere reflection of our own. I shall show how shocks and wounds affect them as they affect animals; how a common death-throb marks the crisis when life passes into death. The exuberance of life, on the other hand, will be shown by pulsing throbs of animal's heart and spontaneous heart in vegetal tissues. Another aspect of this exuberance will be shown in the imperceptible growth of plants. My recently invented Crescograph, to be exhibited at my lecture a fortnight hence, will magnify growth a million-fold and record ultra-microscopic movements, smaller than a single wave length of light. By this new apparatus growth will be instantaneously recorded and conditions which foster or inhibit growth discriminated. I shall demonstrate my discovery of the nervous system in plants, and show how shocks from without pass within, and how this nervous impulse modified during transit. It will further be shown how various stimulants, anaesthetics and poisons induce effects which are identical in man and in plant. It will be obvious how these studies will open new fields of inquiry in different branches of science; in Physiology and Psychology; in Medicine and in Agriculture.

THE MAGNETIC CRESCOGRAPH.

I

[Sir J. C. Bose delivered, on the 18th January 1918, at the Bose Institute, the second of the series of discourses on Revelations of Plant Life. The audience had the opportunity of witnessing the working of Bose's newly perfected Crescograph, an apparatus that gives a visual demonstration of movements far beyond the highest powers of miscroscope.]

LAW VERSUS CAPRICE.

Dr. Bose began by first describing the infinite variations in life reactions in plants. The same external stimulus, he said, apparently produces one effect in one plant: and precisely opposite in another. Some leaves move towards light ; others are repelled by it. The root bends towards the centre of the earth, the shoot rises above away from it. Numerous other " tropic " movements are caused by contact by electricity, by moisture and by invisible radiations. These effects appear so extremely diverse and capricious that some of the leading physiologists were forced to come to the conclusion that there was no law guiding such movement, but that the plant decides for itself what should be the effect of external conditions on it.

RECORD OF GROWTH.

Most of these tropic movements are brought about by changes induced in growth by the action of different forces. But growth is so excessively slow that slight changes induced in it are impossible of detection. The proverbially slow paced snail moves two thousand times faster than the growing point of a plant. Hence to visualise growth and its changes, apparatus has to be invented which would magnify growth something like a million times. If such a thing were possible, the pace of the snail would be quickened to the speed of a rifle bullet. The difficulties in connection with the devising and construction of apparatus with this extraordinary power appear at first an impossibility. The jewels for the fittings of the apparatus could not be found fine enough. The lecturer had to discard ordinary jewels for diamonds, such bearings being only made in Germany. But the outbreak of the war put an end to this source of supply. He had then to turn to resources available in India.

ADVANCE OF AGRICULTURE.

The invention of method for immediate record of growth and its variations under various conditions is one of immense practical importance. Experiments on gigantic scales are in progress all over the world for this purpose. At Rothamstead, this work has been going on for more than half a century. The great Department of Agiculture in Washington spends millions every year on such experiments, there being a thousand men employed in research. Recently many experiments have been undertaken on the effect of electricity on growth.

The results obtained have been mostly contradictory. For real advance in agriculture we must first discover the laws of growth. Ordinary experiments on growth are of little value because they take weeks for detecting changes of growth which might have been brought about by charges in the environment. The only satisfactory method is to devise an apparatus which would make the plant itself record the rate of its growth, and the changes induced by food or treatment in the course of less than a minute, during which short time it is possible to maintain external conditions constant.

THE MAGNETIC CRESCOGRAPH.

All the difficulties connected with the devising of apparatus has been completely removed by the lecturer's successful invention of his new magnetic crescograph in which practically unlimited magnification is obtained without the difficulties arising from the unavoidable friction of bearings. Magnetic forces are so exactly balanced that a disturbance in the balance caused by slightest movements such as that of growth is magnified ten millions of times. The application of this new principle will be of great importance in various investigations in Physics.

[*Sir J. C. Bose next demonstrated some marvellous results obtained with his apparatus. A seedling which on account of the winter season appeared stationary jotted down by taps on a moving plate, the rate of its growth. The application of a* *chemical instantly arrested this growth, but an antidote timely applied, not only removed the torpor but enhanced the growth at an enormous rate*]

The lecturer explained how the effect of a given agent—a chemical solution or an electric current—is profoundly modified by the dose, a given intensity producing one effect and a different intensity giving rise to an effect diametrically opposite. This is the reason of the inexplicable anomalies which have baffled many investigators. Numerous are the forces which act on growth, some helping, others retarding, the effects being further modified by the strength and duration of application. These factors that determine growth are each to be studied in detail, and the laws of effect of each to be discovered. There can be no real advance in scientific agriculture until this is done.

II

[*Sir Bose's Super-magnifier was exhibited again before an appreciative gathering in Calcutta on the 10th January, 1919. A number of lady students, professors, lawyers, doctors and several eminent personages gathered to hear the great Indian scientist. We take the following report from the 'Patrika.'*]

In his discourse on the above subject Sir J. C. Bose illustrated how the limitations imposed on the advance of science by the imperfection of our senses may stimulate the invention of super-sensitive apparatus which reveals to us the existence of phenomena hitherto unknown. Thus the invention of the microscope from a simple lens magnifying 3 or 4 times into progress up to 1500 diameters has given birth to new sciences. But still higher [illegible] is demanded in unravelling the mystery of movements associated with the simplest type of life as seen in plants. Greatest potentiality in life is often latent; the gigantic banian tree grows out of a thing which is smaller than the mustard seed. Within the seed-coat the dormant life remains in safety, protected from dangers outside. The seeds may thus be subjected without harm to cold so intense as will freeze mercury into solid and air into liquid. Winds and hurricanes scatter the seed of life and the cocoanut rides the tumultuous waves till anchored safe in an island yet to be inhabited. In due season there begins a series of most astonishing transformations; the latent life wakens, and the seedling begins to grow. The root turns downwards and the shoot upwards. Underground, the root winds its way round stones and obstacles towards moist places. Above ground the stem bends as if in search of light. Tendrils twine about a support. These visible movements are striking enough, but within the unruffled exterior of the plant-body there are others, [illegible] and incessant, which escape our scrutiny. The bending of a growing organ towards or away from stimulus must be due to unequal growth on two sides of the organ, a retardation of growth on the proximal or acceleration on the distant sides.

Various theories have been advanced which have proved inadequate. For, the identical stimulus of gravity produces one kind of curvature in the root and the very opposite in the shoot. The possibility of direct experimental investigation has been frustrated by the excessive slow rate of growth rendering accurate measurement impossible.

THE SLOWNESS OF GROWTH.

The movement of growth is two thousand times less rapid than the pace of the proverbially slow-footed snail. Taking the average annual growth in height of a tree to be 5 ft., it will take a tree a thousand years to cover a distance of a mile. We take a piece of 2 ft. in the course of half a second, during the interval plant grows through a length of 1,100,000 part of an inch or half the length of a wave of light. For investigation on the effect of external conditions on growth we have to measure even a fraction of that excessively small length.

The peasant has eagerly watched the growth of his plants on which his own life and the world's depend and, even realised something of its vicissitudes, so the vegetable physiologist has here one of the many problems of his science. The invention of growth-measuring instruments has thus been one of his main endeavours. He has hitherto succeeded by the use of levers with unequal arms to obtain a magnification of about 20 times, and even then it takes many hours for growth to become perceptible; owing to the practical impossibility of maintaining the external conditions constant for so many hours, the results of measurement of growth become vitiated. It is therefore necessary to produce a magnification so high that growth should become measurable in less than a minute. The first improvement effected by the lecturer, now some fourteen years ago, was his Optical Lever, which at once raised the magnification from 20 to 1000 times, an advance which at the time seemed to many incredible, but it is at length coming into use in advanced laboratories in Europe.

THE RECORDING CRESCOGRAPH

A new apparatus devised by the lecturer, the Recording Crescograph, is described in the Transactions of the Royal Society, and of the Bose Institute. By a compound system of levers the magnification is raised to 10,000 but this is not without great technical difficulties, which cost five years of efforts to overcome. Thus the levers require to be extremely light; this was secured by the use of an alloy of aluminium used in the construction of Zeppelins: this combines lightness with rigidity. Another difficulty almost unsuperable arises from the friction at the bearings of the fulcrum; the best watch jewels made of ruby were employed, but the supply was cut off from Germany by the war. This proved a blessing in disguise, for it forced the lecturer to devise a new principle of suspension using local material. This was found in practice to be far superior to jewel bearings, which became clogged by invisible dust particles present in the air. With this Recording

Crescograph many phenomena of extreme interest have been discovered. The plant itself not only recorded its normal rate of growth but the slightest change induced in it by the action of different forces. So delicate was the apparatus that it analysed growth into a series of pulses, a sudden shooting out followed by a partial recoil. It showed how the growth of plant was retarted by a mere touch, and the time it took the plant to recover from the effect of contact, and all these in course of a few seconds. The effect of different food on growth, the effect of different drugs on living capacity, these and many more became revealed by the automatic record made by the plant. This has opened out fresh and more exact method of medical inquiry, and of practical agriculture.

The Magnetic Crescograph.

Such unlooked for results called for yet higher magnification, and at first it seemed that further multiplying lever might be added to the previous system. But this failed on account of added mass and friction; and some altogether new solution had therefore to be sought. Material contact having proved unworkable the ideal weightless and frictionless linking was obtained by introducing a new magnetic contrivance, and this with the surprising potency of magnification from 5 to 100 million times. The mind cannot grasp the meaning of this stupendous magnification; how then could we translate it in terms which may be understood? Let us take once more our slow-footed snail; a magnification of ten million times would convert its speed to something for which there is no parallel even in modern gunnery practice. The 15 inch cannon of the "Queen Elizabeth" has a muzzle velocity of 2360 ft. per second or 8½ million feet per hour. But the speed of the snail when magnified ten million times would render it 200 million ft. per hour or 24 times faster than the fastest cannon shot. We may next turn to the cosmic movement for a parallel. A point in equator whirls round at the rate of 1037 miles per hour. But a snail with the magnified speed would beat the earth by going round 40 times during the period the earth makes but one revolution!

Life in State of Suspense and its Subsequent Resolution.

With the experiments carried with the Magnetic Crescograph life becomes subservient to the will of the experimenter. The rate of growth is indicated by the speed with which a spot of indicating light moves across the scale. The actual rate of growth is fifty-thousandth part of an inch per second; this, under magnification, is seen by the indicating spot of light to move at the rate of 36 inches per second: this is the normal rate. The plant is made to imbibe soda water and the growth becomes suddenly exalted some ten times; but a puff of tobacco smoke instantly retards the rate. To induce further retardation a depressing drug is next applied. The growth gradually comes to a stop and the quiescent of the spot of light shows life in a state of suspense. The plant is now hovering in an unstable poise between life and death, a slight tilt one way, and life gets interlocked in the rigidity of death. But the antidote is applied just in time, the torpor and suspense is over, and life renews her activity once more with the fullest vigour.

It is true that man is but poorly provided for his voyage of discovery in seas unknown, he can hear little and see less. A single octave of light circumscribes his vision: even of the visible the size of the ripple of light imposes an impassable barrier. But he has not been deterred by his limitations but has, on the contrary, been spurred on its greater efforts in his explanation of the invisible. The mysterious movements of life are not to remain for him inscrutable and indecipherable for all times: but his untiring and single-minded pursuit will someday reveal to him the secret that lies behind the manifestations of life.

THE UNITY OF LIFE.

[Under the auspices of the Bombay University, Sir Jagadis Chandar Bose deliverea, on the 31st January, 1918, a lecture on the " Unity of Life." It was illustrated by lantern slides and an instructive exposition was given of some of his unique discoveries in the realm of Plant Life The following is a summary of the lecture].

HIDDEN HISTORY IN PLANT'S LIFE.

. The subject of my address to-night is the " Unity of Life." Under a placid exterior there is a hidden history on the life of the plant. Is it possible to make the plants write down their own

and thus reveal their history ? In order to succeed in this we have first to discover some compulsive force which will make the plant give an answering signal ; seeondly, we have to invent some instrument of extreme delicacy for the automatic conversion of these signals into an intelligent script ; and last of all, we have ourselves to learn the nature of the hieroglíphics.

[Sir J. C. Bose then explained the principle of his epoch-making Reasonant Recorder which writes down the perception period of the plant within a thousandth part of a second, and writes down the

action of light and warmth and drugs on the plant; the effect of vitiated air, of passing clouds, of excess of food and of drink].

The plant is very human in its virtues and weakness. Plants like animals become exalted, grow tired or despond. An easy green-house life makes them less than themselves, overgrown and flabby, capable of response, till they have become hardened by adversity to a fuller existence. A time comes when, after an answer to a supreme shock, there is a sudden end of the plant's power to give any further response. This supreme shock is the shock of death. Even in this crisis there is no immediate change in the placid appearance of the plant. Drooping and withering are events that occur long after death itself. How does the plant then give its last answer? In man at the critical moment a spasm passes through the whole body and similarly in the plant I find a great contractile spasm takes place. This is accompanied by an electrical spasm also. In the script of the Death Recorder the line that up to this time was being drawn, become suddenly reversed and then ends. This is the last answer of the plant.

These our mute companions, silently growing beside our door, have now told us the tale of their life-tremulousness and their death-spasm in script that is as inarticulate as they. May it not be said that this story has a pathos of its own beyond any that we may have conceived?

We have now before our mind's eye the whole organism of the perceiving, throbbing and responding plant a complex unity and not a congeries of unrelated parts. The barriers which separated kindred phenomena in the plant and animal are now thrown down. Thus community through it the great ocean of life is seen to outweigh apparent dissimilarity. Diversity is swallowed up in unity.

In realising this, is our sense of final mystrey of things deepened or lessened? Is our sense of wonder diminished when we realise in the infinite expanse of life that is silent and voiceless the foreshadowings of more wonderful complexities? Is it not rather that science evokes in us a deeper sense of awe? Does not each or her new advances gain for us a step in that stairway of rock which all must climb who desire to look from the mountain tops of the spirit upon the promised land of truth?

[*Sir Jagadis then gave an interesting exposition of his researches with the aid of magic lantern slides.*]

Sensitiveness in Plants.

Referring first of all to his discovery of sensitiveness in plants, he said that in that respect they were akin to the human system.

[*He illustrated this truth by a demonstration of the reaction that takes place in the frog when a shock is communicated and side by side presenting the reaction that is similarly effected in the plant.*]

"Plants have a nervous . system like our own," he said, and, with the aid of an enlarged illustration of the mimosa, he showed the changes that took place when the plant was disturbed. Turning to the plant autograph, he spoke of the Resonant Recorder, a special apparatus which he has invented to prove how even plants are tuned to environment. Certain tunes had no effect on plants, he said, while others had and he asked them specially to observe the beautiful and variegated colour formation produced by their response to tunes.

[He gave an interesting experiment on this point, and both Lord and Lady Willingdon tried it. There was a great outburst of cheering, which was renewed each time the effect was produced, and it was noticed that the cheering, which was vociferous, had its own effect.]

It had taken him a long time, he said, to produce and perfect the complete apparatus to determine the latent mimosa and by the aid of that apparatus, he was able to record the movement of the plant to one-thousandth of a second.

He next went on to say that all plants were endowed like ourselves, but at first the news was received with great scepticism. He did not despair, however, of success and was continuously engaged in discovering, in collecting fresh evidence. Thanks to the action of the Government of India in sending him on a world tour, he got at last the opportunity to prove before the scientific societies of the world, the truth of his discoveries.

[*An illustration of the Mimosa which accompanied him in his world tour was screened. The next illustration was to show how long plants took to feel shock and what time they took to recover*].

Like the great human system plants were subject to periodic changes and had their periods of sleep and awakening. The extra water pressure produced during sunset had nothing to do with true sleep. Plants, too, were subject to exaltation and depression and at certain hours of the day they were fully conscious and active while at other hours they were dormant and lazy.

[*He showed by means of a chart that they were fast asleep between 6 and 9 in the morning and his humorous remark that, in that respect, they had taken a leaf from our modern society ladies, provoked a great deal of laughter. A series of records were then shown to illustrate the various degrees of plant consciousness, which were deeply appreciated by the audience.*]

Proceeding, Dr. Bose said that plants were far more conscious of nature than human beings and described his experience how plants were sensitive even to passing clouds, which produced on them a depressing effect. He spoke of the difference between thin and wiry grown plants and those that were stout and robust. In that respect they resembled again human beings and thin and wiry grown plants were far more susceptible of excitement than the others. They, too, needed rest and without it, they were flabby and depressed.

[*A cartoon from the London "Punch" entitled "A Successful Trial" was screened to the merriment of the audience, in which the Professor was humurously depicted by that journal, after his exposition before the Royal Institute in London. He gave an illustration of the "Praying Palm of Faridpur" and the changes it exhibited to environment.*]

All plants displayed similar power and these changes were no longer inscrutable. They had been brought within the realm of scrutability and could be recorded.

"PROTECTING" PLANTS.

It was a mistake to suppose that, when "protected", plants would thrive better. Mothers had a tendency to keep their children away from contact with the outside world with a view to "protect" them. He had placed a plant under a glass case and the effect of it was he had a gloated and effete specimen, flabbly-looking in appearance and weary under adversity, they recovered sooner and their growth was healthy just as it evolved true manhood in men. It had been commonly believed that carbonic acid gas was conducive to plant growth. That was a great mistake. In sunshine, plants readily absorbed it; but it was no more true that plants thrived on CO_2 than did human beings. He illustrated the effect of carbonic acid gas as well as oxygen. The latter was as much necessary for plants to thrive on as it was for them. Another illustration exhibited the effect of alcohol on plants and he declared amidst laughter that alcohol produced the same alternate maudlin depression and exaltation on plants that is to be observed on the human system. He said that this experiment had tickled the Americans a great deal and referred to a conversation he had with Mr. Bryan, who was a teetotaller, regarding alcohol given to plants. Some American papers had given characteristic headlines to introduce his lecture on the effect of stimulus on plants.

Another plant, Desmodium, which accompanied him in his world tour was filmed on the screen.

He spoke, next, of the apparatus which he had invented to record plant pulsation and the struggle they exhibited between life and death. Poisons had as much effect on plants as on men, and they could be revived by applying antidotes, [this was illustrated by another chart.] Another point of interest dealt with by him was the effect of warm water on plants, and he gave an exposition of his discovery to show that plants died when placed in 60 degree (centigrade) warm water. He referred to the stupendous phenomenon of invisible writing by means of which the plant recorded its own evolution.

THE AUTOMATIC WRITING OF THE PLANT.

[*On the 8th February 1918, Sir J. C. Bose delivered the following discourse on "The Automatic Writing of the Plant,', at the Bose Institute. The following summary is taken from the 'Patrika:'*]

Sir J. C. Bose spoke of two different ways of gaining knowledge, the lesser way is by dwelling on superficial differences, the mental attitude which makes some say 'Thank God, I am not like others:' "The other way is to realise an essential unity in spite of deceptive appearance to the contrary. He had recently been on a visit to the Western Presidency, he went there as a stranger, but he has come back with a pang at parting from kindreds. Never in his life did he realise so vividly as now the great unity that drew together all who regarded India as their home and place of work. They were bound to each other by mutual ties of dependence. He had for many years been engaged in discovering community in physical manifestations of life. Now he has realised an abiding unity in the highest manifestations of human life, in community of thoughts and ideals.

In the wide expanse of life itself few things would appear so strikingly different as the life activities in plants and in animals. But if in spite of the seeming differences, it could be proved that these life activities are fundamentally similar, this would undoubtedly constitute a scientific generalisation of very great importance. It would then follow that the complex mechanism of the animal machine, that baffled us so long, need not remain inscrutable for all time, for the intricate problems of animal physiology would then naturally find their solution in the study of corresponding problems under simpler conditions of vegetative life. That would mean an enormous advance in the science of philosophy, of agriculture, of medicine, and even of psychology.

How then are we to know what unseen changes take place within the plant? The only conceivable way would be, if that were possible, to detect and measure the actual response of the organism to a definite testing blow. When an animal receives an external shock it may answer in various ways; If it has voice, by a cry, if dumb, by the movement of its limbs. The external shock is the stimulus, the answer of the organism is the response. If we can make it give some tangible response to a questioning shock, then we can judge the condition of the plant by the extent of the answer. In an excitable condition the feeblest stimulus will evoke an extraordinarily large response, in a depressed state even a strong stimulus evokes only a feeble response, and lastly, when death has overcome life, there is an abrupt end of the power to answer at all.

Prof. Bose then explained the principle and action of his apparatus by which the plant attached to it is automatically excited by successive stimuli which are absolutely constant. In answer to this the plant makes its own responsive records, goes through its own period of recovery, and embarks on the same cycle over again without assistance from the observer at any point. In this way the effect of changed external conditions is seen recorded in the script made by the plant itself.

It has been thought that plants like mimosa alone were sensitive. But the apparatus demonstrated the unsuspected fact that every plant and every organ of every plant answered to a shock by a contractile spasm, as by an animal muscle. If perception of feeble stimulus be taken as a measure of ascent in the scale of life then the superiority of man must be established on a foundation more secure than sensibility. The most sensitive organ by which we can detect electric current is our tongue. An average European can perceive a current as feeble as six micro-amperes, a micro-ampere being a millionth part of the electric unit. Possibly the tongue of a Celt is more excitable, and I have no doubt that my countrymen can easily boast the Celt in this particular test. But the plant mimosa is ten times more excitable than the tongue of an advocate in this province.

[*Professor Bose then showed how identical were the effects of light, warmth and various drugs on plant and animal.*]

These experiments bring the plant much nearer than we ever thought. We find that it is not a mere mass of vegetative growth, but that its every fibre is instinct with sensibility. We are able to record the throbbings of its pulsating life, and find these wax and wane according to the life conditions of the plant, and cease in the death of the organism. In these and many other ways the life reactions in plant and man are alike, and thus through the experience of the plant, it may be possible to alleviate the sufferings of man.

CONTROL OF NERVOUS IMPULSE.

[*Sir J. C. Bose delivered the following address at the first Anniversary Meeting of the Bose Research Institute held on Nov. 30, 1918, under the presidency of H. E. Lord Ronaldshay, Governor of Bengal :*]

It is one of the greatest of all mysteries how we are put in connection with the external world; how blows from without are felt within. Our organs of sensation are like so many antennæ radiating in various directions and picking up messages of many kinds. All of these, when analysed to their utmost, consist of shock effects on different chords. An extremely feeble stimulus is below the limit of perception, a moderate stimulus transmits excitation, which is perceived as sensation of not an unpleasant character : but the tone of sensation becomes painful when the excitation is very intense. Our sensation is thus coloured by the intensity of the nervous excitation that reaches the central organ. We are subjet to human limitations, through the imperfection of our senses on the one hand, and over-sensibility on the other. There are happenings which elude us because the [illegible] stimulus is too feeble to waken our senses, on the other hand, the external shock may be so intense as to fill our life with pain. Since we have no direct power over the shocks which come to us from the outside world, is it possible to control the nervous impulse so that it should be exalted in one case, and inhibited or obliterated in the other? Does advance of science hold any such possibility? This question is plainly fraught with high significance.

Control of Nervous Impulse.

Before proceeding further, it will be necessary first to obtain a clear idea of the function of a nervous tissue and its charactesistics; secondly, the manner in which the nervous impulse is propagated, and lastly we have to discover some compulsive force by which the impulse may be intensified or inhibited during transit. The nerve circuit may be likened to an electric circuit, an invisible impulse bringing about response in the indicator, be it the brain, or the galvanometer. In the electric circuit the conducting power of the metallic wire is constant, and the intensity of the electric impulse depends on the intensity of the electric force applied. If the conducting power of the nerve were constant, then the intensity of the nervous impulse and its resulting sensation would depend inevitably on the intensity of the shock from outside which starts the impulse. In that case the possibility of the modification of our sensation would be an impossibility. But there may be a likelihood that the power of conduction possessed by a nerve is not constant but capable of change. Should this surmise prove to be correct, then we arrive at the momentous conclusion that sensation itself is modifiable, whatever the external stimulus. For the modification of nervous impulse there remains only one alternative, namely, some power to render the vehicle a very much better conductor or a non-conductor according to particular requirements. We require the nervous path to be supra-conducting to have the impulse due to feeble stimulus brought to sensory prominence. When the external blow is too violent we would block the painful impulse by rendering the nerve a non-conductor.

Under narcotic the nerve becomes paralysed. But such heroic measures are to be resorted to in extreme cases, as when we are under the surgeon's knife. In actual life we are confronted with unpleasantness without notice. A telephone subscriber has an evident advantage, for he can switch off the connection when the message begins to be unpleasant. Statesmen and politicians have been known to cultivate convenient deafness; but that is a mere pretence. The unpleasant things heard, would still continue to rankle. It is not every one that has the courage of Mr. Herbert Spencer who openly resorted to his ear plugs whenever his visitor became tedious.

The propagation of nervous impulse is a phenomenon of transmission of molecular disturbance. The transmission could be controlled if a compulsive force were discovered which would confer on the conducting particles two opposite molecular dispositions, one of which would exalt and the other resist the impulse.

Dr. J. C. Bose has made a few experiments for this puruose.

RESPONSE OF PLANTS TO WIRELESS STIMULATION.

[*The following account of the Response of Plants to wireless stimulation appears in the second volume of the Transactions of the Bose Institute.*]

A growing plant bends towards light; this is true, not only of the main stem, but also of its branches and attached leaves and leaflets. This movement in response is described as the tropic effect of light. Growth itself is modified by the action of light: two different effects depending on the intensity are produced; strong stimulus of light causes a diminution of rate of growth, but very feeble stimulus induces an acceleration of growth. The tropic effect is very strong in the ultra-violet region of the spectrum with its extremely short wave-length of light; but the effect declines practically to zero as we move towards the less refrangible rays, the yellow and the red, with their comparatively long wave-length. As we proceed further in the infra-red region we come accross the vast range of electric radiation, the wave-lengths of which vary from the shortest wave I have been able to produce (0·6cm.) to others which may be miles in length. There thus arises the very interesting question whether plants perceive and respond to the long æther-waves, includ ing those employed n signalling through space.

At first sight this would appear to be very unlikely, for the most effective rays are in the ultra-violet region with wave-length as short as 20×10^{-6} cm.; but with electric waves used in wireless signalling we have to deal with waves 50,000,000 times as long. The perceptive power of our retina is confined within the very narrow range of a single octave, the wave-lengths of which lie between 70×10^{-6} cm. and 35×10^{-6} cm. It is difficult to imagine that plants could perceive radiations so widely separated from each other as the visible light and the invisible electric waves.

But the subject assumes a different aspect when we take into consideration the total effect of radiation on the plant. Light induces two different effects which may broadly be distinguished an external and internal. The former is visible as movement; the latter finds no outward manifestation, but consists of an 'up' or assimilatory chemical change with concomitant increase of potential energy. Of the two reactions, then, one is dynamic, attended by dissimilatory 'down' change; the other is potential, associated with the opposite 'up' change. In reality, the two effects take place simultaneously; but one of them becomes predominant under definite conditions.

The modifying condition is the *quality* of light. With reference to this I quote the following from Pfeffer; 'So far as is at present known, the action of different rays of the spectrum gives similar curves in regard to heliotropic and phototactic movements to protoplasmic streaming and movements of the chloroplastids, as well as the photonastic movements produced by growth or by changes of turgor. On the other hand, it is the less refrangible rays which are most active in photosynthesis.' The dynamic and potential manifestations are thus seen to be complementary to each other, the rays which induce photosynthesis being relatively ineffective for tropic reaction, and *vice versa.*

Returning to the action of electric waves, since they exert no photosynthetic action they might conceivably induce the complementary tropic effect. These considerations led me to the investigation of the subject fourteen years ago, and my results showed that very short electric waves induce a retardation of rate of growth; they also produce responsive movements of the leaf of Mimosa when the plant is in a highly sensitive condition. The energy of the short electric waves is very feeble, and undergoes great diminution at a distance; hence the necessity for employment of a plant in a highly sensitive condition.

I resumed my investigations on the subject at the beginning of this year. I wished to find out whether plants in general perceived and responded to long æther-waves reaching them from a distance. The perception of the wireless stimulation was to be tested, not merely by the responsive movement of sensitive plants, but also by diverse modes of response given by all kinds of plants.

THE WIRELESS SYSTEM.

For sending wireless signals I had to improvise the following arrangement, more powerful means not being available. The secondary terminals of a moderate-sized Ruhmkorff's. coil were connected with two cylinders of brass, each 20 cm. in length; the sparking took place between two small spheres of steel attached to the cylinders. One of the two cylinders was earthed and the other connected with the aerial 10 meters in height. The receiving aerial was also 10 metres in height, and its lower terminal led to the laboratory, and connected by means of a thin wire with the experimental plant growing in a pot; this latter was put in electric connection with the earth. This distance between the transmitting and receiving aerial was about 200 metres, the maximum length permitted by the grounds of the Institute.

I may state here that with the arrangement described above I obtained very definite mechanical and electric response to wireless impulse. For the former I employed the plant Mimosa; the latter effect was detected in all plants, sensitive and ordinary.

EFFECT OF WIRELESS STIMULATION ON GROWTH.

For the detection of variation of growth it was necessary to devise the extremely sensitive Balanced Crescograph. In this apparatus a compensating movement is given to the plant-holder by which the plant subsides exactly at the same rate as its growth-elongation, so that the tip of the plant remains at the same point. This perfect balance is attained by a variable regulator. The compound magnifying lever attached to the plant records the movement of growth. Under exact balance the record is horizontal. Any induced acceleration of growth upsets the balance, and, with the particular arrangement of the apparatus, causes a resulting down record; induced retardation, on the other hand, brings about an upset in the opposite direction and an up curve. The results given above show that growing plants not only perceive, but also respond to the stimulus of electric waves. These effects were found in all growing plants. The records were obtained with the seedling of wheat.

EFFECT OF FEEBLE STIMULUS.

I first studied the effect of feeble stimulus. This was secured by decreasing the energy of sparks of the radiator. The response was an acceleration of rate of growth. This is analogous to the accelerating effect of light stimulation of subminimal intensity.

EFFECT OF STRONG STIMULUS.

The maximum energy radiated by my transmitter, as stated before, was only moderate. In spite of this, its effect on plants was exhibited in a very striking manner. The balance was immediately upset, indicating retardation of the rate of growth. The latent period, i.e., the interval between the incident wave and the response, was only a few seconds. The record given in the figure was obtained with the moderate magnification of 2000 times only ; but with my Magnetic Crescograph the magnification can easily be raised ten million times, and the response of plant to the space-signalling can be exalted in the same proportion.

Under an intensity of stimulus slightly above the subminimal, the response exhibits retardation of growth followed by quick recovery. The perceptive range of the plant is inconceivably greater than ours; it not only perceives, but also responds to the different rays of the vast æthereal spectrum.

These revelations are as unexpected as they are startling. They show that the pretension of man and animals for undisputed superiority over their hitherto despised 'vegetative brethren' does not bear the test of close inspection.

WAKING AND SLEEPING PLANTS.

[Sir J. C. Bose's discourse, delivered at the Bose Institute on January 24, 1919, dealt with the mysterious phenomenon of recurrent opening and closure of flowers. The discourse was entitled "The Night Watch of Nymphaea." Some flowers open in the morning and close in the evening; others do exactly the opposite, opening at night and closing during the day. These various effects have been described as the 'waking' and 'sleep' movements of plants. Sir J. C. Bose in the course of his lecture said] :—

The poets have forestalled the men of science. Why does the water-lily, "Kumud or Nymphaea" keep awake all night long and close her petals during the day? Because the water-lily is the lover of the Moon and like the human soul expanding at the touch of the beloved, the lily opens out her heart at the touch of the moon beam, and keeps watch all night long; she shrinks affrighted by the rude touch of the Sun, and closes her petals during the day. The outer floral leaves of the lily are green, and in the day time the closed flowers are hardly distinguishable from the broad green leaves which float on the water. The scene is transformed in the evening as if by magic, and myriads of glistening white flowers cover the dark water.

The recurrent daily phenomenon has not only been observed by the poets, but an explanation offered for it. It is the moon-light then that causes the opening of the lily, and the sunlight, the movement of closure. Had the poet taken out a lantern in a dark night, he could have noticed that the lily opened at night in total absence of the moon; but a poet is not expected to carry a lantern and peep out in the dark: that inordinate curiosity is characteristic only of the man of science. Again the lily does not close with the appearance of the sun; for the flower often remains awake up to eleven in the forenoon. A French dictionary maker saw Cuvier, the Zoologist, about the definition of the crab as "a little red fish which walks backwards." "Admirable," said Cuvier. "But the crab is not necessarily little, nor is it red till boiled: it is not a fish, and it can not walk backwards. But with these exceptions your definition is perfect." And so also with the poet's description of the movement of the lily, which does not open to moonlight, nor yet close to the sun.

SLEEPING AND WAKING FLOWERS.

The waking and sleeping of the water lily is by no means an isolated instance. My attention was first drawn to another remarkable floral display by the folk song which begins with:

"Our day of work is over
Like life's span, but an hour!
For now behold the gold-starred fields
Of opening "Jhinga" flowers!"

Since then I witness every afternoon a glorious transformation in my experimental garden at Sijbaria on the Ganges. The gardener has planted a large field with Jhingha (Luffa ' :). The flowers when closed at day time are very inconspicuous, the lowest stem of the sepals being dull green; in my afternoon walk I can hardly recognise the old familiar field, which is now covered with masses of flowers in their golden glory. Here also the flowers remain open ·'·. .' .. the night; but they close early in the morning and the fairy field of cloth of gold vanishes suddenly.

The revolutions made by the plant-scripts led to the discovery of certain new and suspected reactions in the life of plants, notably the influence of variation of temperature in modifying the geotropic curvature. There are at least ten variables, which by their joint effects give rise to over a thousand variations in the resulting movement of plants. The effect of each of these different factors has been isolated and a new theory propounded which offers a complete explanation of the so-called sleep movements. The life reaction of plants to the various stimuli of the environment was most strikingly illustrated by means of super-sensitive Magnetic Crescograph. The plant was shown to perceive the shock of light, to which it made an answering signal, so also to the action of warmth and cold. And it was explained how the various combination of effects induced by environmental change found diverse expressions in the movement of plants.

The scientific explanations offered for the opening and closing of the water-lily is that the flower is closed under sun-light and that the opening takes place under darkness. But Prof. Bose has been able to keep the lily awake even in day-time by placing it in a cool place. Simultaneous record of the movement of the flower and the thermograph of daily variation of temperature proved conclusively that a rapid fall of temperature in the evening brought about the opening of the flower, at first slowly, then rapidly, and by 10 P. M. the flower was fully expanded. About 6 A. M. in the morning there is a rise of temperature and the reverse movement of close sets in. The flower continues to close very rapidly, the sleep movement of closure is complete about 10 A. M.

It will be been how different flowers, through their sensitiveness to heat and cold, execute movements of "sleep" or of "waking." Some of them have the healthy habit of normal humanity to sleep at night and keep awake at day-time. Others turn night into day, and make up for their long night-watch by sleeping it off at the day-time.

WOUNDED PLANTS.

[Sir J. C. Bose, in the course of his discourse at the Bose Institute in Calcutta on the 7th February, 1919, said.]

It is a little over four years now that the embodiment of world tragedy stalked over Western Europe. The fair field of France and her bright sky was under a pall of battle-smoke. Our sight could not penetrate through the dense gloom, and the mortal cry of the wounded and dying, drowned by hoarse roar of a thousand cannon, did not reach our ear. But from the time the Sikh and Pathan, the Gurkha and Bengali, the Mahratta and the Rajput flung themselves in front of battle, from the day our perception has become intensified. The distant cry of those whose life blood crimsoned the white fields of snow, has found reverberating echo in our heart. What is that subtle bond by which all distances are bridged over, and by which an individual life becomes merged in larger life? Sympathy is that bond by which we come to realise the unity of all life.

Before us are spread multitudinous plants, silent and seemingly impassive. They, too like us, are actors in the cosmic drama of life, like us the plaything of destiny. In their checkered life, light and darkness, the warmth of summer and frost of winter, drought, and rain, the gentle breeze and whirling tornadoes, life and death alternate. Various shocks impinge on them, but no cry is raised in answer. I shall nevertheless try to decipher some chapters of their life history.

When a man receives a blow or shock of any kind, his answering cry makes us realise that he is hurt; but a mute makes no outcry. How do we realise his sufferings? We know it by his agonised look, by the convulsive movement of his limbs, and through fellow-feeling, realise his pain. When a frog is struck it does not cry, but its limbs show convulsive movements. But from this it does not follow that the frog is hurt, for some would urge that there is a great gap between us and lower animals. One who feels for the humblest of His creatures, alone knows whether the frog is hurt or not. Human sympathy always aspires: it is sometimes extended to equals, hardly ever to inferiors. And so it happens that many would doubt whether the lowly and the depressed possess the fine sense of the exalted, to feel the same joy and sorrow and to resent social tyranny. When human attitude is so finely discriminative as regards different grades of his own species, it might be extravagant to believe that the frog could have any consciousness of pain. A concession might however be made, that the frog perceives a shock to which it responds by convulsive movements. It is as well that we should be careful about the use of terms; for, an eminent biologist insisted that animals never felt any pain; when an oyster is swallowed alive, it did not, according to him, feel any pain, but rather a sensation of grateful warmth at contact with the alimentary tract. The question will remain undecided for no one has as yet returned from the gastic cavity of the tiger to expatiate on the exquisite sensation.

TEST OF LIVINGNESS.

Responsive movement being a test of life, we shall try to construct a scale with which the height of livingness may be measured. What is the difference between the living and the dead? The living answers to a shock from without; the most lively gives the most energetic, the torpid or dying the feeblest, and the dead no answer at all. Thus life may be tested by shocks from without, the size of the answer being the gauge of vitality. The answer of the strong will be violent and almost explosive in its intensity, while the [illegible] will barely protest. The responsive movements may be recorded by suitable apparatus. The successive responses to similar shocks will remain uniform, if the living tissue remained always the same. But the living organism is always in a stage of change; for environment is always building us anew, and we are changing everyday our life. Thus subject to change, some day we are in a state of high exuberance, and other time in a state of lowest depression; we pass through numerous phases between the two extremes. Not merely does the present modify, but there is also the subtle impress of memory of the past. The sum total of all these characterise one individual from another. How is the hidden to be made manifest? To test the genuineness of a coin, we strike it and the sound-response betrays the true from the false. The genuine rings true, and other gives a false note. In this way, perhaps, the inner history of different lives may be revealed by shocks and the resulting response.

EFFECT OF WOUND.

There are three separate investigations that have been carried out on the effect of wound on plants. The first is the shock effect of wound on growth; this, generally speaking, retards or arrests growth. In the second series of investigations the change of spontaneous pulsation of the leaflet of the Telegraph plant was recorded. Death begins to spread from the cut end of the leaflet, and reaches the throbbing tissue which becomes permanently stilled on occasion of life. Experiments are in progress to arrest the march of death and the cut leaflet which died in 24 hours has now been kept alive for more than a week.

PARALYSIS OF SENSIBILITY.

Another series of investigations were carried out on the paralysing effect of severe wound. A leaf of Mimosa was cut off from the plant, and the subsequent histories of the wounded plant and the detached leaf are curiously different. The cutting off of one of its leaves caused a great shock to the parent plant and an intense excitation spreads over to the distant organs. All the leaves remain depressed and irresponsive for several hours. From this state of paralysed sensibility the plant gradually recovers, and the leaves begin to show returning sensitiveness. The detached leaf, with its free end placed in a nourishing solution, soon recovers, and holds up its head with an attitude indicative rather of defiance and the responses it gives are energetic. This lasts for 54 hours, after which a curious change creeps in; the vigour of its response begins rapidly to wane. The leaf hitherto erect, falls over; death at last asserts its mastery.

REPLY TO CRITICISMS.

[In responding to the vote of thanks at the Bengal Society, Calcutta, on his return from Europe, May 1920, Sir J. C. Bose said :]

I thank the audience for the warmth of their welcome and the interest evidenced in my demonstration. Dr. Waller spoke in appreciation of the message brought from the East, but it is not in that capacity that I am here this afternoon. I am here to announce and demonstrate new results which may clash with preconceived ideas, and exhibit new methods of experimentation by which phenomena hitherto in the realm of the invisible, are brought early to view. Science knows no geographical boundaries, and the test of truth is the same in the East as in the West. I go further, and say that when anyone brings forward facts which challenge existing theories, then the burden of proof must lie with him, and his work ought to be subjected to the closest scrutiny, for without such precaution, fact and fancy would become inextricably confused with one another. But criticism must be legitimate instead of suggesting vague doubts, it must be directed to eliciting definite information in respect to the subject under inquiry.

One speaker referred to the difficulties repeatedly experienced by me in publication of my results, till their recent acceptance; my special investigations have, by their very nature, presented extraordinary difficulties, and these have been greatly aggravated by [illegible] or misrepresentation. The tide however, turned when I was able, five years ago, to bring my apparatus from India, and give public demonstration before the different Universities and Scientific Societies, including the Royal Society of Medicine, and it was a matter of much gratification to me that my work on the establishment of unity of physiological reaction in plants and animals, received very cordial appreciation from the late Sir Lauder Brunton and your Society. The success of my present visit also makes me forget the painful incidents of the past which may now be left to oblivion.

I shall now meet the objections raised by Dr. Waller.

1. That the enormous magnification employed by me, would according to his calculation enlarge a blood corpuscle to something like 70 metres in diameter. But if magnification is the objection, then all the great advances of knowledge made by the microscope labour under the same [illegible].

2. That the movement shown by my crescograph may not be due to growth, but to physical disturbance such as that of variation of temperature. With reference to this, my paper on "Researches on growth and movement in plants by means of the High Magnification Crescograph" was after careful scrutiny by the Committee accepted by the Royal

Society and published last year (Proc. Roy. Soc. B. Vol. 90, 1919). In that paper full account is given for eliminating physical disturbance. It is there shown that "the physical elongation due to rise of temperative reaches a maximum after which the indication remains in a fixed position; whereas acceleration of growth by rise of temperature, as shown by quicker rate of movement of the indicating spot of light, persists indefinitely. Dr. Waller has seen that paper and I am at a loss to understand his omission in the present discussion of so important a part of my communication to the Royal Society. As regards the indications of my crescograph exhibiting induced physiological changes my audience had the fullest opportunity of watching the enhanced rate of movement of spot of light when the plant was treated with a dose of stimulating drug, a slowing down of the movement being brought about by the action of a depressing agent. Any hypothetical physical disturbance could not have brought about these definite "physiological" effects.

3. A further experiment was shown to decide between the question physical and physiological action. I have shown how growth-movement becomes retarded by any mode of stimulation, by light, by rough handling or by electric shock. This retardation has also been shown by me to culminate in an actual contraction under sufficiently strong stimulus; "the movement of elongation due to growth may

thus be reversed to an opposite movement of contraction." This important corroborative experiment was demonstrated before the audience by applying electric shock to the plant, when the normal growth-movement of the spot of light was reversed to the opposite movement to the left. This Dr. Waller regards as merely " degrowth " whatever that may mean. Dr. Waller adduces this as a proof of the dubious character of my demonstration, for according to him " the indicating spot of light should have stopped on the cessation of stimulus," instead of which the spot of light persisted to exhibit contractile effect by continuing to move to the left. Dr. Waller is in error in supposing that the effect of stimulus on growth lasts during the application. Reference to my Royal Society paper referred to above will show that the after-effect of stimulus persists for a long period.

4. But the most direct and simple test of discriminating physical from physiological movement would lie in repeating the experiments with a dead plant and growing plant. If, under similar conditions, the dead plant exhibits no movement in the crescograph, and the growing plant does exhibit movement, then the inference is clear and obvious that the crescograph does indicate the movement due to growth. Indeed Dr. Waller himself suggested the desirability of such a test and when I at once expressed my willingness to repeat this particular experiment, he waived his objection.

As regards the suggestion that my demonstration should be repeated before physiologists, I may say that a very large number of plant and animal physiologists have visited my laboratory and witnessed the experiments. Public demonstrations have also been given before the Universities of Oxford and Cambridge.

The president kindly referred to the recognition of the value of my work by the Royal Society's recent nomination to its Fellowship. This is a matter of gratification to me as an expression of good will and appreciation on the part of my numerous scientific colleagues in this country. And the best return that I can make for this confidence is to stand up for truth and for freedom of inquiry. We are at one both in the East and in the West, for the spread of knowledge and for the removal of ignorance. We shall pass away, nations will disappear ; Truth alone will survive, for it is Eternal.

VISUAL IMPRESSIONS.

[Sir J. C. Bose's observations of the recurrence of visual impressions are briefly summarised in the following paragraph quoted by Prof. Geddes] :

The visual impressions and their recurrence often persist for a very long time. It usually happens that owing to weariness the recurrent images disappear ; but, in some instances, long after this apparent disappearance, they will spontaneously reappear at the most unexpected moments. In one instance the recurrence was observed in a dream about three weeks after the impression was made. It thus appears that, in addition to the images impressed on the retina of which we are conscious, there are many others which are imprinted without our knowledge. We fail to notice them because our attention is directed to something else. But at a subsequent period, when the mind is in a passive state, these impressions may suddenly revive owing to the phenomenon of recurrence. This observation may afford an explanation of some of the phenomena connected with ocular phantoms and hallucinations.

TWO TYPES OF MEMORY.

[*Prof. Geddes in his " Life of Sir J. C. Bose" records the latter's investigations of some phenomena connected with Memory*].

Of that mental revival of past experience which we call memory, we may notice two different types. One is the spontaneous and recurrent revival of some strong impression from which we cannot escape: in the second case the primary impression has faded away, and it is only after an effort that we succeed in reviving the latent image. As regards spontaneous or recurrent revival of impression, I have shown elsewhere that in living tissues a very intense stimulus gives rise not to a single, but to multiple or repeated responses. Since an intense excitation is liable to recur spontaneously, without the action of will or even in spite of it, it follows that any single impression, when very intense, may become dominant and persist in automatic recurrence. Instances of this are only too familiar.

A more interesting form of memory is the revival of an impression, the after-effect of which has faded out. Here we find that, when no tangible effect of the impression remains, it may still be recalled by an effort or impulse of the will. It is clear that such a revival of impression can only take place by bringing about the original condition of excitation; in other words repeating the effect of original stimulus in its complete absence.

As a concrete example we may take the visual impression of a bright cross against a dark background. Under primary stimulus, it is clear that we have in the sensory field two areas under differential excitation. The one—the excited area—in the form of a cross; the other outside this, remaining unexcited. The image of the cross is therefore due to the differential excitation of a definite region in the sensory field. It is therefore obvious that in order to revive the picture we have to reproduce, in the absence of the primary stimulus, the same state of differential excitation as was originally induced.

THE SURGE OF LIFE.

[After his return from the West, Sir J. C. Bose gave his first lecture on Friday evening, 4th February, 1921, at his Institute, illustrated with striking demonstration of the Recording Crescograph. In the course of his address he said :—]

The multifarious complexity of life has been one of the baffling problems in science. Inorganic matter remains practically unchanged day after day; but the living organism is in a state of incessant change under the stimulus of the environment. Not only does the present modify, but there is also a subtle impress of the memory of the past. How then are we to get an insight into the mysterious workings of life? The problem became less obscure by the lecturer's success in his researches on physiology, leading to the establishment of fundamental unity of life-reactions in plant and animal. This has been shown in the possession of common characteristics in plant and animal of a nervous impulse; in the periodic insensibility in both, corresponding to what might be called sleep; in the death-spasm which takes place in the plant as in the animal. This unity is further exhibited in that spontaneous pulsation, which in the animal is the heart-beat; it appears in the similar effects of stimulants, of anaesthetics, and of poisons in vegetable and animal tissues. The establishment of this great generalisation meant a far-reaching advance in the science of physiology, of medicine, of practical agriculture and even of psychology.

ARTIFICIAL ORGANS OF PERCEPTION.

The underlying reactions of life cannot be detected even by the highest powers of microscope. For the solution of the intricate problem of life it is necessary to bring into the realm of the visible what had hitherto remained invisible; to detect and record the tremor of excitation: to measure the speed of the invisible impulse; to compel the apperently stationary organ to trace a single pulse of its imperceptible growth. The question of stimulation of growth is a matter of great practical importance, for the world's supply of food depends on vegetative growth. .. It is therefore of the highest importance to be able to discover those conditions which are favourable to growth. The different apparatus hitherto available for [illegible] have been very crude and inefficient. The lecturer has been successful in inventing three types of growth recorders: the Optical and the Recording Crescograph, which magnify ten thousand times, formed the subject of the present lecture. The demonstration of the Magnetic Crescograph, with its practically unlimited magnification would form the subject of a future discourse.

The results of investigation on various agents which enhance the activity of growth show that we have been using only a few stimulating agents, whereas there are thousands of whose action we had no conception. The rule of thumb method hitherto employed in the application of a few chemical stimulants and of electricity has, moreover, not been uniformly successful. The cause of anomaly is found from the discovery made at the Institute of an important factor, namely, the dose of application which had not hitherto been taken into account. He has, however, found that, while a moderate intensity of electric current accelerated growth, any excess above a critical point retarded it. The same was found to be true of chemical stimulants. A striking practical result was obtained with certain poisons, which in normal doses killed the plant, in quantities sufficiently minute acted as an extraordinarily effecient stimulant, the treated plant growing far more vigorously and flowering much earlier. The detailed account of these investigations are emhodied in the Transactions published by the Institute.

ROMANCE OF THE LILAC BLOOM.

In winter, when the plant is in a state of hibernation, the incipient flower buds of lilac remain in a state of arrested growth, blossoming into flower on the approach of spring. It has, however, been found that the application of an anaesthetic forces the blooming of the flower even in the depth of winter. A romantic explanation which has found more or less wide acceptance is that the lilac has an ingrained habit of putting forth all its growth activity after normal wakening in spring from its winter sleep. The plant being put prematurely to sleep by the action of a narcotic, loses its bearings; and the recovery from its narcotic sleep it mistakes as the normal spring waking with efforts for growth and full blossoming. A more rational explanation is, however, available from certain new facts of which the lecturer gave striking demonstration.

UNITY OF LIFE.

[*Sir J. C. Bose said in conclusion*] The results of various experiment brought the plants much nearer to us than we thought. We find that it is not merely a mass of vegetative growth, but that its every fibre is instinct with sensibility. We find it answering to outside stimuli. We are able to record the throbbings of its pulsating life and find these wax and wane according to the life conditions of the plant, and cease with the death of the organism. We have seen how the whole plant is made one by the conducting threads, so that the tremor of excitation initiated in one place courses through the whole and how this nervous impulse as in man, can be accelerated or arrested under the several actions of drugs and poisons. In these and many other ways the life reactions in plant and man are alike: and thus, through the experience of the plant, it may be possible to alleviate the suffering of man.

SCIENCE AND RESEARCH.

[*Sir J. C. Bose delivered a lecture on " Science and Research" in St. Xavier's College, Bombay, in January 1921, Prof. Patric Geddes presiding. Sir Jagdish said* :—]

It was three years ago that he had the opportunity of meeting the young students of that College and also other colleges, and although now his stay was very short in the city, he thought it was his duty to meet again the students of his country, for he believed that the future of India whether for good, or for ill, depended on their efforts (Applause). They would be the makers of India. The time had now come when the older generation would have to lay down their work, and it was for the students to take up the work, which was laid aside for a time. For in a certain sense they were immortal. Their bodies might disappear, but their thoughts, their efforts, their ideals would live. They would live for ever ! He had only a few things to tell them. First about what was meant by science and what was meant by trying to find new secrets of the world. The lecturer then quoted the story from the Mahabharata when the princes were asked to shoot a bird which was sitting on the tree. They were called one after another, and asked what they saw and only Arjun alone said that he saw nothing but the eyes only. He was unconscious of any thing except those. The students wasted a great deal of their time and intellect and energy, which were meant for one great end—that great end was to serve their country, so that she could take her place once more. (Applause.) He did not want their applause, but he wanted them to feel deeply. They could serve their country in only one way; the students could serve their country by sharpening their intellects, by going through years of concentration of mind. The students had been living a parasitic life, and they had followed what had been told in the books for want of finding it out for themselves. There was no other way of growing. Unless they, by their purity of life, by the concentration of life, and by taking little, tried to grow, they would never be able to do so. They should try to reach the highest perfection in whatever they undertook. What were they going to strive at? Were they going to accumulate all their life? That had been the greatest disaster in the world—always hoarding. The greatest thing to do was to win: they should by their own efforts conquer the world and after they had conquered, then renounce. Then they should give it away. Let the burden of life lie on those who were strong, and not those who were incapable of bearing it.

LIFE AND GROWTH.

Coming to the subject of the lecture, he said he had for twenty years been engaged in the study of the activities of plant life as compared with the corresponding functioning of animal life. But since plants for the most part seem motionless and passive, and are, indeed, limited in their range of movement special apparatus of extreme delicacy had to be invented, which should magnify the tremor of excitation and measure the perception period of plant to a thousandth part of a second. Ultra-microscopic movements had to be measured and recorded, the length measured being often shorter than a fraction of a single wave length of light. The secret of plant life became thus revealed by the autogations of the plant itself. These investigations have established the fundamental unity of life-reaction in the plant and in the animal, as seen in a similar periodic insensibility in both corresponding to what we call sleep; as seen in the death spasm which takes place in the plant as in the animal. This unity is further exhibited in that spontaneous pulsation which in the animal is the heartbeat; it appears in the similar effects of stimulants, of anaesthetics and of poisons in vegetable and animal tissues.

THE MAGNETIC CRESCOGRAPH.

For the instant detection and measurement of growth and its changes, he had perfected his Crescograph whose magnifying power has been within a short time raised from a million to fifty million times. Under a similar magnification of speed a snail would race round the earth two hundred times during the course of 24 hours. It might be thought that an apparatus of such inconceivably high magnification would be upset by the slightest tremour in a busy city. By means of special shock-absorbing devices the lecturer has been able to protect his instrument from the slightest external disturbance as was seen from the perfect steadiness of the indicating spot of light. As an example of the extreme sensitiveness of his apparatus, he attached to his apparatus a piece of metal. A piece of brass one inch in length when passed through one degree would expand about 1,50,000 of an inch, which is equal to a single wave-length of light. If a candle is held at a distance of some three feet there would be produced an extremely minute rise of temperature less than a thousandth part of a degree, that is to say, the expansion of the rod of metal would be less than one-thousandth part of the wave-length of light—an amount which would be regarded as beyond the power of detection. Sir J. C. Bose, however, subjected his apparatus to a severer test. When the finger was pointed towards the metallic rod, the indicating spot at once responded by rapid movement, and on the removal of the finger the spot came back to exact zero.

A piece of plant is attached to the apparatus, and the active growth of the plant is exhibited by the rapid movement of the spot of light. The plant is next subjected to the action of dilute vapour of chloroform, whieh caused a very great stimulation of the rate of growth. Under continued action of the anaesthetic growth became at first arrested, and a violent contractile spasm indicated the onset of death.

In conclusion the lecturer said that the results of his experiments showed that the plant is not a mere mass of vegetating tissue, but that its every part is full of sensibility. We are able to record the throbbings of its pulsating life, and find these wax and wane according to the life conditions of the plant, cease with the death of the organism. We find the different parts of the plant connected together by conducting threads, so that the throb of excitation initiated at one place courses through the whole, this "nervous" impulse as in man, being modified or arrested under the several actions of drugs and poisons. In those and in many other rays the life-reactions of plant and man are alike; thus through the experience of the plant it is possible to alleviate the sufferings of man.

ADVICE TO STUDENTS.

In a few concluding words of advice to the students Sir Jagadish said that they were living a parasitic life, for they wanted everything easy. They wanted to be provided with everything either by the Government or by somebody else. That killed all their initiative. The greater the difficulties the greater was the honour for them. For then they had to be patient, as he had to be patient with his work, which was regarded by every one in the beginning as imaginary. There was no power on earth that could stop truth, that could hide truth; there was truth and righteousness in the world, and they could await patiently and bring an era of justice and an era of righteousness—and that could only be done if they worked with their heart and soul and their mind. It was only after twenty years of work that his work was acknowledged. It was by their patient work, by their efforts, and by their winning fame for their intellect, for their efforts and for their character could they win the world. What a fine power they had! What an immense amount of youthful power they had! They should try to do something for their country and in serving their country they would serve the whole world. That work of advance must be in different direction—medicine, in one directionf agriculture, in another direction, and their idea o, life in another direction. In advancing India they would advance the whole world. If they could make their life one of righteousness and nobility they would be serving not only their country, but the whole world.

SENSE ORGAN OF PLANTS.

[*In course of his discourse at the Bose Institute on the 25th February, 1921 Sir J. C. Bose said :—*]

From the moment when the germinating seedling bursts its seed-coat a complex series of movements is initiated. The root bends downwards and the stem upwards. Underground the root gropes its way towards moist places and contrives to avoid hard stones and obstacles. Above ground the stem and leaves are seen to bend in search of light. Tendrils twine about a support. Various terms were invented, such as helietropism or geotropism, which served as cloaks to hide our ignorance about the real cause of the diverse reactions. New methods of investigation initiated at this Institute are, however, found to unravel the mysteries of plant movements. The plant sometimes responds locally to the direct impact of a stimulus, and at other times, the effect is transmitted and the responsive changes are manifested at a distance. Again, it is not the skin, but living protoplasm inside the plant which becomes irritated. What are the means by which the various stimuli coming from outside react inside the plant? This is accomplished through contrivances by which the feeble external stimulus becomes accentuated. In animals hairs and bristles act like levers in intensifying the stimulus of touch. The lens of the eye concentrates the diffused light on the sensitive retina. These contrivances together with the special receptive area form the sense organs even of the lowest type of animals, where psychic powers may be regarded as doubtful. We shall find similar sense organs possessed by plants by means of which its various parts place themselves in favourable attitude so as to gather energies derived from outside—so essential for the maintenance of life activity itself. We shall find that it has organs which respond to touch, rudimentary eyes to perceive light, and special organs by which it perceives direction in space.

DIFFICULTIES OF INVESTIGATION.

There had been three main obstacles which had hitherto stood in the way of advance in plant physiology: (1) the belief that only a few plants are sensitive, (2) the erroneous idea that plants do not possess a nervous system and (3) our inability to detect internal irritation which causes movement.

THE WRITING OF TENDRILS.

In refutation of the popular assumption which distinguishes animal and vegetable tissues, as relatively mobile and non-mobile a striking experiment was exhibited in which a curled tendril of passion flower was subjected to electric shock, under which the tendril began to writhe and twist about, the violent contortions being strongly suggestive of a worm under torture. Experiments were also exhibited which showed that a nervous impulse was transmitted from one part of the plant to another with a measured velocity such an impulse being retarded or inhibited under the action of various anaesthetics and physiological blocks.

THE ELECTRIC PROBE.

The most puzzling question is in regard to the sense organ by which the plant is enabled to perceive the vertical direction and move accordingly. We get an idea of direction of the force of gravity by means of plumb lines and in lower animals theotoliths of the fish's and the sand grains in the lobster enable them to orientate themselves. The test needed for the localisation of the geo-perceptive layer must be in some physiological reaction of the living organ giving unmistakable signal of geotropic stimulus as the plant is displaced from its normal vertical position. The lecturer has been able to invent for this purpose the device of the Electric Probe by means of which it is possible to explore the interior of a living plant and detect the state of excitation in its different layers. He has been able to localise the special layer of cells which perceives the stimulus of gravity. Thus, by means of this Electric Probe, it is possible to map out the contour lines of physiological excitation in living organs.

THE POLYP AND THE PLANT.

There has been up to the present a sriking difference between our conception of plants as a whole and of such animals, as the stationary zoophytes. These latter, we pictured to ourselves as possessed of a host of nascent sensibilities and quivering with multiform movements in free and immediate response to various kinds of stimuli; while the plant was regarded as merely passive moving only as it was moved or as it grew. But now the forest of plants has heen made to exhibit as many of the activities as we are accustomed to associate with the life in the forest of polyps. The plant like the polyp sees light, feels contact, responds to heat and cold. And in the one case as in the other, the tremor of excitation is transmitted with a definite and measurable speed from point to point. Thus community through the great occean of life is seen to outweigh apparent dissimilarity.

THE POWER OF WILL.

[*At a special meeting of the Sahitya Parishad, held at the Bose Institute, Sir J. C. Bose gave his discourse in Bengali, on "The Power of Will in Controlling Nervous Impulse." The lecture was illustrated by original experiments.*]

In regard to sensation two extreme cases may be considered. In the first the external stimulus is too feeble for the resulting impulse to cause perception; here he would desire to exalt the conducting power of of the message bearing vehicle, the nerve, so that what was subliminal shall become perceptible. Excessively strong stimulus, on the other hand, on account of its character or intensity causes sensation which is intolerably painful. Could such a message be altogether blocked by arresting the nervous impulse during transit?

The modification of the nervous impulse is only possible if we could discover some means of rendering the vehicle which carries the message, a better conductor or non-conductor, according to particular requirements. We require the nervous path to become super-conducting in order that the impulse, due to subliminal stimulus, might be brought to sensory prominence. When the external blow,. on the other hand, is too violent, we would block the pain-causiug impulse by rendering the nerve a non-conductor.

[Sir J. C. Bose described the experiments by which he was able to confer on the experimental nerve two opposite "molecular dispositions" in consequence of which the conducting power of the nerve was enhanced or inhibited at will. He was able to do this by the application of external force of a polar character. He further explained that similar effects might be produced by the internal power of evil.]

MAN VICTORIOUS OVER CIRCUMSTANCES.

In the determination of sensation then, the internal stimulus of will may play as important a part as the shock from outside. And thus through the the inner control of the molecular disposition of the nerve the character of the resulting sensation may become profoundly modified. The external, then, is not so overwhelmingly dominant and man is no longer passive in the hands of destiny. There is a latent power which would raise him above the terrors of his inimical surroundings. It remains with him that the channels through which the outside world reaches him should, at his command, be widened or become closed.

Function is created by action of institution, which may be external or internal. Does the mind make the body or does environment fashion the organisms? Are the two statements opposite to each other, or are they but one fact, described from different points of view? If the internal stimulus be the resultant of inpouring forces from outside, then, when in this infinite transfusion came the birth of thought? Even in the smallest living particle we may trace the dim beginnings of the faculty of choice. A speck of protoplasm accepts or refuses, submits to or resists the multiplex forces of destiny about it. When in all this did perception begin to manifest itself? If in throbbing lies response to stimulus, then, the smallest speck of life has it. If in nervous commotion, then the tree has it. Mind and matter thus become transfused. The macrocosm is that whose highest term is the one, and its lowest the other. And man opening himself at will to new areas of stimulation, thereby determines his own higher evolution.

ADDRESS AT THE ROTARY CLUB.

[The members of the Rotary Club, Calcutta, entertained Sir Jagadis Bose at dinner at Pelitie's on Tuesday, April 12, 1921. Captain H. Newman, President of the Club, presided, having Sir J. C. Bose on his right and Lady Bose on his left. About sixty including ladies sat down to dinner. During the course of the evening it was announced that the Rotary Club had unanimously elected Sir J. C. Bose an Honorary Member of the Club. Sir Jagadis Chandra Bose in accepting the honour said :—]

I thank the members of the Rotary Club for the warmth of your kind reception. You have expressed your appreciation of the di coveries made in my Institute. You are also not unaware of the great advances made by my ancestors in other branches of knowledge—notably metaphysics. I, on my own part, must now pay homage to the great Western invention for the advancement of modern civilisation, —the inventions of Social Clubs and the institution of public dinners. Everywhere else in daily struggles and in keen competition truth is lost sight of and men know not their own souls. But all becomes changed when we gather round a hospitable board. We then learn to appreciate each other's work, understand each other's point of view, and realise that we are human beings, that we are neighbours and would love to do neighbourly service. We even learn to enjoy fun at our own expense. I would herefore take the fullest advantage of the present occasion. One of the great characteristics of the Anglo-Saxon is that he identifies himself with the place of his work. So it happens that, when he settles in Australia he does not call himself an Anglo-Australian, but an Australian. In the States he becomes an American and soon begins to look down on Europe as a "back number." He resents hyphenated prefixes of any description. And I think you will also come to regard your present prefix equally superfluous and take pride in being known as Indians. For, if one reads the history of this country rightly, he will realise that India has a great assimilative power by which many races and peoples who came to this country came to call this their home. And it is through our united efforts that we could look forward to the rejuvenescence of India and the world services she is again to render.

IS THE WORLD A COSMOS OR A CHAOS?

I would now make the briefest reference to some of my scientific conclusions. Instead of special creation and specific characteristic I find that all life is one. The world is not a chaos, but a cosmos. From the unity of life there follows as a postulate the unity of all human efforts. It is a misreading of the laws of Nature to regard conflict as the only factor in evolution. For more potent than competition is mutual aid and renunciation in the scheme of life. It is true that the weakling who has refused the conflict, having acquired nothing, has nothing to renounce. He alone who has striven and won, can enrich the world with the fruits of his victorious experience. It is only out of struggle that some inner power is born through which we come to realise the essential kinship of all humanity. It is through the eternal interaction of the outer and the inner that the world evolves. And the most living man is he, who having acquired through years of patience gives out in spontaneous outflow. Thus in modern times we have a Rockfeller or a Carnegie. Is this an exception? Some twelve centuries ago the merchant princes of India adventured forth across unknown seas and shared their ancient heritage with the people among whom they lived. The ruins of Java and Cambodia still testify the creative impulse of that epoch. And Bengal too was not behindhand. Her scholar-adventurers with palm leaf manuscript as their sole merchandise crossed the Himalayan barriers and extended the great Indian culture to the farthest East.

THE PRESENT UNREST

I shall now briefly refer to the present unrest.

In the physical world I find that, whenever in a system there is a great accumulation of energy at any one point, there is a tendency for equalisation. Should there be any obstruction to this natural process a dangerous tension is set up, ending in explosion. A parallel phenomenon in the system of human conglomeration is known as revolution. And the most stable and enduring form of Government is that in which undue tension is not allowed to develop. The present unrest is not confined to India, but is almost world-wide due to economic conditions. In my recent travels in Europe I found the acutest symptoms of unrest in London, in Paris and in Berlin. The prevalent idea is that the produce of the world is not sufficient for all.

The conflict is between the "haves" and "have-nots." Tbe idea that dominates one group is that the produce of the world is not sufficient for all and therefore they must have more than their share. The "have-nots," who are many, however fail to realise this logic. And thus has arisen the tragedy of the present situation. But is it true that the productive capacity of the world has been fully developed? The only place where I found this unrest to be at its minimum was in Norway and Sweeden. Norway, for example, has an area of a few thousand square miles and a population less than that of Calcutta and Bombay combined. She nevertheless maintains her own army and navy, has her system of universal education, and the most up to date University. Poverty is practically unknown. The country is not rich in its natural resources. How is this miracle accomplished? By utilising to the utmost through science all her available resources. In many of the provinces in India, Bengal for instance, I find inexhaustible resources alike in her soil and in her mineral wealth. India could be the richest country in the world if she only knew how to utilise nature's gifts. As regards the beneficent powers of science my own researches show the possiblility of making four ears of corn grow, where one grew before. In this aspect science is a divine gift and the call is imperative which compelled, men to choose a life of unending struggle to extend the bounds of human knowledge.

Is there any solution of the present difficulties? The conflict in the industrial world perhaps reached its climax in the United States. But in the same country there is also a different method in operation. They there realise that it pays to make every one actively interested in the success of an enterprise; thus the operative of to-day may become the director to-morrow.

Why is this obvious method not in evidence in this country? Here there is a large diffuse capital and a large number of men trained in the methods of science, and a growing feeling of patriotism, an increasing desire of developing the natural resources of the country. What they lack is business training. On the other hand you have remarkable experience in business and power of organisation. The two should have complemented each other, but are now in conflict. Why should they not work for mutual benefit. The present conflict brings vividly before my mind a picture where two claimants were pulling the milch-cow—one by the horn and the other by the tail—while thus fixed, a third party came by and walked off with the milk. I am sure that you would be able to identify the respective parties.

Your kind invitation has tempted me out of the seclusion of my laboratory. I have been accustomed to wait patiently; and perhaps from my isolation I have been able to see things a little more clearly. I have spoken to you freely about a few things which concern us all. I know that some of you will take pride in the work in which all must participate who regard this country as their own. Whether India is to gain her salvation through conflict or through the other method more consonant with her ancient tradition, there can be no misgiving about her future. For there is something in the Indian culture which is possessed of extraordinary latent strength, by which it has resisted the ravages of time, and the destructive changes which have swept over the earth. And indeed a capacity to endure through infinite transformations, must be latent in that mighty civilization which has seen the intellectual culture of the Nile Valley, of Assyria, and of Babylon wax and wane and disappear, and which to-day gazes on the future with the same invincible faith with which it met the past.

Researches and Discoveries.

[The following account of Dr. Bose's Researches and Discoveries compiled in chronological order was published in the "Modern Review" as early as 1912. Since then Dr. Bose has added considerably to the list. It shows at a glance the extent and scope of Dr. Bose's achievements in what may be rightly termed the Romance of Science]

Prof. Bose's first contribution was on his discovery of

(1) *The polarisation of electric ray by crystals,*—Asiatic Society of Bengal, May, 1895.

This supplied a very important confirmation of the identity of electric radiation and light. At this time he discovered the very important property of the crystal *Nemalite* which, as regards electric radiation, behaved like Toutmaline to light. His next contributions were :—

(2) *On a New Electro-polariscope :* and

(3) *On the Double Refraction of the Electric Ray by a Strained Di-electric.*

These two Papers were published in the *Electrician*, (December, 1895) the leading electrical journal.

The determination of the index of refraction of various substances is of much importance; it has been possible to do this only in the case of substances which are transparent to light. But a very large number of the so-called opaque substances such as pitch, coal-tar, etc,, are transparent to electric radiation. The determination of the index for this invisible radiation offered however great difficulties till Prof. Bose devised a method which enabled this to be done with the highest accuracy, The results of his researches were communicated by Lord Rayleigh to the Royal Society:

(4) *On the Determination of the Indices of Electric Refraction.*—Royal Society, December, 1895.

The Society showed its appreciation of the high scientific value of the research, not only by publication, but the offer of a subsidy from the Parliamentary grant made to the Society for the advancement of science.

His next countribution was:—

(5) *On a Simple and Accurate Method of determining the Index of Refraction for Light.* —1896.

With reference to this it may be said that Dr. Gladstone, F, R. S., the discoverer of Gladstone's law in Optics, spoke in the highest terms of Bose's Refractometer.

His next contribution published by the Royal Society was:

(6) *Determination of the Wave-length of Electric radiation.*—Royal Society, June, 1896.

At this time in recognition of the important contributions made by him for the advancement of science, the University of London conferred on Prof. Bose the degree of Doctor of Science.

During his first scientific deputation to Europe by the Government of India, he read a paper before the British Association:—

(7) *On a complete apparatus for investigating the properties of Electric waves.*—British Association, Liverpool, 1896.

"Among the most interesting features at the British Association this year was the paper on Electrical Waves by Professor J. C. Bose. This gentleman had, by his strikingly original researches on the polarization of the electric ray, won the attention of the scientific world. His later papers on the Determination of the Indices of Electric Refraction and of the Wave Length of Electric Radiation were published, with high tributes, by the Royal Society. Lord Kelvin declared himself literally filled with wonder and admiration for so much success in these difficult and novel experimental problems. The originality of the achievement is enhanced by the fact that Dr. Bose had to do the work with apparatus and appliances which, in this country, would be deemed altogether inadequate. He had to construct himself his instruments as he went along. The paper which was read before the British Association the other day "On a Complete Apparatus for the Study of the Properties of Electrical Waves" forms the outcome of this twofold line of labour—construction and research."—*Times.*

His next paper published by the Royal Society was:—

(8) *On Selective Conductivity exhibited by Polarising Substances.*—Royal Socicty, January 1897.

The behaviour of crystals like Tourmaline in exhibiting selective power of absorption of light had hitherto found no explanation. Prof. Bose working with electric waves showed that the selective transparency of crystals like Tourmaline was due to selective conductivity exhibited by them.

The fame of the Royal Institution of Great Britain, rendered illustrious by the labours of Davy and Faraday, of Rayleigh and Dewar, has reached every quarter of the globe. The honour of being asked to deliver a Friday Evening Discourse in this Institution is regarded as one of the highest distinctions that can be conferred on a scientific man. Such a selection is only made in the case of one who has done the most distinguished work in the course of the year. This offer was made to Prof. Bose in the following letter:—

"It would afford the Managers of the Royal Institution very great pleasure indeed to find that you could give a Friday Evening Discourse, embodying the results of some of your original work on Electric Radiation (which has excited so much scientific attention) and illustrated by your apparatus."

(9) *Friday Evening Discourse at the Royal Institution on Electric Waves.*—Royal Institution, January, 1897,

"There is, however, to our thinking something of rare interest in the spectacle presented, of a Bengalee of the purest descent possible, lecturing in London to an audience of appreciative European savants upon one of the most recondite branches of the modern physical science. It suggests at least the possibility that we may one day see an invaluable addition to the great army of those who are trying by acute observation and patient experiment to wring from Nature some of her most jealously guarded secrets. The people of the East have just the burning imagination which could extort a truth out of a mass of apparently disconnected facts; a habit of meditation without allowing the mind to dissipate itself, such as has belonged to the greatest mathematicians and engineers."—*Spectator*.

"Professor Bose's description of the inductive method by which he was led to devise his form of receiver for wireless telegraphy and the reasons of its superiority to other forms of receiver were exceedingly interesting It is also worth remark that no secret was at any time made as to its construction, so that it has been open to all the world to adapt it for practical and money-making purposes."—*Electrical Engineer*.

That Prof. Bose's researches have materially helped practical application will be seen from the following letter form Messrs. Muirhead & Co., who hold patent for wireless telegraphy in the United States of America:—

"Just a line to say how pleased we were to have the opportunity of discussing with you the bearing of some of the results of your recent researches upon certain practical points in the manufacture of wireless telegraphic apparatus. We have already benefited by your work in the construction of the most important part of such apparatus."

He was next invited to address the scientific societies in Paris.

"Professor J. C. Bose exhibited on the 9th of March before the Sorbonne, an apparatus of his invention for demonstrating the laws of reflection, refraction and polarisation of electric waves. He repeated his experiments on the 22nd, before a large number of members of the Academic des Sciences, among whom were Poincare, Cornu, Mascart, Lipmann, Cailletet, Becquerel and others. These savants highly applauded the investigations of the Indian Professor."—*Revue Encyclopedique, Paris*.

The celebrated physicist, Professor Cornu, President of the Academy of Science, wrote to him:—

"For my own part, I hope to take full advantage of the perfection to which you have brought your apparatus for the benefit of the Ecole Polytechnique and for the sake of the further researches I wish to complete. The very first results of your researches testify to your power of furthering the progress of science. You should try to revive the grand traditions of your race, which bore aloft the torch-light of science and art and was the leader of civilization, two thousand years ago. We in France applaud you and wish you every success."

He was next invited to lecture before the Universities in Germany. At Berlin he gave, before the leading physicists in Germany, an address which was subsequently published in the *Physikalischen Gesellschaft*.

(10) *On Electro-magnetic Radiation.—Physik-Ges. Zu Berlin, April, 1897.*

The Royal Society next published his Paper

(11) *On the Determination of the Index of Refraction of Glass for the Electric Ray.*

In this he showed the unexpected increase of the index of refraction of glass under ether vibration of slow frequency : this explained the theoretical difficulties raised by certain electrical properties of glass.

The thinnest film of air is sufficient for producing total reflection of light with its extremely short wave-length. But with the longer waves, Professor Bose discovered a new phenomenon, an account of which was published by the Royal Society.

(12) *On the Influence of Thickness of Air-space on Total Reflection of Electric Radiation.*—Royal Society, November, 1897.

It was shown that the critical thickness of the air-space was determined by the refracting power of the prism and the wave length of radiation. It opened out a possibility of new methods of determining the index of refraction and also the wave-length.

Certain substances produce rotation of the plane of polarisation of light. Professor Bose discovered similar rotation of the plane of polarisation of electric waves.

(13) *On the Rotation of Plane of Polarisation of Electric Waves by a Twisted Structure.*—Royal Society, March, 1898.

He constructed two kinds of artificial molecules, which rotated the plane of polarisation to the right or to the left, analogous to the effects produced by dextrose and levulose. As a result of this research many of the obscurities in the phenomenon of Rotation were cleared up.

(14) *On the Production of a "Dark Cross" in the Field of Electro-magnetic Radiation*—Royal Society, March, 1898.

This important research reveals the circular molecular arrangement of various bodies. A disc of wood with concentric rings was shown to produce polarisation effect similar to that exhibited by crystals like Salicine.

(15) *A Self-recovering Coherer and Study of Cohering Action of different Metals.*—Royal Society, March, 1899.

The effect of electric radiation on fragments of metals has hitherto been regarded as due to cohering action, bringing about a diminution of electric resistance. As a result of Professor Bose's extensive researches on the effect of radiation on inorganic substances, the theory of coherence was rejected. This was due to his discovery that, under electric radiation, potassium and other metals not only exhibited an increase of resistance but also an automatic self-recovery.

(16) *On the Electric Touch and the Molecular changes produced in Matter by the Action of Electric Waves.*—Royal Society, February, 1900.

Instead of so-called cohering action, the effect of electric radiation on matter is shown to be one of discriminative molecular action; it is further shown that the effect of radiation on metallic particles is to produce molecular or allotropic changes, attended by changes of electric conductivity.

A description of Prof. Bose's apparatus and an account of his researches on electric radiation will be found in the New Edition of the Encyclopædia Britannica. Frequent references to his contributions will also be found in the classical work of M. Poincare, on Electric Waves.

During his researches on the behaviour of different receivers, he was led to the discovery of various reactions in inorganic matter parallel to those of living matter; the result of these researches were given in his Address to the International Congress of Science at Paris, during his second scientific deputation to Europe by the Government of India.

(17) *De la Generalite des Phonomences Moleculaires produits par Eelectricite sur la matiere Inorganique et sur la matiere Vivante—Travaux du Congress International de Physique, Paris, 1900.*

He read another paper before the British Association

(18) *On the Similarity of Effect of Electric Stimulus on Inorganic and Living Substances.*—British Association, Bradford, 1900.

The investigation of this subject was carried on later by the employment of a method altogether different, but which afforded independent support to his previous results.

(19) *On an Artificial Retina.*—Exhibited at British Association and Royal Institution, 1900.

"Prof. Bose exhibited an artificial eye the interior mechanism of which was such as to enable it to give an electric response to radiation of every description, whether ordinary light, or Hertzian or Rontgen rays. Like all the inventive work of its originator it exhibits a marvellous delicacy and perfection of workmanship combined with a degree of simplicity in which few inventions can rival those of Dr. Bose. As to the mode of action of this eye, we believe that it involves an effect the discovery of which is originally due to Dr. Bose; it may be convenient to describe this as the "Bose effect." This model is not a mechanism capable of merely imitating the phenomena of vision; it goes much deeper and acts in identically the same manner as the living eye acts when sending an impulse to the brain on being exposed to light. Dr. Bose's model, therefore, essentially embodies a physical theory of vision Such a sensitive receiver of electro-magnetic radiation, perfectly prompt as it is also in its self-recovery after stimulus, should serve to revolutionise existing methods of wireless telegraphy and aetheric signalling."—*Electrician.*

Certain characteristics of his artificial retina led Prof. Bose to predict that the human retinae should exhibit binocular alternation of vision—a peculiarity which was quite unsuspected. For detection of this peculiarity he invented a special apparatus by means of which he demonstrated the new phenomenon before the Physiological Society of London.

(20) *On Binocular Alternation of Vision.*—Physiological Society, London, 1900.

His next contributions published by the Royal Society related to the action of light on matter.

(21) *On the Continuity of effect of Light and Electric Radiation on Matter.*—Royal Society, April, 1901.

(22) *On the Similarities between Mechanical and Radiation Strain.*—Royal Society, April, 1901.

In his next paper he advanced a new theory of photographic action, which explained many anomalous results.

(23) *On the Strain Theory of Photographic action.*—Royal Society, April, 1901.

At the British Association meeting at Glasgow he described a new method of investigation for determining the molecular change produced in metal by electric variation.

(24) *On the Change of Conductivity of Metallic particles under Cyclic Electromotive Variation.*—British Association, 1901.

(25) *The Conductivity Curvograph.*—British Association, 1901.

The very thorough study which has been given to the curious action of coherer by Professor Jagadis Chander Bose renders his paper before the British Association (Glasgow) a very important contribution to this branch of electro-physics. In order to study the whole subject from a broad standpoint, the author made a number of experiments with a most interesting apparatus which he terms a curvograph. A number of properties is revealed by the curves drawn by this ingenious apparatus."—*Engineering Magazine.*

Prof. Bose was for a second time honoured with the request from the Royal Institution to give a Friday Evening Discourse.

(26) *On the Response of Inorganic Matter to Stimulus.*—Friday Evening Discourse, Royal Institution, May, 1901.

"The lecture on The Response of Inorganic Matter to Mechanical and Electrical Stimulus which Dr. J. C. Bose delivered at the Royal Institution last Friday evening, affords a striking illustration of the far-reaching character of the long and elaborate series of researches which the lecturer has been carrying on during the past few years.

"All these researches have rendered invaluable assistance, both in the progress of scientific research into electromagnetic radiation and in the practical improvement of wireless telegraphy and other forms of ætheric signalling. The latest researches, however, which served as the subject for last Friday's discourse, carry us further than the domain of theoretical and applied physics, into the regions of physiology and chemistry They lead to the discovery of an universal action underlying certain phenomena in both living and inorganic matter. Returning to the actual researches, we may observe that a stupendous problem arises from their indications; the co-ordination between the response of living and that of the inorganic matter is a riddle, in front of which neither physicist nor physiologist should rest until they have obtained the solution; and no one is so well qualified to solve it as is its originator. The scientific world is immensely indebted to Dr Bose for the researches he has already completed and presented to it—researches which redound greatly to the credit of India, and more specially, of the Presidency College of Calcutta."—*Electrician.*

Prof. Bose's next subject of inquiry was whether the ordinary plants were not fully sensitive. The prevailing view was against such supposition. He, however, was successful in devising a new mode of investigation by which the universal sensitiveness of plants was fully demonstrated before a special meeting of the Linnæan Society.

(27) *On the Electric Response in Ordinary Plants under Mechanical stimulus.*—Linnæan Society, March, 1902.

"Prof. Bose performed a series of experiments before the Linnæan Society showing electric response for certain portions of the plant organism, which proved that as concerning fatigue, behaviour at high and low temperatures, the effects produced by poisons and anæsthetics, the responses are identical with those hitherto held to be characteristic of muscle and nerve. He drew the final conclusion that the underlying phenomena of life are the same in both animals and plants, and that the electrical responses which he had demonstrated are but the common physiological properties of these."—*Nature.*

Prof. S. H. Vines, F. R. S., President of the Linnæan Society, wrote to the author—

"Your experiments make it clear beyond doubt that all parts of plants not merely those which are known to be motile—are irritable, and manifest their irritability by an electrical response to stimulation. This is an important step in advance, and will, I hope, be the starting point of further researches to elucidate what is the nature of the molecular condition which constitutes irritability, and the nature of the molecular change induced by a stimulus."

The President of the Botanical Section at Belfast in his address said,—

"Some very striking results were published by Bose on the Electric Response in ordinary plants. Bose's investigation established a very close similarity in behaviour between the vegetable and the animal. Summation effects were observed and fatigue effect demonstrated; while it was definitely shown that the responses were physiological. They ceased as soon as the piece of tissue was killed by heating. These observations strengthen considerably the view of the identical nature of the animal and the vegetable protoplasm."

(28) *Sur la Reponse Electrique de la Matiere. Vivante*—Society de Physique, Paris, 1912.

(29) *On the Electromotive Wave accompanying Mechanical Disturbance in Metals.*—Royal Society, May, 1902.

He was next asked by the Royal Photographic Society to give a Discourse on his Strain Theory of Photographic Action.

(30) *The Latent Image and Molecular Strain Theory of Photographic Action.*—Transactions, Photographic Society, London, June, 1902.

His next communication was to the Linnæan Society giving on account of his discovery of rhythmic electric pulsation in the Telegraph Plant.

31) *On the Electric pulsation accompanying Automatic movements in 'Desmodium' gyrans.*—Linnæan Society, 1902.

His next work gives a complete account of the investigations on the response of inorganic and living substances.

(32) Response in the Living and the Non-Living —*Longmans, Green & Co., 1902.*

"The responses in plants and metals were shown by Professor Bose, to be modified exactly in the same way as animal tissues are modified, there being not a single phenomenon in the response in muscle or nerve that has not an exact parallel in the response of metal and plant. Just as the response of animal tissue is found to be exalted by stimulants, lowered by depressors and abolished by poisons, so also it is found that,under the action of appropriate reagents, the response in plants and metals undergoes similar exaltation, depression or abolition. The conclusion reached by Prof. Bose, therefore, is that: capacity for response is not confined to living tissues; the living response in all its diverse manifestations is but a repetition of phenomena exhibited by the inorganic; there is in it no element of mystery or caprice, as is admitted on the assumption of a hypermechanical 'vital force' acting in contradiction or defiance of those physical laws that govern the world of matter; the respose phenomena are not determined by the play of an unknowable and arbitrary vital force, but by the working of laws that know no change, acting equally and uniformly throughout the organic and inorganic world."—*Engineering Magazine.*

"Dr. Bose's remarkable experiments on living and dead matter show that there is a continuous transition from the one kind of matter to the other, and that some inorganic materials are capable of being stimulated, fatigued, poisoned and temporarily 'killed.' Thus another function of living matter has been annexed to physical science, or rather, the idea of life has been expanded. Prof Bose has opened up a field which was hitherto considered absolutely closed."—*Electrician.*

"J. C. Bose, in his *Response in the Living and the Non-Living*, after showing that under electrical stimuli plants exhibit fatigue, etc., and are affected like animals by anæsthetics and poisons, goes on to prove the same properties of tin and platinum wire. These also become fatigued; there is a threshold of response; subliminal stimuli become effective by repetition; response increases with the intensity of stimulus up to a certain point at which another limit is reached; response is affected by temperature and the median range is most favourable to it; some substances act as stimulants upon tin and platinum, others like anaesthetics, others as poison destroying all response. A small dose may increase the response and a large dose of the same abolish it. The resemblance of these results to some obtained in Physiological Psychology is obvious."—*The Metaphysics of Nature* by Prof. Carveth Read.

Herbert Spencer wrote to the author:—

"Notices of your investigations have, from time to time, excited my interest. The topic is one of extreme interest, and one which in earlier years would not improbably have received due recognition in my book."

During the next three years (1903—1905) Prof. Bose turned his attention to researches into the various responsive reactions of plants. For this he invented a number of original types of recorders which revealed many unsuspected phenomena in plant-life. We give accounts of only the most important of these.

(33) *The Mechanical Response of Ordinary Plants.*

By means of his delicate instruments he demonstrated that even ordinary plants gave motile response.

"These effects (of contraction) are observable not only in so-called 'sensitive' plants, but in all living parts of plants, and it is a definite advance due to Dr. Bose's delicate experimentation, to have it shown that all radial organs, stems, styles and stamens, shorten on stimulation."—*Nature.*

(34) *Effects of Drugs on Response of Plants.*

In this he demonstrated the remarkable similarities of effect produced by drugs in plant and animal.

(35) *Death-Spasm in Plants.*

No sign has hitherto been found to determine the exact moment of the death of a plant. Prof. Bose discovered that a spasm passes through the plant at the critical moment.

(36) *The Morograph.*

This instrument records the critical point of death of the plant with great exactness. It also demonstrates the translocation of the death-point under different conditions.

(37) *Polar Effect of Current in Excitation of Plants.*

This important discovery by Prof. Bose shows that the excitatory reaction in a plant is determined by the point of entry or exit of an electric current. It establishes the identical nature of excitation in the animal and the vegetal protoplasm.

(38) *Electro-Tones in Plants.*

In this the variation of excitability induced by Anode or Kathode, is demonstrated to be identical in the case of animal and vegetal tissues.

(39) *Electro-tractile Response.*

This discovery furnishes a new mode of detecting the passage of excitation in plants.

(40) *Multiple Response in Plants.*

The discovery of repeated responses in plants under strong stimulation, led to the elucidation of the most obscure phenomenon of spontaneous movements.

(41) *Inquiry into causes of Automatic Pulsation.*

One of the most intricate phenomena in physiology, is the occurrence of spontaneous movement, so-called. No satisfactory explanation has been offered to account for it. As a result of a long course of investigation, Prof. Bose succeeded in tracing the exciting cause.

"This is a most valuable and interesting account of experiments, offering an explanation of autonomous movement, and its relation to multiple response. After a careful perusal of this, one is convinced that 'Automatism' has simply been the name used to cover our ignorance of the reason for movements, which we did not understand, and for which we could see no immediate stimulus. Experiments here described on *Biophytum* and *Desmodium* show how 'automatism,' to use the old name for the movements characteristic of these plants, is simply the result of the condition of the plant, and the stimuli to which it has been submitted—"—*The Athenæum.*

Prof. S. H. Vines, F. R. S., President of the Linnæan Society. wrote to him:—

"It seems clear that you have revolutionised in some respects, and very much extended in others, our knowledge of the response of plants to stimulus. Spontaneous movements have always been a difficulty, but your work seems to give the clue, to suggest that there is no such thing as an absolutely spontaneous movement, but that every movement is the result of the action of a stimulus which has been stored up. This discovery alone would be a striking result of all the time and labour you have devoted to these researches. However I cannot think, but that there must be a great deal more to be discovered along the lines that you have opened up."

(42) *Influence of Temperature on Automatic response.*

In this is shown the parallelism of effect of temperature on rhythmic plant tissue and the cardiac tissue of the animal.

(43) *Effects of Various Drugs on the Rhythmic Pulsation of Plants.*

"Among the most interesting of the experiments are those dealing with the action of drugs. The identity of phenomena in both the contractile and rhythmic tissues of animals and plants is most striking. The author seems to have demonstrated in the most conclusive manner that there is an essential unity of the physiological effects of drugs on plant and animal tissues; and if this be the case, it is clear that investigations of the utmost value may be carried out on plants for the purpose of getting light on the problem of the modification of the effects of drugs on individual constitutions."—*Westminster Review.*

He next investigated the important problem of:—

(44) *The Different Effects of Drugs on Plants of Different Constitutions.*

By subjecting a specimen to certain specific conditions, he was able to make it immune to the action of poison from the effect of which others succumbled.

(45) *The Shoshungraph for Researches on the Ascent of Sap.*

This is a new type of instrument invented to record the suction of liquid by the plant.

(46) *The Growth Recorder.*

Accurate investigation on the phenomenon of growth has been rendered possible by the invention of this apparatus, which records and gives instantaneous measurement of the rate of growth.

"The apparatus and the experimental methods employed show great ingenuity .and praiseworthy simple directness of attack. One feels that valuable results are to be got with the delicate optical levers, the Kunchangraph, the Balanced Crescograph and the Morograph. Workers on growth will be forced to abandon their primitive and clumsy methods and much good will result from the refinements here introduced."—*Nature.*

(47) *The Balanced Crescograph.*

This instrument based on a novel principle is employed for determining the influences of various agencies on growth.

(48) *Researches on Thermo—crescent Curve.*

This is a long investigation on the effect of temperature on growth, and the determination of optimum point of growth.

(49) *Researches on Positive and Negative Geotropism.*

The outcome of this investigation is to show that the opposite reactions of growth on the shoot and the root are not due, as has been supposed, to two different sensibilities but to the differences in the points of application of stimulus in the two cases.

(50) *Determination of the Laws of Growth.*

Certain important factors in growth discovered by Prof. Bose, had not hitherto been recognised. Taking account of these, a complete law of growth curvature is enunciated.

(51) *Fundamental Responsive action of Plant to the Stimulus of Light.*

(52) *Researches on Positive and Negative Heliotropism.*

All the various responsive movements of plants under the action of iight is shown to result from certain definite and fundamental reactions.

(53) *Researches on Diurnal Sleep.*

(54) *Torsional response under stimulus of Light and Gravity.*

The conditions which determine this response are traced and a law enunciated.

Prof. Bose next published his exhaustive work on "Responsive Reactions of Plants."

(55) *Plant Response as a means of Physiological Investigation.—Longmans & Co. 1906,*

"A biologically equipped reader will experience dazzlep admiration for the logical progressive way. in which the author builds up, not in words, but actually by experiment on experiment a complete functioning plant from three simple conceptions. These conceptions are: *Stimulation,* the transference of the external energy to the plant; *Contraction*, the 'direct response' of plant cells to stimulation; *Expansion* including growth the 'indirect response' to stimulation. There are literally scores of special points of the greatest interest in the course of the book. All such experimental cross-examination will make for the progress of knowledge, and we think that Dr. Bose can claim that his book will be an external stimulus to the growth of plant physiology and the responses of future investigators."—*Nature.*

"This book may be acclaimed as a path-breaking one; for it shows a method of attack and refinement of instrumentation for the study of the phenomena of irritable reactions in plants, that is sure to be of the utmost service"—*Botanical Gazette.*

"Prof. Bose's work is a monument of scientifically directed industry, patient observation, far-reaching ingenuity and logical investigation. While chiefly of interest to botanists, it can not fail to attract the attention of serious biologists, and every student will welcome it as a helpful contribution to the unravelling of the problem of life. The many experiments here described are admirable in conception and in their execution the author has designed many peculiarly delicate and beautiful forms of apparatus. The chief merit of the work is that it demonstrates the fundamental unity of physiological response in plant and animal."—*Medical Review.*

"The work represents an enormous stride in our conception of the vegetable kingdom. It throws light on many problems in general physiology, and is a welcome contribution to our knowledge of molecular physics. It fully and clearly demonstrates, that the various energies of the outside world influence the vegetable like the animal organism, and by a more or less similar mechanism."—*Electrical Review.*

"With the appearance of the important book by Professor Bose, on "Plant Response," we have for the first time a conception which embraces all the expressed or unexpressed "sensitiveness" of plants. We are now presented with a complete theory of their movements. We may add that it is one which no plant physiologist can afford to ignore, which no student of any branch of botany should overlook, and which should prove suggestive to animal physiologists, possibly even to psychologists."—*The Athenaeum.*

"It may be unhesitatingly said that a careful reader oi the present volume must be impressed by the ingenuity of device, and the delicacy of manipulation, obvious throughout the whole of the experimenting. Assuming that the instruments work exactly as described, it is difficult to reach conclusions which differ materially from those stated by Professor Bose."—*American Journal of Science.*

"His theory of the fundamental uniformity of all plant response is certainly most illuminating, and one for which he brings forward a great weight of evidence. The value of his book lies in the general theory put forward, and in the fact that he is the first to apply to the study of plant response, apparatus which he has elaborated to an extraordinary degree. The book certainly marks an epoch in the method of attack on the problems of irritability in plants."—*Journal of Botany.*

In the Plant Response, various excitatory effects were detected by means of mechanical response and recorded by the specially sensitive instrument invented for the purpose. Prof. Bose next turned his attention to discover and perfect other methods of investigation by which the various invisible excitatory reactions in the plant induced by different forms of stimuli, could be detected and recorded. The methods now employed were electrical, by means of which various response phenomena were discovered in the plant, the existence of which was quite unsuspected. These particular investigations were carried on for the next three years from 1906 to 1909.

(57) *The Electromotive Response of Plant.*

This gives an account of the result of the research on various effective methods of quantitative stimulation of the plant, and the electric record of the resulting response.

(58) *The Relation between Stimulus and Response.*

Webber-Fechner's law is shown to be applicable to the plant-response as in that of the animal.

(59) *Rheotomic Observation of Electric Response of plant.*

This research determines the time-relation of initiation. climax and decline of electrical response.

(60) *Demonstration of Dual Character of Response.*

In this is given an account of the discovery of the existence of two distinct kinds of response, whose signs are opposite. The discovery of positive response throws ligbt on many physiological reactions which had hitherto been regarded as very obscure.

(61) *Detection of Physiological Anisotropy by Electrical Response.*

An account is given how owing to the differences in the previous history, different parts of an isotropic organ become anisotropic; an electrical method is described to detect such physiological anisotropy.

(62) *Natural Current in a Plant and its Variation*

This investigation was carried out to determine the condition under which there is a fiow of electrical current in a plant, and the changes in the current.

(63) *Electrical Investigation on the Action of Drugs on Plant-tissue.*

The physiological change induced in the plant-tissue by various drugs is determined by means of variation of electrical response.

(64) *Determination of Variation of Excitability of Plant-tissue by Method of Interference.*

This is a new and extremely delicate method by which a slight physiological change is detected.

(65) *The Current of Injury and Negative Variation in Plant.*

(66) *Current of Death.*

(67) *Effect of Temperature on Electrical Response.*

(68) *The Electrical Spasm of Death.*

This is a remarkable phenomenon, discovered by Prof. Bose of a sudden electrical current generated in the organism at the critical moment of death.

(69) *Multiple and Autonomous Electrical Response.*

It is here shown how the electrical rssponse becomes repeated under a single strong stimulus. This is an independent demonstration of the fact that living tissue can store up, for the time being, the energy of its environment, to be given out later in the form of repeated pulsations.

(70) *The Electrical Response of Leaves.*

It has been supposed that the leaf of *Dionaea* was alone sensitive. This research shows that every leaf is excitable and gives electrical response on excitation.

(71) *The Leaf considered as an Electrical Organ.*

It is shown that owing to physiological anisotropy of the upper and lower surfaces of leaves, a feeble electrical discharge takes place across the leaf when certain conducting tissues in the petiole are excited.

(72) *The Theory of Electrical Organ.*

The complex organ of the electrical fish consists of a series of plates. Prof. Bose shows that the electric action of each plate is fundamentally the same as that which causes an electrical of discharge in a leaf. In connection with this he shows that the so called "blaze current" which has been supposed to discriminate a vital reaction, is observed also in certain inorganic preparation made by him.

(73) *Researches on the Electrical Response of Skin, Epithelium, Gland and Digestive Organs in Plant and Animal.*

(74) *Electric Response of plant to the Stimulus of Light.*

The various characteristics of the response of plant to light is shown to be similar to the electric reaction of light on an animal retina.

(75) *Geo-electric Response.*

In this research is described a new method of detecting excitation induced in the plant by the stimulus of gravity.

(76) *The Conductivity Balance.*

The invention of this method enables very accurate determination of the effect of various drugs on the conductivity and excitability of the plant-tissue.

(77) *Response by Variation of Electric Resistivity.*

Another new method depending on variation of electrical resistance, is described for the detection of excitatory change.

(78) *The Molecular Theory of Excitation and its Transmission.*

In this the author enters into detail of the molecular aspect of excitatory change induced by stimulus.

(79) *Inorganic and Organic Memory.*

"Prof. Bose puts forward an interesting theory of memory as an after-effect of sensory stimulation, and deals with the much more difficult problem of the revival of an image long after it has apparently faded It has been suggested that this process of revival depends on the existence of some "scar" or fixed impression on the brain, or on a certain persistent disposition or tendency to movement created there. Prof. Bose gives reason and some experimental evidence to show that such a revival of memory consists of two distinct factors; first, that molecular change with concomitant change of properties: and second, the effect of an internal stimulus, delivered as a blow from within, by an impulse of the will upon the sensitive surface in which the image is latent."—*The Athenæum.*

His next work is a complete study of various electric responses in plants and their relation to the corresponding phenomenon in the animal, treated according to the comparative method.

(80) Comparative Electro-Physiology.—*Longmans & Co., 1908.*

We must regard the common divisions represented by the various sciences—say physics and biology—as purely man-made categories, excusable, and indeed convenient for our purposes, but without any ultimate warrant in reality. We shall, therefore, always be prepared to listen when a student of one science introduces his methods into another. It might easily be shown from the history of science that the great steps in our knowledge have coincided with these invasions It might also be predicated from current inquiries in many fields that the great scientific achievement of our century will be none other than the synthesis of the sciences. The less we recognise boundaries and demarcations, the more we recognise the supreme truth. Notable at the present day, amongst those who see how puny and artificial and cramping are the accepted barriers among the sciences, is the Indian Physicist, Prof J. C. Bose of Calcutta Seven years ago Dr. Bose began with inquiries into response in the living and non-living which he has now carried a long stage further in his book "Comparative Electrophysiology."—*Westminster Gazette.*

The electrical physiology of muscle and nerve has undergone many changes both in theory aad practice. It has been left to Prof. Bose to take a wide view of the subject and to correlate the electrical changes in the neuro-muscular apparatus of the animals with similar, but less known, changes occuring in the botanical world. The author has made a valuable contribution to the knowledge of the extremely difficult subject of electro-physiology. His observations are useful alike to the physiologist (concerned with animals and plants), the physicist and the psychologist."—*The Athenaeum.*

"This book will interest a large circle of scientific readers dealing as it does with the problems of physics, botany, physiology and experimental psychology. The author, when he was in England, acquired a reputation for the skill and ingenuity with which his apparatus was designed, and in the present volume he has given further instances of this. The book contains much that is novel. His *Sensimeter* will probably become a part of the curriculum of the psychologist. To the physicist, perhaps the most interesting thing is the Magnetic Conductivity Balance. These experiments are of exceeding interest."—*Electrician.*

"In sequence to his books on Response in the Living and the Non-Living (1902) and Plant Response (1906) Prof. Bose has published a third volume on Comparative Electrophysiology. Prof. Bose has great ingenuity in device of experimental apparatus, fertility in initiating new lines of observation, and a clear style of setting forth his experimental results. There are in Prof. Bose's book a great many very interesting observations and ingenious methods of experimentation which repay the reader's attention. In particular his experiment 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 sundew and pitcher plants with animal glands; his demonstration of "blaze current" in a brominated lead plate and assertion that it cannot be regarded as a sign of life; his demonstration on the motile leaflets of *Biophytum* of the anodic and kathodic effects of constant current, and the velocity of transmission of excitatory waves; his comparison of retentiveness of molecular change in metals with memory, in fact the whole book abounds in interesting matter skilfully woven together."—*Nature.*

After the publication of the *Comparative Electro Physiology*, the Government of India sent Prof. Bose on his third Scientific Deputation to the West (1908-1909). In answer to invitations extended to him by different Universities and Scientific Associations, he visited America and delivered a series of lectures on the results of his own researches. He gave an Address at the Annual Meeting of the American Association for the Advancement of Science held at Baltimore, and lectured before the New York Botanical Society, the Medical Society of Boston, and the Society of Electric Engineers at Chicago. He also delivered a series of post-graduate lectures on Electro-Physics and Plant-Physiology at the Universities of Illinois, Ann Arbor, Wisconsin and Chicago.

We have given a list of 80 important investigations carried out during fifteen years, between the years 1895 and 1910—investigations that have profoundly affected not one, but many branches of science. Dr. Bose continued his researches and the extended series of investigations carried out during subsequent years were published by Messrs Longmans in 1913 under the title of "Researches on Irritability of Plants.

One of the essential conditions for the discovery of new physical or physiological phenomena, is the successful invention and elaboration of apparatus which should combine at the same time an extreme sensitiveness and the highest accuracy. Facilities for this are only available in Western countries with expert mechanicians and high class instrument-makers. The lack of such facilities was regarded as one of the difficulties that could not be surmounted in India. Prof. Bose accepted the limitations imposed, and succeeded with the help of Indian workmen in constructing those instruments of exquisite delicacy, which were so invaluable for research, and which have been so highly eulogised in Europe. It must be a matter of much gratification to us that America, which stands unrivalled in her mechanical and instrumental resources, should have to come to India for instruments of research.

We have in these pages described Dr. Bose's new instruments to record the slightest movements of plants. His further studies and investigations of plant life are recorded in the two volumes of "Life Movements in Plants" published in 1918 and 1919.

THE BOSE RESEARCH INSTITUTE.

THE INDIAN TEMPLE OF SCIENCE.

By Prof. Patrick Geddes.

THE scientific event of the year (1917) 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 refinement, 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 the Institute and its work is a large double tracing, being 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 these 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, notes the perception-time within the thousandth part of second, and measures 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 to Galileo and Leonardo da 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 complimental advances we call "discovery" and "invention" respectively.

Let us first pass through the great Lecture Hall, to 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 waterplants and with a group of trees, partly old inmates of the garden, partly lately transplanted hither, at full size, under anaesthetics. 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 seience, the rhythm of its intellectual life.

From these beginnings of the future Bio-physical 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 physiologieal.

For so many enquiries the new three 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 1500 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. Other courses and individual lectures will also be announced from time to ·time, and fresh researches deseribed 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.

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.

BOSE INSTITUTE RESEARCH STATION.

THE hill station of Darjeeling will soon become a scientific centre of international importance. Sir J. C. Bose's last visit in Europe, as is well known, created the widest interest among the leading scientists. The unexpected revelations of plant life have opened out great possibilities in the advance of various sciences and also in their practical application. The Bose Research Institute has within 4 years of its existence won for itself a very important place among the world's great scientific centres. The leading scientific men of the world have become its foreign members. Among these may be especially mentioned the President of the Royal Society of London; the President of the Academy of Sciences in Paris, Lord Rayleigh, the eminent physicist Professor Arrhenius of Sweden; Prof. Haberland of Berlin; Prof. Molisch of Vienna, Professors Millikan and Stanley Hall of the United States.

The transactions of the Institue are in great demand by all the scientific centres of Europe and America. Sir J. C. Bose's works will soon be translated into French and German,

The Government of India have obtained the sanction of the Secretary of State and his Council for a permanent Imperial Grant to the Institute in furtherance of the researches which have advanced the world's science and which redound greatly to the credit of India as a centre of scientific research. The amount of the Imperial Grant will be double the income derived from public donations. It is understood that Sir J. C. Bose's own contributions to the Institute will ultimately total the sum of ten lacs of rupees. The Institute has roused wide national intersst.

Though it is barely six months since Prof. Bose has returned from Europe, yet within this short time he has been able to make several new discoveries of signal importance. He had proved that plants have a nervous system, but it is only recently that he has been able to localize by his elctrical probe the actual tissue which functions as a nerve. This new method of localising internal irritation will probably prove of great importance in medical practice. He has also been able to localise the particular organ by which the plant is enabled to recognise direction in space. But the most startling discovery is the detection of the nervous impulse and the corresponding reflex by which the plant's attitude is adjusted in regard to the environment. These and other results will be published in the forthcoming Transactions of the Bose Institute.

Applications have been received from foreign post-graduate scholars for permission to enrol themselves as workers, in order to acquaint themselves with the new methods of investigation in the Institute and already a distinguished French physiologist took advantage of its facilities.

The Institute in Calcutta will be engaged in investigations of wider scientific interest. The necessity has arisen for its extension both at Sibjeria on the Ganges and at Darjeeling. The Sibjeria Experimental Station will be utilised in practical experiments relating to the advance in scientific agriculture and other problems in which the Government of

Bengal are especially interested. Sir J. C. Bose is the President of the Commission recently appointed by the Government of Bengal for inquiry into the question of the water hyacinth problem.

Prof. Bose has been requested by various scientific societies of the West to undertake [illegible] on plant life under European conditions. These are fulfilled at Darjeeling and his Mayapuri laboratory will be fitted up with his latest types of apparatus. The laboratory is situated at a [illegible] height and an entire hillside has been turned into a unique natural part to be maintained as far as possible in a state of nature. The vandalism of tourists has practically denuded the district of its wonderful orchids. These will be replanted in the nature garden and others introduced from Sikkim and Tibet. Wild flowers of the district will also find here a sanctuary. Darjeeling is to be congratulated on this great civic enterprise which will, at no distant date, attract scientific visitors from all parts of the world. And India is thus taking an active part in great world movements.—*Collegian.—Aug. 1921.*

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