JAGADIS CHUNDER BOSE AND HIS SPONTANEOUS MACHINES : DEVICES, DEMONSTRATIONS, AND DISCOURSES OF LIFE

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Introduction

The fairly long historiography on Jagadis Chunder Bose, with its primary focus on the philosophical content and "alternative" genesis of his scientific theories,[1] has largely ignored the *actual* material practices which Bose had to engage with while *doing* science. Foregrounding these practices, this article wishes to understand the material culture of Bose's experimentalist science which standard histories of ideas often tend to obscure.[2] Unlike the narratives which deal with Bose's *theories* and hypotheses, this article focuses on the practico-infrastructural cluster which made Bose an experimenter. The instruments designed by Bose, especially those for plant-researches, thus constitute one of the main subjects of this paper. The primary task of this paper is to situate those machines within the contemporary global tradition of scientific instrument-making. Secondly, our discussion on the discourses on Bose's instruments tries to show that the instruments were "dense with meaning".[3] They embodied particular "strategies of demonstration". The history of their *making* hinted at the "work relationships in the laboratory" and outside. We will also try to point out that the instruments could have a life outside the immediate concerns of the experiment in the "material and symbolic connections to the outside cultures in which these machines have roots".[4] Bringing forth the instruments in our studies, as Peter Galison believed, would help us to better understand Bose's "life associated with experimentation" and "not the life affixed to theorizing".[5]

Another type of machines constitutes the subject of our discussion: "machine" as an analogical model.[6] In calling Bose's instruments "spontaneous machines", I wish to refer to John Tresch's impactful

study of the "romantic machines" of early nineteenth-century Paris. Like the steam engines, voltaic batteries, sensitive electrical devices discussed by Tresch, Bose's instruments too were understood as "flexible, active, and inextricably woven into circuits of both living and inanimate elements".[7] In the cosmology of Bosean science, the scientific instruments were alive with the same energy which was throbbing inside living bodies in nature. With the border between the animate and the inanimate collapsing in case of the scientific apparatuses, we also have the plant-bodies appearing more and more machine-like in Bose's discourse. Translations of different kinds happen frequently. Organic life itself seemed to be more and more machinic. However, the imagination of an equivalence between the machine and the living-body, as this paper argues, was productive in nature. It held promise for unlimited improvement of organic life, modification of nature to that end through artificial intervention. This mutual reconfiguration of the living and the machinic, I contend, opens up the traditional vitalistic imagination of the nation-form[8] to further enquiries.

I. Doing Science: Demonstration in Action

Trained in the science classes of Father Eugene Lafont at St. Xavier's College, Calcutta during 1875-77 and then at the universities of Cambridge and London between 1881 to 1884, Jagadis Chunder Bose had little doubt that the true duty of a scientist was not merely observing the nature from the isolation of his laboratory, but also making nature demonstrate itself through his army of instruments.[9] The scientific-minded Calcutta literati of the late nineteenth century, well before the rise of Bose to eminence, was no less aware of the necessity of "public" demonstrations of scientific experiments in the diffusion of scientific knowledge and temperament. With Father Lafont's St. Xavier's lectures and the establishment of Mahendra Lal Sircar's Indian Association for the Cultivation of Science in 1876, a culture of public lectures aided with demonstrations of experiments and instruments had emerged in Calcutta.[10] Many of the Bengali science-enthusiasts of the early twentieth century repeatedly emphasized the importance of sophisticated scientific instruments and physical laboratories in science education.[11] There was no substantial

indigenous production of scientific instruments before the Second World War, most of the apparatuses and devices were imported from Europe and America.[12] The event of Bose emerged within this twofold practice of science which had visual demonstration on one hand and instrumentation on the other. Starting with his lecture on the self-made microwave transmitter and receiver at the Calcutta Town Hall in 1894-95 until his death in 1937, Bose gave numerous public demonstrations in Calcutta and several other cities in Europe, Japan, and the United States. Unlike Lafont or the early lectures at IACS, however, Bose's demonstrations were meant to present before the Calcutta public original experiments. The instruments involved in those demonstrations were also new and therefore vulnerable to doubt and extra scrutiny.

Staging Demonstration

Bose was aware of the fact that "nothing short of visual demonstration" would convince the scientific community of west about his theories and remove the "blank incredulity that stood in the way of their wide acceptance".[13] The contemporary Indian press enthusiastically covered Bose's long scientific trips to Europe, United States where he exhibited his "inventions" and "discoveries" before the scientific community of the West. The frequent long-distance trips had one significant consequence for the design of the instruments: they demanded portability of the apparatuses. Patrick Geddes, the famous biologist and city-planner, and also a biographer of Bose, was particularly full of praise about the microwave receiver, completed during 1894-95, for it was "a small and compact set of appliances, which stands conveniently upon one end of a writing-table, and may be packed into a suit-case, and thus carried and exhibited to any audience".[14] The truth-claim of a scientific experiment, the legitimacy of the involved instruments depended on successful repetitions of the experiment.[15] Repetition, on the other hand, demanded portability of the instruments. When Bose had communicated his discoveries regarding the unity of life, which "were incredible and opposed to accepted theories", he was challenged by his opponents to come to London and demonstrate the instruments at work.[16] During his travel to London, the porter entrusted with his instruments "carried the instrument box upside down, with the result that the heavy base

crushed the delicate recording portion [of the ordinary Crescograph] beyond recognition". Bose complained, "so the costly visit to Europe was for that time complete failure".[17] This incident inspired him to make the next instrument he designed, the Magnetic Crescograph, small enough to carry on his own.[18]

Theatrics of Science: Staging Instruments in Action

At Bose Institute, public demonstrations of scientific experiments involving Bose's instruments took place on the dais over the stage inside the grand lecture hall.[19] The instruments were kept in a small chamber below the stage during the demonstration. Abaninath Mitra, the architect of the Institute building, recounted that this small instrument-chamber was built as Bose wanted the instruments to be supplied upstage one by one instead of all of them crowding the stage together since that would confuse the focus of the spectators.[20] During live demonstrations, "whenever a particular instrument appeared on stage", Mitra informs us,

> a powerful spotlight from the gallery was focused on it and an image of that instrument was reflected on the screen behind the stage. Everybody in the audience could then watch that image.[21]

Bose's public demonstrations were often pre-rehearsed. On the day of his Royal Institution lecture on "plant-autographs" in 1914, Bose took his assistants, Basiswar Sen and Jyotiprakash Sircar to the Institution early in the morning to arrange the whole experiment "in the preparation room on a table the top of which could be transferred to the Hall immediately before the lecture". He made the two go through the whole sequence in strict order, considered the possibilities of accidents and took precautions.[22]

The public demonstrations of his experiments, with the carefully designed lighting arrangements, studied display techniques, scripted projections and timed entry and exit of the instruments into the stage, entailed a certain amount of theatricality to the practice of doing science. It was here that modern science could accommodate the performative of the premodern magic and entertainment shows alongside the disciplinary rigor of its dry, putatively objective regime of laboratory-practice.[23] Though he was "never a natural orator",[24] in his public demonstrations of scientific experiments Bose consciously

used a particular style of elocution full of anecdotes and witty comments. Like all theatrical performances, Bose's demonstrations too demanded a space for impromptu improvisations on stage and were always circumstantially contingent. Sometimes not the success, but failure of the aiding instruments could come to crucial help during a live demonstration. Or so happened with Bose during his lecture at the Botanical Lecture Hall of the Cambridge University on 2 June 1914. Due to the cold and mist of Cambridge weather, the Desmodium plant to be used in the experiment became paralyzed. In a desperate attempt to save the day, Bose injected it with a stimulant. Meanwhile the optical lantern tasked to project photographic slides explaining parts and functions of Bose's instrument began to malfunction. This bought him enough time for the stimulant to take effect while he kept the awaiting spectators engaged with passionate, impromptu, and inspired elocution.[25]

Instruments at Rest: Displayed

Bose realised the necessity of live demonstrations of his experiments early in his career. However, in order to be accepted as legitimate scientific instruments by the global scientific community, it was not sufficient to just demonstrate Bose's instruments *at work*, that is, to only repeat his experiments before different audiences and in different sites. The truth-claim of his live demonstrations, however, demanded more than successful repetition of the instrument's performance. Even successful demonstrations generated skeptical responses among the spectators where they doubted the scientificity of the instrument and considered the performance on stage to be magic-like, beyond rationalities.[26] The "pulsations" of the plant life recorded by Bose's devices were declared the results of faulty, "imperfectly adjusted instruments". Some scientists in Europe and America alleged that the duplicates of Bose's instruments of plant researches made in their laboratories failed to provide the desired results. There was an allegation that the electric probe and the sphygmograph did not work when the apparatuses were properly insulated from vibrations and electrical disturbances.[27] Therefore, alongside the demonstration of their performance, Bose's instruments were often exhibited *at rest* so that any doubt over their constructional integrity could be quashed. During his visit to Vienna, Bose invited the leading men of science

and specialists of medicine to explore his instrument closely, to "take the instrument to pieces, reassemble them and repeat the experiments themselves" so that no one could doubt "that none but its inventor could work the extra-ordinarily sensitive instruments".[28] Along with other scientists, "[t]he head of the department for construction of high-class precision instruments for research of the Vienna University was also present to take notes and sketches of the different part of the apparatus[.]" During his public demonstrations, detailed images of the instrument used in the experiment were projected through slide-shows to explain the construction and the function of the device to the present audience.

Access to the instruments had always been an issue in the claims of credibility of Bose's machines. One can recount here the famous Waller-Bose controversy, a well-narrated account in the traditional historiography, in this context.[29] Following the debate between Augustus Waller, the British physiologist who produced the first echocardiogram, and Bose in 1902 regarding the claim of discovery of vegetable electricity, an expert committee was formed by the Royal Society of London which examined his instruments and certified their legitimacy.[30] During the controversy many physiologists alleged that not "all the controls necessary" for working the machine were made public.[31]

Instruments as Models of National Political Economy

Since the early days of the Bose Institute, the instruments of Bose's own designs were exhibited within glass-cases in the entrance lobby adjoining the lecture hall, arranged in order of their increasing perfection in observation and recording capacities.[32] By 1917 Calcutta had already developed a wide network of scientific displays in terms of taxonomic museums, public collections and zoological garden.[33] The showcasing of Bose's instruments can be read in context of that. But a simple analytic of the pedagogical display culture does not exhaust the particular form of Bose's scientific practices, nor does it help us understand the function and status of his instruments in his discourse of science. Demonstrations of Bose's instruments served not only as the revelations of indisputable scientific facts but also as expressions of the creative potential of the politically subjugated nation. The political economic agenda of swadeshi was to free the sphere of

production from the clutches of foreign capital. The success of Bose's public demonstrations with his army of instruments lay in the fact that they promised to bring together the two spaces of the laboratory - which was a site of production - and the space of scientific display - which was concerned about spectatorship and its pedagogical imports. On the occasion of the inauguration of the Institute, referring to the instruments in the glass-cases the entrance hall, Bose reminded the visitors, "They [the instruments] will tell you of the protracted struggle [...] of the continuous toil and persistence and of ingenuity called forth for overcoming human limitations".[34] For Bose, the instruments not only embodied the skill of the scientific investigator in exact experimentations, or specialised scientific knowledge, but also a more general "practical skill" that could be useful for other areas of practical utility beyond the immediate domains of laboratory sciences. The instruments embodied the practical skills whose indigenous origin was repeatedly emphasized in the popular discourse around Bose's instruments. Taraknath Das claimed that the expert of instrumentation at Vienna University confided that "how direct and simple the principle involved" in the construction of the instrument might seem, "the perfection of the apparatus" could only be achieved "due to the extra ordinary skill of men trained in the Bose Institute".[35] The claims of particularity of Bose's instruments in these occasions depended on the citations of the "indigenous" workmanship and labour embodied in their constructions.

Instruments between Construction and Invention

The local artisans whom Bose employed to build his instruments were so crucial in making them that sometimes construction of a new machine would be halted temporarily in absence of a particular artisan.[36] His notebooks suggest that he had to consult a professional clock-maker from time to time while designing and building his instruments.[37] The actual making of the different parts of the instruments was entrusted to Bose's assistants and the mechanics he employed.[38] However, those mechanics and assistants who supplied the "local" skills failed to generate any significant attention in the popular press. In most of the cases even their names do not survive. The popular narratives insinuate that all theoretical knowledge emanated from the scientist-innovator, who directed the mechanic's

hands towards the end of creating his machine. As an obituary of Bose in *Prabasi* recounted:

> He [Bose] found a skilled Bengali mechanic who was capable of making those instruments under his commands. He trained him in his own hands. Another scientist managed to lure him away from Bose by promising him extra wages. But this incident could not prevent Mr. Bose from continuing his research. He immediately trained other mechanics and recruited them.[39]

The story could not be clearer in its emphasis on the hierarchical relationship: it was the scientist-innovator and not the native mechanic that the Western-educated *bhadraloks* sought to celebrate as the ultimate source or the symbol of the creative genius. The indigenous mechanic appears in this narrative only to perform a particular task: they illustrate the *limits* of the material condition in which those machines were made and thereby highlight the transcending genius of the scientist-innovator. What the narrative of the designer-innovator does is to blackbox the equally important history of labour entangled in the construction of the instruments. Making of Bose's instruments involved several skills and trades. Construction of the bases of the instruments required a carpenter, the automatic movements of the machines needed a clock-maker, and screws, clamps, scales and other accessories needed nickelling and gilding. Bose's instruments connected different sites of production, many of them were far from the controlled laboratory space.

The account of the lone genius-inventor where the mechanics are "absent" disseminated a particular concept of creativity that reflected a strong bias for the idea or the plan over the actual object. When asked in an interview whether he himself built all the different parts of one of his instruments, Bose replied that he built them with insufficient local help at Calcutta, but on arriving in London he made duplicates by the best instrument-making firms there. Those firms supposedly expressed wish for producing more copies of the same so that they could be supplied to the laboratories in Europe and America.[40] If the celebration of the swadeshi production of Bose's instruments invoked a particular materiality of those machines, the above statement hinted at something else. Even if they were made in foreign workshops with the help of foreign labour, Bose's machines could claim to be

indigenous machines. In this narrative, the instruments could become a two-dimensional reality only - a pure design detached from its material body and the dexterity of craftsmanship. It is this particular "reality" of the Instruments which further upheld the supreme position of the scientist-innovator in the popular discourse.

However, one must note the peculiarities of a colonial situation which inherently constrained this narrative of the autonomy of the designer-inventor vis-à-vis the traditional artisan or the assistant-mechanic. In the anti-colonial agenda of highlighting the colonial difference, the superiority of the Indian craftsman provided a significant and popular rhetoric. References to the supreme dexterity of the manucacturing *hand,* therefore, keep reappearing in the popular discourse of "invention". A story which circulated in the contemporary press is symptomatic of this. It was said that after the successful demonstration with his instruments of electrical wave research at the Royal Institution of London in 1897, Hiram Maxim, the American-born British inventor, who was in the audience, asked to feel the hands of Bose "to realise for himself that tactile sensibility which could so unerringly feel the pulse of Nature".[41] The high sensitiveness and the perfection attained by the instruments were thought to be the results of not only good design but also of the "tactile sensibility" possessed by the Hindu craftsman/mechanic, which for Bose and his many contemporaries was a racial quality,[42] and therefore was never to be found in any other nation.[43] The instruments were therefore like extensions of the body of the emblematic Hindu craftsman. In this context, they were not quite *universally repeatable* as scientific instruments needed to be. Bose and his contemporaries celebrated the fact that despite the instruments being simple in construction, and its design being made public, they were so delicate that they became virtually irreproducible outside India.[44]

Very much like the Indian artisan of ornamental crafts in the Victorian discourse,[45] his counterpart in traditional mechanical trades too was believed to be in possession of a superior instinct but lacking the universal scientific knowledge necessary for modern design and invention.[46] To Bose, Nankuram of the Presidency College physics laboratory illustrated a similar case.[47] Bose was impressed by Nankuram, who was originally appointed as a menial servant in charge

of cleaning bottles and such, after some years of experience could "arrange [...] the most difficult experiments" or work the dynamo-electric machines and engines with considerable skill. For Bose, Nankuram's progress was made possible by a process that was nothing but instinctive, acquired through a close living with the machines.[48] Apprenticeship in the laboratory was therefore considered to be a legitimate practice of learning science. Gopalchandra Bhattacharya, the amateur scientist and popular science-writer, began his research-career at the Bose Institute in 1921 as an assistant to the scholars and also to the draughtsman responsible for making scientific drawings for the *Transactions of the Bose Institute* and other publications. He was soon to be trained as an electrician and entrusted with the task of regular maintenance of Bose's instruments.[49]

In the political economic imagination of swadeshi, a mere skill of turning the machine - a practical know-how - although very much coveted and celebrated,[50] was never thought to be sufficient without proper dissemination of the theoretical knowledge of science. It was never deemed as an end in itself. In concluding this account, Bose almost sighed in despair that Nankuram, the washer of bottles, was likely to remain so till the end of his life and could never become Faraday whose beginning had been similar.[51] Nankuram's story provided a template for Bose's main argument in that particular article : it was the lack of an appropriate combination of this traditional artisanal instinct and the knowledge of science that hampered the growth of scientific researches in India. However this combination was not without any hierarchy: the hand, in the last instance, must be subordinated to the eye or the mind.[52]

II. Instruments in Action: How and What did They Perform?

What did Bose's instruments actually perform? What were they supposed to demonstrate? Bose's instruments were meant to present before the ordinary human senses otherwise imperceptible natural phenomena, like the invisible microwaves, or inner designs of plant-life; that is why they were believed to be "sensitive" machines.[53] They were supposed to *magnify* ordinary human sense-perceptions which were thought to be inherently limited. As instruments of demonstration through magnification,[54] Bose's instruments seemed to be in a dialogue with other contemporary instruments of similar nature, especially the

scientific apparatus that provided the fin-de-siècle Bengali *bhadraloks* with a new sense of wonder: the microscope.[55] In simpler terms, Bose's scientific instruments are like the various types of detectors present in physics labs that brought the imperceptible "microphysical world" into the purview of empirical investigations of science.[56] As recording-instruments on the other hand, they appeared to be in a dialogue with various other contemporary machines of similar nature. One of the reports in *Nature* clubbed the Crescograph with a long list of other contemporary recording and measuring instruments such as the cardio-phonograph, the viscosimeter, the stethograph, the portable ergograph, the micro-nitrometer, the colorimeter, the chronograph with electro-magnetic signal, the pursuit-meter, etc.[57] The shared commonality between these instruments and those of Bose's was that all-of them "demonstrated" before the naked eye the invisible phenomena of nature. Moreover, all of them extracted and recorded statistical data from the hidden mechanisms of nature.

A Messy History of Design

The scientific instruments designed by Bose were complex and composite machines. If we reduce the Cresocograph to its parts for example, it would seem to be an assemblage of different small contrivances such as the optical levers, clockworks, different jewels and screws, guillotines etc. Instead of a monolithic story of an organic "invention" according to a premeditated design, the narrative of their construction, similarly, highlights efforts of combination (all of which were not successful), borrowed influences, contingent decisions. Bose's writings on his own instruments, show traces of a long tiring process of construction involving a constant introspection on the methods and circumstantial manoeuvring of the process.[58] The High Magnification Crescograph (or the Recording Crescograph) [Fig. I] was a device that employed a compound system of two optical levers to magnify the growth of plants by 10,000 times and record it. For the machine to work with precision its levers had to be extremely light-weight yet rigid. It was Navaldum - an alloy of aluminium used in the construction of Zeppelins - that proved to be the right kind of material.[59] The bearings of the fulcrum of levers were required to be frictionless in order to get accurate results. Initially imported clock jewels of ruby from Germany fulfilled the requirement. But when the

Fig. I. The High Magnification Crescograph. Bose, *Growth and Tropic Movements*

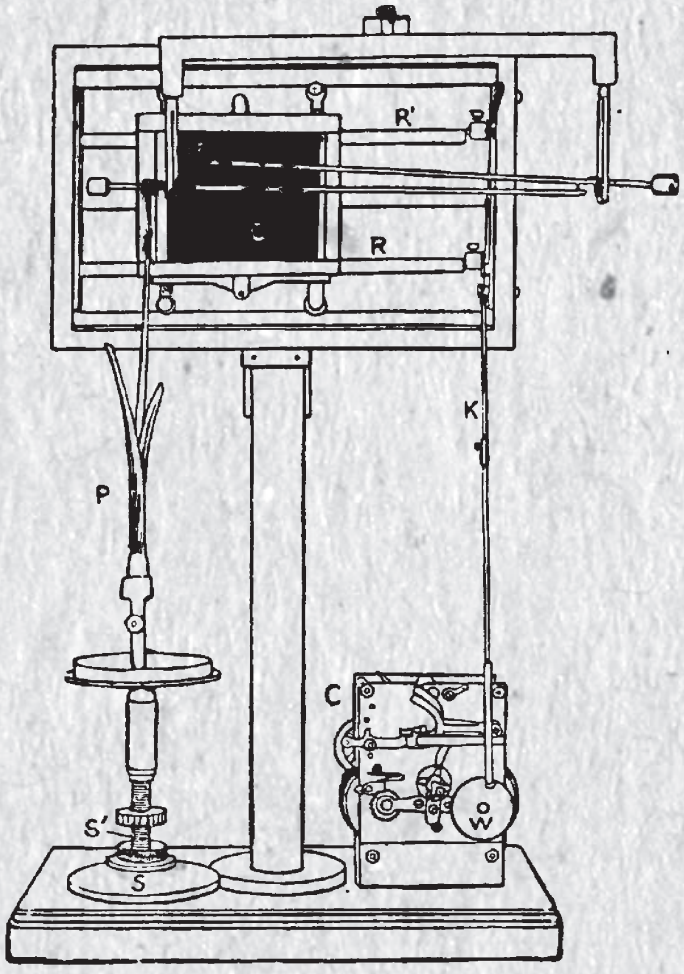


FIG. 3. Complete apparatus.

P, plant; S, S′, micrometer screws for raising or lowering the plant; C, clockwork for periodic oscillation of plate; W, rotating wheel.

First World War interrupted the supply, Bose was forced to devise an alternative system based on "a new principle of suspension using local material".[60] He faced another issue while designing the recording system of the machine: the leaf attached to the instrument failed to move the recording lever by overcoming even the slightest of resistances produced from "the friction of contact of the bent tip of the writing lever against the recording surface".[61] He first tried to resolve this glitch by replacing paper, the popular material for tracing response-curves of the physiologists, with a smoked glass-plate in order to obtain a smoother surface.[62] Still unresolved, the problem of friction was to be finally overcome by adding to the instrument another Bose contraption - the "oscillating device in which the contact, instead of being continuous, is made intermittent"[63] — "Samatal Yantra"[64] or the isorythmic machine. Not satisfied with the High Magnification Crescograph, Bose wanted to make a more powerful instrument on the same model. When he attempted to add a third optical lever to the original instrument in order to amplify its magnifying power, it failed hopelessly. What these anecdotes tell us is this : rather than a simple linear flow from the germ of an idea, the concrete object emerged through a complex process which could not be anticipated in its totality at the level of a pure idea or plan.

The traditional narrative of the genius of the designer-innovator reflected a bias for theory over practice. In its imagination of a smooth, one-directional movement from idea to object, it banishes the *accidental* from the narrative of the design process. However, we can find traces of it here and there that can problematize the said one-directionality. Consider the following statement made by Bose himself:

> [I]t 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.[65]

Thinking through the theoretical principles of a problem was not enough. Desiging of an instrument at times entailed complex processes of visual thinking on the part of the designer. Bose acknowledged these "informal" sources of inspirations behind the designs of his instruments. During his trip to London in 1901, when he was casually

visiting "a second-hand shop of discarded instruments" on an afternoon, "[t]he stimulus of sight of these broken things evoked a complex set of molecular thrill in that detector which they call the 'brain'; and standing there the vision of a new apparatus suddenly appeared complete in all details" to his mind. These types of *transfer of knowledge* or *skills,* where the sight of one object could stir the design of another in the maker's mind, were crucial instances of the use of "tacit knowledge"[66] in the making of Bose's apparatuses.

Many Lives of an Instrument

If Bose's machines borrowed freely from technological solutions meant for other hypotheses and purposes, his machines also had the potential to generate multiple uses, or imaginary functions at least, beyond their original objectives. Not always "the agreement between theory and instrumental behaviour" was a necessary condition to believe that the instrument is working properly.[67] There could very much be a certain asymmetry between the performances of the instrument and the original hypothesis it meant to demonstrate, even then the instruments seemed to be *working* perfectly. We witness several illustrations of this in the case of Crescograph. When many European physiologists were skeptical about its credibility, in the contemporary world of metallurgical engineering and technology, the Crescograph promised uses and solutions beyond its intended field of application.[68] Dr. Albert Abrams, a "fringe" American scientist who claimed to diagnose and cure diseases with electronic methods, acknowledged the Crescograph as the inspiration behind his own invention — the Oscillophone.[69] The instrument also served some metaphoric functions in the contemporary nationalist imagination where it could promise to perform fantastic tasks. The editor of *Young India* was so moved by the particular potential of the Crescograph in speeding up an experiment and its magnification power that he mockingly suggested to employ the device for detecting the microscopic growth of self-government under the colonial rule.[70]

Instruments of Translation, the Grammar of Curves

Instruments of plant-research like the Crescographs or the Oscillating Recorder did not only *magnify* life-movements of the plants,

they also made the plant *record* its own life-histories by means of tracing lines on the blank surface of the paper or the plate. It is as if the nature demonstrated itself through the instrument. The post-Enlightenment agenda of modern experimentalist science demanded that the need of nature must be into present itself for recording and observation.[71]

Bose's instruments of recording plant-responses, including the much-publicised Crescograph, were actually built upon contemporarily available practices of automatic recording of natural phenomenon which were developed since the last decades of the nineteenth century. In a sense, Bose's recording devices were to be seen as developments in a field of instrumentation which began with the popularization of James Watt and John Southern's Indicator-Diagram, the pioneer of recording instruments, in the nineteenth century.[72] At one place Bose directly compared his instrument with Watt and Southern's indicator-diagram.[73] In the last decades of the nineteenth century, this method of automatically tracing curves and mechanically recording them on smoked plate or paper became quite popular among the physiologists who employed similar techniques in recording response-curves of animal muscles.[74] The invention of the galvanometer in 1858 further facilitated *this* practice of curve-tracing among the electro-physiologists of the late nineteenth century Europe.[75] Soon, the emergent discipline of plant-physiology embraced this new technology. In the last decades of the nineteenth century and the early twentieth century, instrumentation in this line was further advanced and a whole range of modified auxanometers were developed by physiologists like Sachs, Pffefer and others to demonstrate and record minute modifications in plant growth.[76] Bose himself considered his instruments to be advancements in the line of physiologists' curve tracing machines.[77] The Crescograph and Bose's other plant-research instruments must be situated within this particular genre of instrument-making that was simultaneously unfolding in the contemporary west.

The curvatures produced through the Crescograph were automatic records of the plant's growth-movements. Bose deemed those curve-records "plant-autographs". By tracing response curves of plant movements the instruments were supposed to translate the everyday

experiences of the plant-life into information or data. However, I argue that more than objective scientific records, these curve-drawings constituted a particular affective register in Bose's discourse. Bose believed that the curves traced by the machine attached to the plant could successfully retrieve the "everyday life histories of plant" from the depth of silence.[78] For him, the curve-drawings traced by his instruments constituted a new language and a script - *Tarulipi* (arboreal script). According to him, "the script made by plants is similar to Devanagari to an extent - it is illegible to the untrained or half-trained eye".[79] Recording the "voices" of the unvoiced, was only one half of the task; the other crucial half was to learn to read and understand this new language. One contemporary newspaper compared the curves traced by Bose's devices to "a story told in a hieroglyphic script, but a script that a physicist can understand".[80] For the author of the article, Bose's instruments "are but pens with which petal, stem and leaf may write down a story of joy or suffering, of life and death".[81]

Now, how does one read into these lines the history of the plant-life? As Bose emphasised repeatedly, one must *learn to read* those unfamiliar scripts traced by the plants - *Tarulipi* - a script that was supposedly legible to the scientists only. To one who did not know how to read the script, the lines would be little more than doodles. No doubt Bose was referring to the language of curve-drawings that the twentieth century scientists frequently used to in communicating scientific data. Language presupposes the existence of a community. In the early twentieth century Bengal, it was a new, still emerging community that Bose's language of plant response-curves anticipated. Ramendrasundar Trivedi's article in the Bengali journal *Prabasi* on "New Discoveries made by Professor Bose" tried to train the newly forming scientific community in the grammar of this new language. Trivedi seemed convinced by the power of the curve-drawings in communicating all kinds of data or knowledge.[82] Justifying the long introduction where he tried to familiarise his readers with the scientific practice of curve-drawing by means of data-plotting, Trivedi wrote, "For those who are not familiar with this method, this introduction is necessary. Otherwise, the lines exhibited by Jagadishchandra would appear meaningless to them".[83]

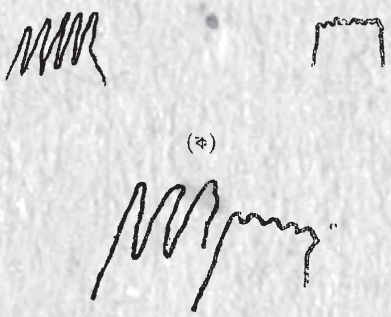
An Affective Reading

However, in Bose's discourse, *reading* Tarulipi was something more than a simple reading of scientific diagrams. The curve-drawings seemed to transcend their diagrammatic functions in order to become symbols. Response-curves of plants were presented in a series with response-curves obtained from animals and metals.[84] By means of a technique of pattern-comparison (between curve-tracings of electrical responses of different objects) they strove to show the semblance of responses in metal, plant and animal bodies and thereby highlight the all encompassing unity in the universe. Bose and the popularisers of his theories cited these tracings again and again, displayed them side by side, pointed out the visual similarities [Fig. IIa & IIb].[85] For Bose and his sympathisers, they invoked the presence of life itself - symbolised the unity in nature. In this context, they were elevated to a particular iconic status in Bose's discourse. The response-curves traced by the Crescograph and others were, as Bose repeatedly emphasised, "plant autographs", and as *autographs* they automatically drew comparison to human signatures. A usual ploy of Bose in his lecture-demonstrations of the investigations into the plant-life was to begin by presenting a popular image of the two signatures of Guy Fawkes, made before and after his torture, and asking the audience to notice the change between those two. He would then ask the spectators if stories of life could be recovered from human autographs, why could it not be the same in case of plants and proceed with the recording of plant-responses through his instruments on stage.

In and through circulation, the curve-drawings of plant-responses could become scientific relics and have a life outside the immediate context of the experiment. Basiswar Sen claimed that during Bose's visit to the University of Vienna in 1914 Professor Molisch, the renowned Botanist and the head of the Department of Botany, asked Bose if they could preserve the response curves produced during the lecture in their departmental museum. The curve-drawings of plant-responses were further reified by their architectural appropriation in the Bose Institute itself. Geddes informed his readers that "[a] distinctive sign of the Institute and its work is" the display of "a large double tracing, being automatically made in two parallel curves before

Fig. IIa. Curves showing similarities of responses in animal muscles and metals. Jagadananda Roy, *Vijnanacharya Jagadishchandrer Abishkar* (1912), pp. 192 & 194.

৩০শ চিত্রের (ক) অংশ পেশীর সাড়ালিপি এবং (খ) অংশ ধাতুর : উভয়ের ঐক্য অতি অদ্ভুত। গুরু আঘাতে পেশী ও ধাতু উভয়েই অবসন্ন এবং আড়ষ্ট। তাই চিত্রের রেখা উপরে উঠিয়াই সরল



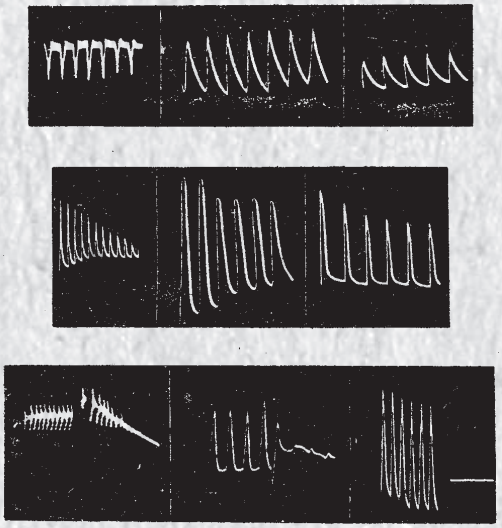
(ক)

(খ)

৩০শ চিত্র

হইয়া গিয়াছে। পরে কিছুকাল বিশ্রামের পর সেই রেখা নামিয়া পেশীর স্বভাবপ্রাপ্তির কথা জানাইতেছে।

Fig. IIb. Curve-tracings showing similarities of responses in animals, plants and metals. Charuchandra Bhattacharya, *Jagadishchandrer Abishkar* (1942), p.16.



বাম দিকে : প্রাণীর সাড়া। মধ্যে : উদ্ভিদের সাড়া। দক্ষিণে : ধাতুর সাড়া
উপর হইতে নীচে : বিভিন্ন অবস্থায় উহাদের সাড়া

the eyes of the observer" as one entered through the main gate of the Institute. "One of these curves records the result of the essential changes of the atmospheric environments-temperature, light, etc. — while the other summarizes the responses of a large tree to those changing conditions for every minute of the twenty-four hours". For Geddes,

> *This* autograph of the tree gives striking and vivid demonstration 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 devised for the purpose.[86]

At moments like this, the tracing got detached from the material body which produced it and became an icon in itself. In Bose's discourse, the response-curves produced by his machines had lives beyond the site of the laboratory and the plant-body which supposedly produced it. "[W]hich is the more real", Bose asks in a rhetorical manner, "the material body or the image which is independent of it? Which of these is undecaying, and which beyond the reach of death?"[87] The lines traced through Bose's instruments not only represented the "everyday life history" of the particular plant under investigation, but also stand in for the unity of life in nature. The curve-drawing symbolized all forms of life in nature. The language of the curves, in discourse, seems like the pre-Babel perfect language referred to in Christian theology which was said to epitomize the unity in God's nature.

The Image Machine

This iconic use of the response-curves traced by Bose's machines inspires one to identify those apparatuses as "image machines" following Peter Galison.[88] Though Galison uses this category to discuss significantly different instruments used in the physics laboratories of the twentieth century like the cloud chamber, Bose's instruments of plant researches seem to share some of its criteria. Bose's instruments were image making instruments;[89] they produced images which *could* escape a statistical reading of them yet present a scientific fact. Though the curves were by nature statistical data, their use as symbols invoked

a different epistemology altogether. To extend Galison's classification, they are hybrids of image and logic machines. *The British Medical Journal* praised the Photosynthetic Bubbler for making available the data in the forms of curves, reading of which required elementary knowledge of mathematics.[90] There is another commonality between Galison's "image machines" and Bose's instruments: it is quite clear from Bose's writings and the story of the construction of Crescograph which we have noted earlier that "the passivity of their systems of registration" of natural events was considered to be a virtue in both cases.[91]

However, while developing different versions of the Crescograph, it seems that Bose favoured one type of visualization over others. The imperative of live demonstration before a large public sometimes singularly affected Bose's technical choices in designing the instruments. While developing the High Magnification Crescograph, the photographic method of recording the growth was discarded in favour of a direct method of public demonstration. Bose rejected the photographic method as it involved the "discomfort and inconvenience of the darkroom". He wanted the spectators to "visually" follow the results produced by the instrument directly, without the detour via darkroom.[92] Still, Bose was reportedly unhappy with the performances of the High Magnification Crescograph, the problem being the records of the rate of growth produced by the machine required a very careful inspection and interpretation. Instead, he wanted an instrument "which would *instantly* show, by the up or down movement of an indicator the changes in growth". The resulting machine was the Balanced Crescograph, which had an attached scale to indicate the actual rate of growth, and a higher power of magnification [Fig. III].[93]

Reading as Witnessing

We must also keep in mind here Bose's strong attraction to sonic metaphors. According to him, these scripts of curve-drawings would give "voice" to the "dumb companions" of humans. As if one could hear voices emanating from the flat dimensions of those graphic records. "Use these instruments intelligently", as one of the commentaries on Bose suggested, "and vegetations, hitherto mute,

Fig. III. The mechanism of the Balanced Crescograph. Bose, *Growth and Tropic Movements of Plants* (1929), p. 29.

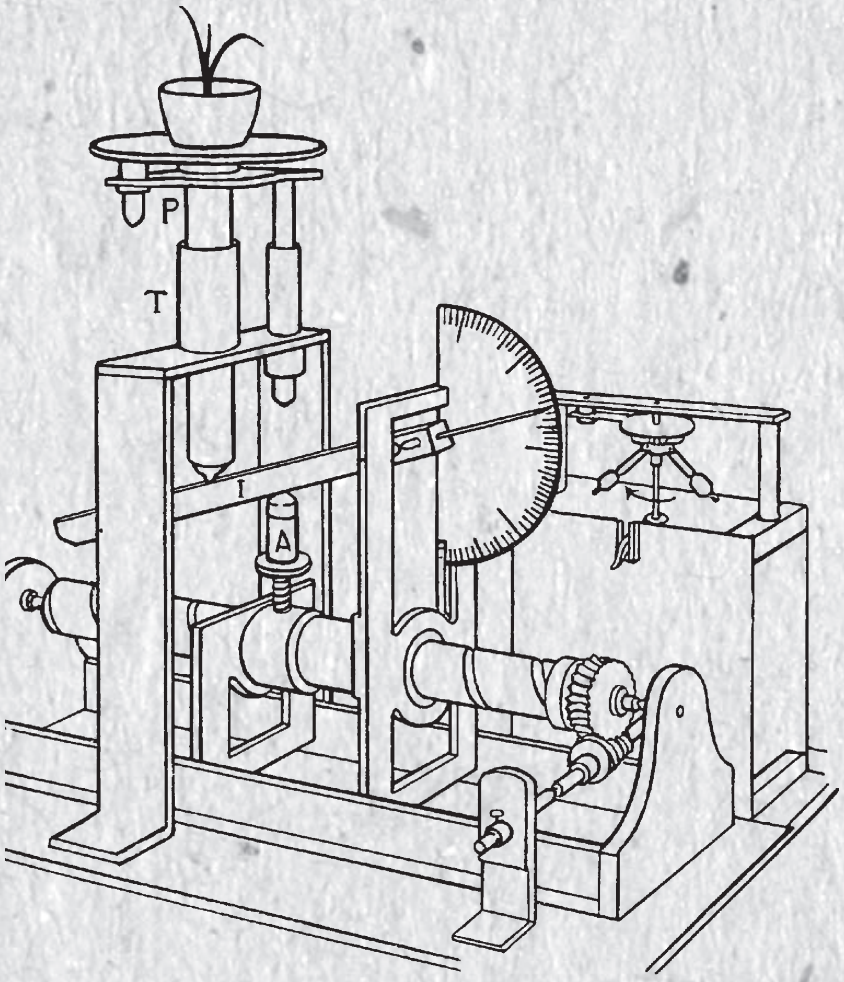


FIG. 12. The complete apparatus for Balance by Inclined Plane.

A, screw for adjustment of angle of inclination of plane I, read in circular scale; P, rod supporting plant-holder enclosed in outer tube T.

will *whisper* its story".[94] To Bose, plant-life was an *echo* of human life, and the curve-drawings produced by his instruments were icons of life itself.[95] Through Bose's instruments, therefore, "writing speaks, [...] to read is to listen".[96] One should remember, Bose was one of the early connoisseurs of the gramophone technology in Calcutta.[97]

Listening to those stories of plant-life, for Bose, was much more than a simple disenchanted witnessing of the *other* life by a passive investigator. Instead, through his instruments man would be able to experience not only the plant-life but also his own life and thereby identify with the object of experiment. Experiencing life in those mute records, I argue, was integral to the scientific project of Bose and involved mental faculties like compassion or empathy which were banished from the Enlightenment discourse on scientific investigation.[98] As we already know, a crucial project of the western modern science was to discipline "experience" in terms of information-collection. During the long period from the sixteenth to the eighteenth century, sophisticated and regimented modes of observation through instruments emerged in Europe as the only "scientific" and valid technique of *knowing* the nature, rejecting ordinary experiences as false or erroneous modes.[99] Bose's discourse calls for a somewhat different order: *experiencing* through precision instruments. In one of his Bengali writings, Bose pointed out the two major difficulties for recovering the everyday history of plants:

> First, *winning the consent of the plant to give witness about itself,* and second, recording that testimony with the help of *both* the plant and the instrument. It seems less difficult to make a *child* obey your instructions than hoping to get answers from a plant. … After so many years of close proximity with the plants, now I have begun to understand their nature gradually. Today, I am ready to confess before our compassionate and civilized society that I have done many cruel things to the harmless plants in order to collect evidences from them. For this, I have invented many ways of inflicting pain on them — direct or otherwise. Pierced them with needles, burnt them in acids. Let's not talk about that in detail. Today I realize that such forcefully collected testimonies have no value. To the arbitrator of honest justice, this evidence may appear concocted.[100]

Instrumentality at its Limit

In other words, testimonies could only be accepted as true evidence when they were collected with no (or negligibly little) application of force. Bose's discourse suggested an *ethical* limit for the instruments of life sciences - they must stop functioning as apparatuses of torture. One of the major Romantic criticisms of the "all-embracing determinism" of modern science was that the "[m]echanistic science proceeds by decomposition and analysis, separation and distinction; it kills what it studies".[101] Experimentalist practice of science "essentially involves the *manipulation* of bits of the world"; Davis Baird and Thomas Faust has argued, "belief may help direct this manipulation, but belief cannot take the place of this manipulation".[102] Bose and his contemporary *bhadralok* enthusiasts of science agreed to this principle of active intervention on the part of the investigator and his active manipulation of the real world. Ramendrasundar Trivedi, for example, was of the opinion that one of the main differences between an animal and a man is while the former is only capable of "Abekshan" (simple observation), the latter is capable of "Parikshan" (experimentation), which could artificially create phenomena that did not occur on its own.[103] Instruments, in this understanding, were the sites of active intervention on part of the scientist. Bose's devices too, as laboratory instruments, sought to actively rearrange the site of experiment and control it mechanically. For instance, Bose designed an additional device, a cylindrical chamber built with a sheet of mica, that could be attached to the Crescograph to entrap the plant and expose it to various agents like gases and vapours.[104] Besides controlling and regulating the space of the experiment, Bose's devices also sought to artificially reduce the duration of the experiment.[105] However, the above statement of Bose regarding the validity of the evidence produced by the interventionist instruments of life sciences presents a counter-ethics to this dominant philosophy of instruments. The active intervention was necessary for knowledge- production, Bose knew too well. But, in his philosophy of scientific instruments — given *his* truth-agenda and the hypothesis of unity in nature — the observer, the instrument and the specimen stood in a perfect harmony with one another. Any destabilization in this harmony could provide a scope for doubts in the legitimacy of knowledge arising out of this

relationship. The design of the instruments sought to capture the "everyday history" of the plant life in its "normal" state. It was the "crude and drastic methods of stimulation" employed by the experimenters before him that led Bose to invent a new device (Resonant Recorder) and arrange his own investigation into the subject of transmission of excitation through plant-body. "The object of our inquiry", Bose wrote, "is not to find whether a mechanical disturbance caused by some violent blow is transmitted to a distance, but the determination of propagation of physiological change under *normal* modes of stimulation".[106] For this the plant-witness must be treated with great patience and delicate sensitivity. Rough handling of the specimen under scrutiny, Bose warned, would hamper normal growth and the instrument would thus fail in its purpose. Instead, the correct procedure would be "to mount the plant as gently as possible, and to give it two hours' rest before taking the record".[107] The plant must give the go-ahead.

According to Bose, one could translate the unusual gestural languages - whether that of the human child or the plant which behaved like a child - into meaningful narratives only by the instruments of love, compassion and sympathy.[108] The enquirer must empathise with his subject of enquiry.[109] His instruments are nothing but "sympathy machines"[110] as they demonstrate the "compassionate history"[111] of dumb plants to their fellow beings — the humans, so that they can *sense* the unity everywhere in nature. Within this context, the usual boundary between the subject and the object threatened to collapse. The dominant philosophy of western science and technology in the post-Enlightenment era, with its discourse on patents, conceptualised the instrument as a thing that was *detachable* from both the observer on one end and the specimen from the other, and thereby became *portable.* Bose's discourse suggests a different understanding of the instrument. The operator of the machine, could no longer be completely dissociated from both the object of the study (plant) and the means of it (instrument). Therefore, in one of his Bengali articles, Bose emphasised that in order to successfully use the crescograph, "the hand must be in total control of will power. Otherwise the machine would not work".[112] The instrument was not simply an extension of the phenomenal eye, but also that of the mind's eye in a sense. An ethical horizon marked Bose's philosophy of

instruments which run counter to the principle of absolute intervention and manipulation and emphasized the principle of harmony in nature instead. Given the axiomatic principle of unity between the living and the non-living in Bose's imagination, both the mechanical instrument and the object of experiment (the plant) could no longer be completely detached from the human-investigator. This ethical horizon also marked the aesthetic imperative in Bose's discourse which considered the scientific demonstration of unity in nature as *beautiful* in itself.

III. Performing Bodies : The Living and the Machinic

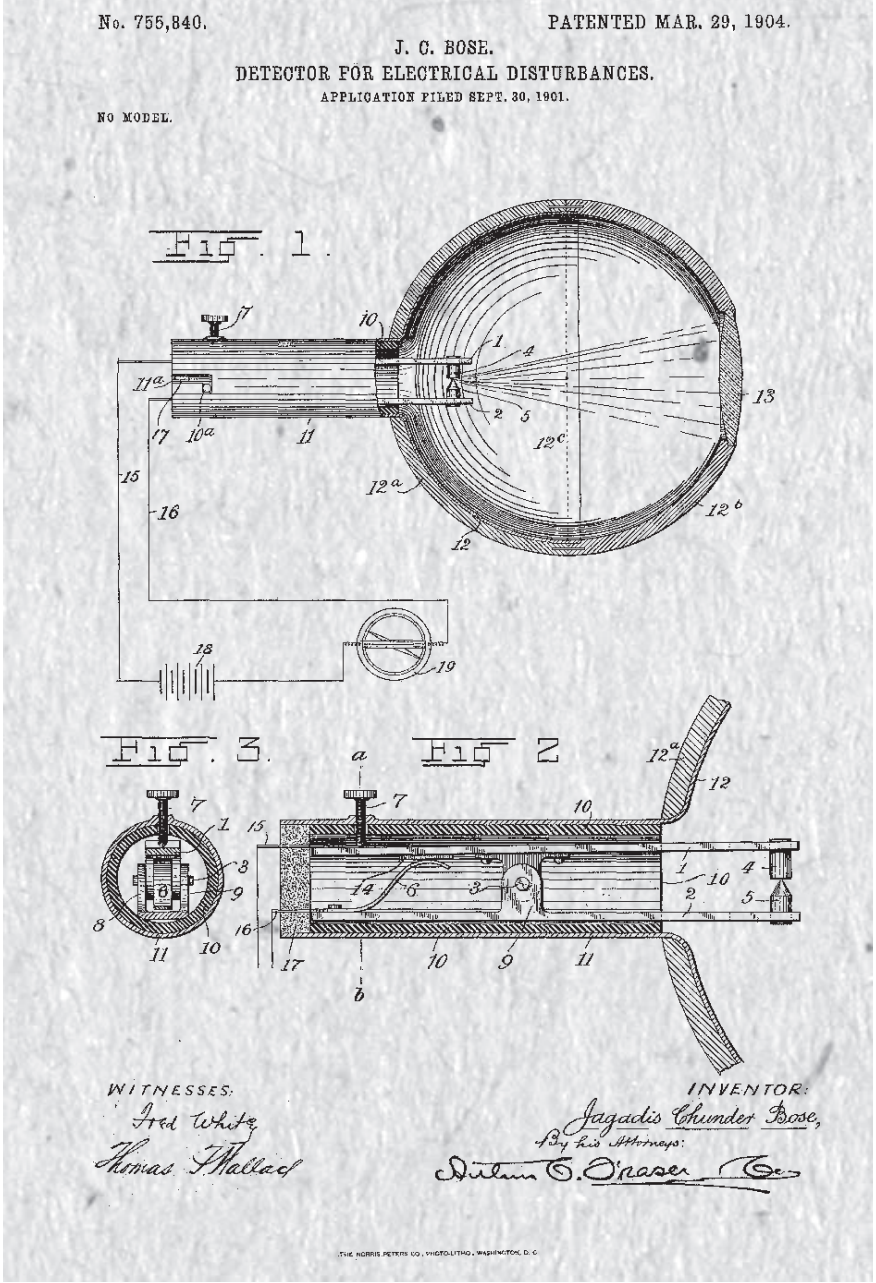
If Bose's instruments were imagined to be located midway within one continuum — between the subject and the object of the experiment — at one level, we will see that they were also entangled in between another: that is the human body and the inert machine. The imperfections of human senses was thought to be hindering the production of scientific knowledge. The post-Enlightenment experimentalist scientific practices therefore tried to regulate the "subjective" human senses with tools and techniques of "mechanical objectivity".[113] Bose's instruments, too, were meant to serve as the vehicle of liberating human beings from the finite limits of ordinary and imperfect sense-perceptions by *extending* them. While discussing the limited scope of human eyes in the perception of light-rays, Bose frustratingly commented that mortal men had no way but to hopelessly wander among the infinity of invisible colour beams in nature and this intolerable finitude of human condition must be transcended.[114] From a location in the colony, this human finitude was thought to be much more aggravated due to the lack of sophisticated instruments of science which could aid human perceptions.

One can witness a certain Promethean ethos in Bose's statements. The hero of the Greek mythology Prometheus was able to recover human beings from their primitive state of helplessness by discovering *technai.*[115] Bose, too, believed that this natural finitude could not stop man from setting off in his voyage to discover new lands hitherto unknown. Mechanization of human actions provided the ultimate solution.

Instruments as Prosthetics of Senses

Bose's instruments were meant to extend the capacities of human sense-perceptions. But they could only do so by mimicking the human actions. Introducing the Galena Detector [Fig. IV] designed for the

Fig. IV. Drawing of the Galena Detector or the Artificial Retina in the Patent Application submitted by Bose to the United States Patent Office on 30 September 1901.



reception of infrared rays, also called the "Artificial Eye" or the "Artificial Retina", Bose wrote:

> It was necessary to build an artificial eye in order to witness invisible light beams. We have a membrane made of nerves behind our eye. When ray of light falls on it, the consequent excitement in the nerves stimulate a specific region of our brain; and then we recognise it as light. The construction of the artificial eye is similar. Two pieces of metals are kept in close contact with one another in this machine. Whenever light rays fall on the very point where they come into contact, it causes atomic distortion within those metals and as a result a wave of electricity originates which moves the arms fixed to the magnet. Like a dumb man expresses himself by signaling with his hands, the artificial eye also indicates existence of beams by moving its arms.[116]

Here, the imitation of the natural in the designing of the artificial eye is too explicit to get unnoticed; but it was a better copy of the organic eye in the sense that the scope of vision is much wider than the latter. In 1901 while lecturing on the Artificial Retina, Bose seemed hopeful that the day was not far when other human sense-organs could also be duplicated with success. At another occasion, he proposed the design of an "artificial ear", based on the same principle of resonance on which his Resonant Recorder was constructed.[117] Though he called the contraption 'ear', it was supposed to indicate its reaction to a particular note via an arrangement of *visual* demonstration. This can be read as yet another example of the constant process of translation of senses in Bose's discourse. Bose, it should be pointed out here, was well aware of the pedagogical implications of these artificial simulations of human organs. In a letter to Tagore, he hoped that the Artificial Retina would help him fill the gaps in his theory of vision.[118] In this context, the Artificial Eye or the proposed Artificial Ear was also a scientific model. But as the *Electrician* commented, they were not models that *merely imitated* the scientific phenomenon, but *represented the theory* behind that phenomenon. In that sense, they were like the "analog models" of Peter Achinstein which do not reproduce all the characteristics of the prototype, rather "establish correspondences on similarities in the relations of respective parts and structures".[119]

In designing the Artificial Eye or proposing the Ear, the famous Aristotelian principle regarding the relationship between art and nature was faithfully followed. *Mechanical Problems,* a text commonly ascribed to Aristotle, emphasised that "art makes creative use of the natural regularities to go beyond what nature itself can achieve".[120] In this sense, Bose's instruments were prosthetics of senses, as they not only imitate but replace the original sense-organs by being better than the originals. And this is not restricted to these two devices alone. The popular press frequently described Bose's instruments of plant-growth research too as "Artificial Organs of Perception".[121] One of the articles written by Bose in *Prabasi* called his instruments *"Anubhab Yantra"*.[122]

Life and the Machine : A Continuum Imagined

If the mechanical instruments seemed to successfully imitate the living body, the latter also appeared to be more like a machine. There seems to be an uninterrupted continuum between the living body and the dead machine in the discourse around Bose's researches.[123] During one of his public demonstrations of "plant autographs" at the Presidency College laboratory, for example, Bose compared the sensitivity of the recording device to that of the tongue of Hindus.[124] Some of his instruments freely used organic substances as part of their construction for their sensitive qullities.[125]

In Bose's discourse, the organic body appeared like spontaneous machines whose automatic movements were caused by the energy that it collected from the nature, preserved, and converted in its own body. "[N]othing is self-originated", Bose declared.[126] Geddes summarised Bose's philosophy of the living body neatly in the following passage:

> The essential problem is thus stated: - Is the plant a mysterious entity, with regard to whose working no law can be definitely predicated? Or can it be interpreted as a machine - i.e. as transforming the energy supplied to it in ways more or less capable of explanation? ... the thesis is here clearly affirmed, and justified in detail, that the plant may nevertheless be regarded as a machine.[127]

At times, the spontaneous body-machines seemed identical to the wind-mill [Fig. V].[128] In his later writings however, Bose compared the spontaneous body-machin to the steam-engine.[129] It can also be

Fig. V. The analogy between the wind-mill and the organic body. Bose, *Plant Responses as a Means of Physiological Investigation* (1906), p. 742.

But the observer, in the course of his further inquiry, finds that the vanes, whose rotation under the impact of the external stimulus of wind first attracted his attention, are but a part of a complex machine, the interior of which had been hidden from his view. He finds that the energy supplied from outside is being transformed by a dynamo inside, and stored up in an accumulator. When the external force is not acting, the reverse movement is caused by the internal energy thus stored up. This very movement, being apparently without a cause, he would formerly have designated as automatic. When the stored-up energy is exhausted, the seemingly autonomous movement comes to a standstill, and only by the accession of fresh external stimulus, causing renewed storage, can it be resumed. At a given moment, moreover, the responsive movement of the vanes is determined by the opposing actions of the external and internal factors. As long as the wind is sufficiently strong, movement takes place in one direction, and when there is a pause the internal energy begins to find expression, by causing movement in the opposite direction. If the circumstances were such that the rise of the wind were synchronous with day, and its fall with night,

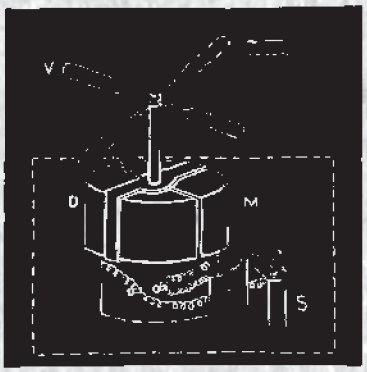


FIG. 278. Diagrammatic Representation of a Windmill with Attached Dynamo, D, and Accumulator, S

Wind acting on vanes, V, from right, represented by arrow (←), causes responsive rotation in direction opposite to that taken by the hands of a watch. This external energy also causes electrical storage. On the cessation of the wind the accumulator begins to part with its stored-up energy, and, the dynamo now acting as a motor, causes a responsive rotation of the vanes in the other direction, as shown by the arrow (→).

argued that for Bose, the machine served as a model for explaining the workings of organic life instead of imagining them as driven by an unquantifiable "vital force". Though it recognised the specificity of the organic body, I argue, the body appeared as a machine in the last instance in Bose's discourse on life.

Psychological phenomena such as emotions like ecstasy, joy, sorrow, pain or memory, for Bose, were nothing but mechanical-chemical responses of the body-machine to external stimuli and were supposed to be transferred to one individual body-machine from another through the fluid called breast-milk.[130] Emotions travelled through the same *circuit* of nervous system in the body which facilitated the circulation of information through the body and from outside. Note that different qualitative virtues were imagined here as variations of the same entity and therefore opened up the possibility of quantification: now, they could all be measured with the use of galvanometer. This was not entirely a new idea for the twentieth century bhadraloks; Trivedi informed his readers that scientists in the discipline of Experimental Psychology or Psyco-Physics had started trying to measure human feelings and sensations to construct a scientific knowledge about them.[131] Similarly, the theory of omnipresence of electric impulses claimed to provide a scientific understanding of those phenomena. No wonder then, emotional qualities like sympathy or empathy, for Bose, would constitute legitimate techniques of data-collection as they too were understood to be forms of the same electro-physiological impulse produced in the body-machine that carried information through mechano-chemical processes.

Bose's notions about the continuity between the energies internal and external to the organic body[132] problematize a strict binary opposition between the organic body and the artificial machine. In his discourse, all living bodies, like machines, collected energy from the outside, stored it in their own body, and with it directed its movements. Every phenomena of organic life, whether physiological or psychological, could thus be explained as the mechano-chemical manifestations of a singular interconvertible energy in nature. In the context of the strong obsession of the nineteenth century physics with interconvertibility of energy, of which the steam engine presented a

practical example, theory of the all-pervasiveness of ether, numerous researches in vegetable and animal electricity,[133] Bose's concept of the body-machine could make perfect sense. The equivalence between the machine and the organic body was increasingly gaining prevalence in the twentieth century popular Bengali press too. The discourses on metabolism, which were gaining currency among the twentieth century bhadraloks, found in the steam engine its favourite explanatory model. Thus one article in the Bengali periodical *Bijnan* remarked that "[i]f the human being is considered to be a machine, it should be recognised that in order to function the human-machine needs food like fuels".[134] Based on the different types of *functions* or works done by different body-machines, the article produced a chart listing amounts of calories needed for different people engaged in different works. It is within this universe of shared concepts, Bose's discourse on the living body could find favourable attention. His 'genius' could only be recognised and celebrated in a world where his ideas could find resonances and therefore appear as something meaningful.

The Engineering Ideal of Life

Imaginations of the human body as a machine with a concrete unchanging plan programmed within it promised certain practical advantages for the contemporaries. Firstly, machines served as particular "types" in the process of knowledge production by serving as a homology between the plant and the animal. Starting from the premise of this homology, the simple form of the plant-machine could serve as a pedagogical model that could facililate the knowledge about the more "complex mechanism of the animal machine".[135]

At another level, this machinic philosophy of life "provided an ever-recurring dream of rejuvenescence".[136] If the organic body resembled the machine, the efficiency of human body could then be believed to be improved or reduced artificially at will, the human power of vision through the construction of the artificial eye for example. This promised a prospect that by means of a perfect knowledge of the mechanism one could improve human capacities to a level unprecedented. Further, Bose's experiments with the effect of electric stimulus on plants had convinced people like Geddes that a dead organ could be artificially brought back to its normal condition of growth by giving it appropriate stimulus from outside.

That life-processes could be planned for improvement seemed feasible within the horizon of this discourse. Therefore, we find Ramendrasundar Trivedi, a commentator on Bose's works and a distinguished natural philosopher himself, saying:

> Perhaps a day will come, when after long investigation into the principles governing the workshop of nature, we will be able to know the proper combination of matters which results into the creation of a living body. That day we will finally be able to create lives artificially.[137]

That day, it was believed, would mark the ultimate liberation of humanity from the bondage of heteronomy and finitude. Writing around 1886, Hiranmayi Devi, one of the co-editors of the Bengali periodical *Bharati*, the elder daughter of Swarnakumari Devi and grand-daughter of Debendranath Tagore, already noted that, "There is a saying, 'man can do anything but cannot infuse life.' ... What was not possible in the nineteenth century perhaps will be made possible in the twentieth century.... witnessing the scientific abilities of man, we also believe that nothing is impossible".[138] While concluding the foregoing discussion on the Siemens electrical devices which claimed to artificially maintain and augment plant growth by applying electric light and heat to it, she hoped, "[n]ow the creation of plants and other jobs can also be easily done by the use of electricity". It is to be remembered in this context that the discourse on eugenics was already doing its rounds in the bhadralok discussions.[139] The news of the breeding experiments for a hybrid of Indian and Australian varieties of cows were already circulating in the popular press. Jagadanda Roy's article titled "Bangsher Unnatibidhan" expressed the ambivalence of the Bengali bhadralok in the early years of twentieth century towards eugenics.[140] Though there were differences of opinion regarding the ethics and morality of such experiments, eugenics was more or less accepted as a credible practice. Trivedi argued that it was nature itself who was capable of creation (Nirman), whereas we, human beings, follow the natural principles in making something new. The latter is not creation per se, but intelligent combination of elements (Yojana) - engineering. He reminded his readers that though the scientists had been able to identify the right ingredients to artificially create life, they were yet to become successful in that respect

as they were unable to determine the exact recipe or formula of their combination.[141] That life could be engineered was a belief shared by many science-practitioners of the twentieth century both in India as well as in the West. German-American biologist Jacques Loeb, who was one of the main advocates of the "engineering standpoint" in biology, was active during 1890-1915 in trying "to define a biology centered around the control of organisms".[142] In 1899, Loeb developed a technique of inducing artificial parthenogenesis: "the artificial production of normal larvae (plutei) from the unfertilised eggs of the sea urchin".[143] Controlling life according to a premeditated design, it seems, was an agenda of both Loeb and Bose. By 1938, a department of genetics attached to that of plant-physiology was already in place in the Bose Institute.

Body as an Instrument of Controlled Precision

Trivedi was skeptical about the success of this project of artificial control of life. In "Praner Kahini", he cited Bergson to point out that the course of life, unlike that of matter or the motion of machines, was "essentially irreversible". Life, according to Trivedi, was spontaneous, free to choose its own course; no scientist would be able to direct its course along their predetermined path, nor could they predict the route. Now, this was precisely the task that Bose was preparing for. After a successful experiment demonstrating the similarity between animate and inanimate responses, Bose wrote to Tagore: "Why does poisoning cause death? [...] Which knob in the human-machine is turned? Why is it turned, can we turn it back - why not?"[144] Researches on the nervous mechanism in plants, in the last phase of Bose's career, held out hopes for the improvement or maintenance of organic growth at *will* by means of control over the nerve impulses. According to Bose's theory, the nervous impulses could be controlled so as to obliterate or inhibit external shocks which hampered or stopped organic growth and facilitate those shocks that instigate growth.[145] The "inner control of the nerve" could help one to modify their senses profoundly so that one could exercise wilful control over body. However it must be clarified that Bose repeatedly refused to reduce this practice of nervous controls to traditional Hindu metaphysics; for him, it could only be possible by the application of "exact" scientific knowledge. When Bose suggested to a reporter that

it was possible for man to voluntarily control nervous impulses, the latter asked him, "Is that not a kind of yoga?" To this question, Bose "emphatically waved his hand in denial, and hastily added 'never attempt such speculations in science lest you should be carried away by the force of interest. Be patient and wary'''.[146] Minute precision was a necessary virtue that one must learn from the practices of physical sciences in the west. Only precise knowledge produced *through* instruments, according to Bose, could promise transcendence by enabling the perfect attuning of the body to the mechanisms of nature.

Again, Bose was not alone in this; that "increased biological knowledge implies increased possibilities of controlling life"[147] was a belief prevalent in both the academic as well as the popular domain of scientific practices in the 1920s west too. Bose was of the opinion that only with the help of precise knowledge, one would be able "to catch those indistinct messages" from nature "that have hitherto passed by him unperceived" and found themselves in a harmonious relation with the outside. One could easily recognize the hint towards an antenna here. His thesis therefore urged for the human body to engage in a "constant communion" with the external forces in order to draw energies from them efficiently.[148] No wonder he would express a strong favour for the extension of physical senses through artificial simulation of the body as it seemed to be put one step forward in this process of "communion" with the outside by highlighting the all pervading unity in the world. The individual body-machine must be attuned with the larger cosmological machine to produce a perfect harmony. The former shared a relationship of *synecdoche* with the latter. After all, for Bose, what were the creative hands of ordinary human beings if not the extension of the tools of the *ur-artificer, Vishwakarma*![149]

Nation : A Necessary Epilogue

Mechanisms designed by Bose were therefore believed to be aiding in the grand project of modernity - that is engineering an ideal infrastructure for life. If life became an object of engineering, of design and planning in this discourse, another abstraction called the nation could not be far away. The "ever-recurring dream of rejuvenescence" Geddes talked of appeared true in the case of nation too. One should remember that the sources and channels of energy could be redistributed to augment growth of the socioeconomic life of the nation

and its social body was an important political economic agenda in swadeshi Bengal.[150] It was believed that with the right kind of external stimuli applied to the body of the nation, it had the potential to take off towards the path of glory again.[151] No wonder, an admirer of curve-plotting like Bose would try to represent this promise by a diagram (Fig. VI) that he drew in a letter to Tagore.[152]

In the diagram, the external shocks or stimuli which could rejuvenate the downfallen "curve of national condition", were marked with the symbol "+", traditionally used to designate the positive end of the electrical circuit in a diagrammatic representation or to suggest the act of addition in an algebraic equation. We must also notice that the part of the curve that represents the "future" of the nation is dotted. It is yet to be a fully formed line, but its course is already plotted; it is a ghostly line. It is on this plot of dots, the future of the nation must be constructed. Salvation was believed to be dependent upon a perfect planning which could provide the essential artificial stimuli for growth and keep the nation-machine functioning by supplying energy from outside.[154]

Conclusion

In drawing attention to the performative nature and the infrastructural context of Bose's scientific practices, this paper has tried to emphasize the materialities of *doing* science within a globally networked culture of instruments and demonstrations. In contrast to the tragic trope of Bose's under-recognized genius in the nationalist accounts, it highlights the various contemporarily available techno-epistemological registers on which the very claim of "innovation" could be enunciated. Bose's scientific demonstrations not only attempted to persuade the scientific community of the west but sought legitimacy from the colonial public as well. The questions of portability, simplicity of design and publicness of his instruments seemed to be of crucial importance in this context. Bose's scientific instruments not only enunciated a different ethic of addressing the question of evidence in scientific experiments but also engaged with the swadeshi politics of labour and skill. The post-swadeshi nationalist appropriation of Bose has always emphasized a mystical oriental meditation on the spiritual aspect of life and vitalism and thus reduced the machines to

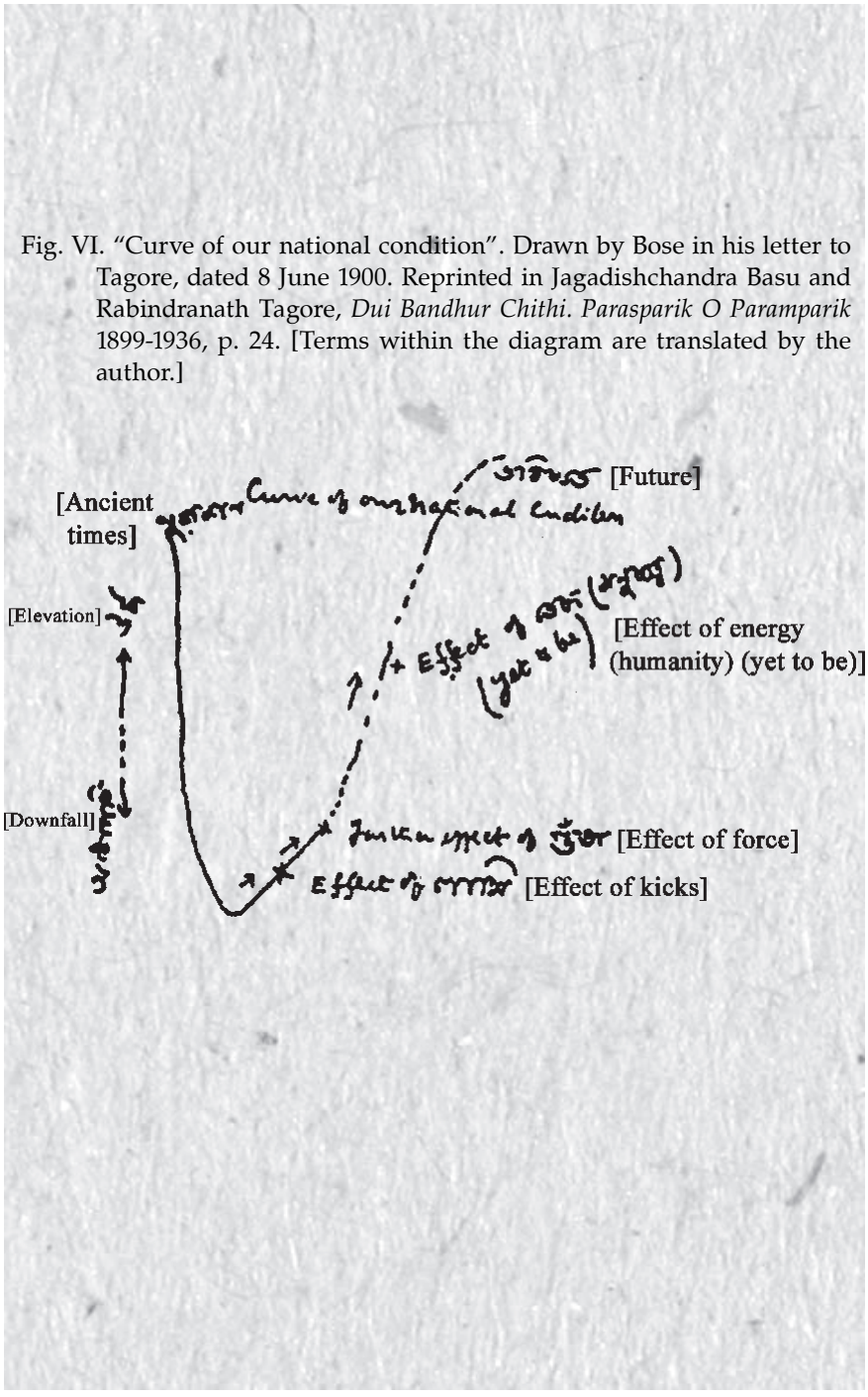


Fig. VI. "Curve of our national condition". Drawn by Bose in his letter to Tagore, dated 8 June 1900. Reprinted in Jagadishchandra Basu and Rabindranath Tagore, *Dui Bandhur Chithi. Parasparik O Paramparik* 1899-1936, p. 24. [Terms within the diagram are translated by the author.]

mere signifiers of both his hypothesis of life as well as his oriental 'spiritual' life. Foregrounding the demononstrations and the instruments of Bose helps to shift the focus to the materialities of his scientific practices which can never be fully subsumed under the category of colonial difference. Bose's scientific practices therefore, I argue, could neither be explained in terms of a simple-minded indigenism, nor through the schema of an 'alternative, colonial science.' Nor were his inspirations purely philosophical and unembodied in nature. Further, the knowing subject of an experiment, in this discourse, could no longer be a detached, impersonal investigator practising an absolutely emotionless objectivity, but was rather entwined with the object of the enquiry in a perfect natural harmony. The organic cannot be understood as a self-standing category. Highlighting the allegorical extension of the machinic to the organic body in Bose's discourse, this paper shows how the notions of the machine as well as of life were reconfigured within a peculiar cosmological imagination which was more mechanistic than organismic in a sense. Finally, I argue that the engineering ideal of life ensuing from the imaginary continuum between the living and the mechanic in this discourse hinted at a particular imagination of the transcendental subject which exceeded the usual framework of an organismic metaphor of freedom. This unsettles the dominant academic penchant for understanding the nation form exclusively in terms of an organism and thereby helps us to rethink the prehistory of the postcolonial imagination of the nation as a totality that could be planned and designed.

Notes

[1] Cf. A. Nandy, *Alternative Sciences: Creativity and Authenticity in Two Indian Scientists*, Oxford University Press, New Delhi, 1995, 17 - 87; J. Lourdusamy, *Science and Nationalist Consciousness in Bengal*, Orient Longman, New Delhi, 2004, 100-143; P. Chakraborty, *Western Science in Modern India: Metropolitan Methods, Colonial Practices*, Permanent Black, Delhi, 2004, 180 - 218; D. L. Gosling, *Science and the Indian Tradition: When Einstein Met Tagore*, Routledge, London and New York, 2007, 91-97. While Subrata Dasgupta's intellectual biography of Bose includes discussions on various apparatuses designed by Bose, it reads them in the context of Bose's theories. As a result of this, rather than taking the centre-stage for themselves, the instruments still

provide only a background to the narrative that highlights Bose's intellectual 'difference'. S. Dasgupta, *Jagadis Chandra Bose and the Indian Response to Western Science,* Permanent Black, New Delhi, 1999.

[2] Jahnavi Phalkey maintains that an obsessive "pursuit of an ideological explanation" has dominated the histories of science in India for long. The new narratives of the science in colonial India, Phalkey insists, should be built around the histories of actual practices that went beyond the "concerns with ideology and authority". J. Phalkey, "Introduction", *Isis,* Vol. 104 (2), 2013, 333-336. For the last three decades or so, historians and sociologists of science have turned their focus on the "materialized epistemology" of scientific practices with a renewed vigour. Cf. M. N. Wise, "Making Visible", *Isis,* Vol. 97 (1), 2006, 75-82; P. Galison, *Image and Logic: A Culture of Microphysics,* The University of Chicago Press, Chicago, 1997; P. H. Smith, *The Body of the Artisan: Art and Experience in the Scientific Revolution,* University of Chicago Press, Chicago, 2004; *Thing Knowledge: A Philosophy of Scientific Instruments,* University of California Press, Berkeley, 2004, J. Tresch, *The Romantic Machine: Utopian Science and Technology after Napoleon,* University of Chicago Press, Chicago, 2012. The present article draws heavily from this new line of research.

[3] Galison, *Image and Logic,* 2.

[4] *Ibid.*

[5] As Galison argues, in the late nineteenth or early twentieth century, it was unthinkable that an experimental physicist would have no knowledge about instrumentation; the life of such an experimenter demanded some knowledge of the 'properties, costs, and uses of materials'. Galison, *Image and Logic,* 8. Bose's life as an experimenter who worked with delicate machines also necessitated possession of different mechanical skills and knowledges other than that of botany or physics. It is at the time of crisis, those 'other' knowledge regimes manifest themselves. For example, on one of his trips to London, when the indicator of a delicate instrument broke just before a scheduled lecture-demonstration, Bose had to instantly mend it with the seccotine capsuler he was carrying with him. J. C. Bose, "Nothing Easy" (1925), in Prantosh Bhattacharyya, ed, *Acharya J. C. Bose : A Scientist & A Dreamer,* Vol. 4, Bose Institute, Calcutta, 1997, 119.

[6] According to Timothy Lenoir, the nineteenth century researches into electrophysiology of muscles and nerves more than often employed a theoretical model what Norton Wise has called a formal analogy. This type of models demonstrated the "similarity between the formal structure of some known or imagined system and the relations discerned to hold among the principal phenomena of the object domain under investigation". T. Lenoir, "Models and Instruments in the Development of Electrophysiology, 1845-1912", *Historical Studies in the Physiological and Biological Sciences,* Vol. 17(1), 1986, 3.

[7] Tresch, *The Romantic Machine,* xi.

[8] For a history of the use of organismic metaphors in the discourses on the nation-form, see P. Cheah, *Spectral Nationality: Passages of Freedom from Kant to Postcolonial Literatures of Liberation,* New York, Columbia University Press, 2003, 17-59. For the Indian context, see A. Sartori, "The Conceptual Structure of an Indigenist Nationalism" in *Bengal in Global Concept History: Culturalism in the Age of Capital,* University of Chicago Press, Chicago, 2008, 136-175.

[9] Bose maintained that a scientific fact was truly a 'fact' only if it was universally demonstrable. J. C. Bose, "Address to the Hindu University", Anonymous, *Sir Jagadish Chander Bose:* His *Life, Discoveries and Writings,* G. Natesan & Co., Madras, 1921, 36.

[10] J. Lourdusamy, *Science and Nationalist Consciousness in Bengal,* 77-79 and 84.

[11] For example, a reviewer of the popular science-text *Prakriti-Parichay* by Jagadananda Roy wrote in *Prabasi,* "Once I came across an article in a Bengali monthly, where the writer said many things about amoebas, but how could he, who never observed an amoeba through a microscope, ever be able to understand them a bit?" The reviewer emphasized that every student of science must build a small laboratory in their own houses. *Prabasi,* Vol. 11 (2), 1318 B. S. [c. 1911].

[12] P. N. Ghosh, "Report of the Sub-Committee on Industries Connected with the Manufacture of Scientific Instruments" (1947), in K. T. Shah, ed., *National Planning Committee Series,* Bombay, 1948, 1. The glass apparatuses used in chemical researches were also to be imported from Europe. This presented a great obstacle for the experimenters as they were often "broken in transit" and "it took months to obtain a new apparatus". P. C. Ray, "A New Enterprise", in S. Ghosh, *Kaler Shahar Kolkata,* Ananda Publishers, Kolkata, 1991, 229-230.

[13] B. Sen, "Round the World with My Master [III]", *The Modern Review,* Vol. 19 (3), 1916, 359.

[14] P. Geddes, *An Indian Pioneer of Science: Life and Work of Sir Jagadis* C. *Bose,* Longmans, Green & Co., London, 1920, 57-58.

[15] S. Shapin and S. Shcaffer, *Leviathan and the Air-pump: Hobbes, Boyle, and the Experimental Life,* Princeton University Press, New Jersey, 1985.

[16] Bose, "Nothing Easy", 118.

[17] The same incident was recounted by Basiswar Sen too. B. Sen, "Round the World with My Master", *The Modern Review,* Vol. 19 (I), 1916,84.

[18] Bose, "Nothing Easy", 118.

[19] Patrick Geddes was full of praise about the lay-out of the seventy-feet-by-sixty-feet lecture hall. "Its purpose", he wrote, "is *neither restrictedly scientific,* as its magnitude shows, *nor yet simply popular".* Geddes, *Life and Work of Sir Jagadis* C. *Bose, 245-246.*

[20] A. Mitra, *Acharya Jagadishchandra 0 Basu-Bijnan-Mandir,* M. C. Sircar & Sons, Kolkata, 1961, 31.

[21] *Ibid,* 31-32.

[22] Sen. "Round the World with My Master [III]", 359.

[23] In the context of early colonial scientific exhibitions and museums, Gyan Prakash demonstrated how the very 'staging' of science which was meant to diffuse rational scientific knowledge among the public, also inspired awe and a sense of marvel among the spectators. G. Prakash, "Staging Science", *Another Reason: Science and the Imagination of Modern India,* Oxford University Press, New Delhi, 2000, 17-48.

[24] R. Tagore, "Acharya Jagadisher Jaybarta", (1901), A. M. Harun-ar-Rashid, ed, *Rabindranathke Lekha Jagdishchandra Basur Patrabali,* Bangla Academy, Dhaka, 1971, 114.

[25] B. Sen. "Round the World with My Master [IV]", *The Modern Review,* Vol. 19 (5), 1916, 553-554.

[26] Cf. Letter from Bose to Tagore, London, 22 May 1901, in Harun-ar-Rashid, ed, *Jagadish Chandra Basur Patrabali,* 55.

[27] Anonymous, "No Heartbeats in Plants", *The Science News-Letter,* Vol. 15 (419), 1929, 241.

[28] T. N. Das, "Sir Jagadis Chandra Bose as a Leading Figure of Asiatic Renaissance", in Prantosh Bhattacharya, ed, *Acharya J.* C. *Bose: A Scientist* & *A Dreamer,* Vol. 4, 420.

[29] For a detailed narrative of the 'controversy', see S. Dasgupta, "Jagadis Bose, Augustus Waller and the Discovery of 'Vegetable Electricity'", *Notes and Records of the Royal Society of London,* Vol. 52 (2), 1998, 307-322.

[30] Anonymous, "Professor Bose's Remarkable Work", *Science Progress in the Twentieth Century,* Vol. 15 (57), 1920, 114.

[31] Anonymous, "Plant Response", The British Medical Journal, Vol. 1 (3093), 1920, 513.

[32] Geddes, *Life and Work of Sir J.* C. *Bose*, 244.

[33] For a brief history of the emergence of Calcutta as a 'science city' in the nineteenth century, see D. Kumar, "Calcutta: The Emergence of a Science City", *Indian Journal of History of Science,* Vol. 29 (1), 1994, 1-7.

[34] Bose, "Voice of Life" (1917), in Samir Rakshit and Kamal Chowdhury, eds, *Jagadishchandra Sera Rachana Sambhar,* 256.

[35] Das, 'Sir Jagadis Chandra Bose as a Leading Figure of Asiatic Renaissance', 420.

[36] Letter from Bose to Tagore, Kolkata, 16 March 1903, Jagadishchandra Basu and Rabindranath Tagore, *Dui Bandhur Chithi: Parosporik* O *Paromporik,* Monfakira and Ababhash, Kolkata, 2008, 236.

[37] Bose's notebook digitised and catalogued at the Bose Institute Museum under the title "Notes on Instrument Design, Instrument Working, Experiments, Bengali Science Fiction".

[38] From Bose's diaries, one gets the specific instructions (sometimes with rough diagrams) left for the assistants named 'Bhupen', 'Bepin', 'Nanku' and others on how to construct those parts.

[39] Anonymous, "Jagadish Chandra Basur Mahaprayan", *Prabasi,* Vol. 37 (2), 1937, 433-434.

[40] Anonymous. "Interview with Prof. J. C. Bose", *India,* December 1896, in Prantosh Bhattacharyya, ed, *Acharya J.* C. *Bose: A Scientist* & *A Dreamer,* Vol. 4, 313.

[41] Sen, "Round the World with My Master [III]", 357; Anonymous, "Jagadish Chandra Basur Mahaprayan", 435.

[42] For Bose, the sensitivity of the tongue of a Hindu was much higher than that of a European. Anonymous, "Plant Autographs: How Plants Can Record Their Own Story", in Prantosh Bhattacharyya, ed, *Acharya J.* C. *Bose: A Scientist* & *A Dreamer,* Vol. 4, 15.

[43] J. C. Bose, "The Unvoiced Life", in Prantosh Bhattacharyya, ed, *Acharya J.* C. *Bose: A Scientist* & *A Dreamer,* Vol. 4, 124; B. Sen, "In America with My Master, III", *The Modern Review,* Vol. 19 (9), 1916, 254-255.

[44] J. C. Bose, "Convocation Address at the University of Punjab on the 19th December, 1924", in Prantosh Bhattacharyya, ed, *Acharya J.* C. *Bose: A Scientist* & *A Dreamer,* Vol. 4, 110.

[45] L. Kriegel, *Grand Designs: Labor, Empire, and the Museum in Victorian Culture,* Duke University Press, Durham and London, 2007, 142.

[46] Dinanath Sen, one of the earliest promoters of engineering education in Bengal, was of similar opinion. See Sen's letter to the editor of the *Hindoo Patriot* of 20 February 1876 reprinted in S. Ghosh, *Kaler Shahar Kolkata, 225-226.*

[47] He was one of those rare laboratory assistants of Bose whose name got a rare mention in the contemporary press.

[48] Bose, "Promotion of the Advanced Study of Physics in India", *Journal of the Society for Arts,* Vol. 45 (2310), 1897, 266.

[49] G. Bhattacharya, "Mone Pore", *Bijnan Omnibus,* Dey's Publishing, Kolkata, 1987, 9.

[50] Swadeshi educationist and promoter of industrial education in Bengal, Benoy Kumar Sarkar was in favour of the dissemination of a practical know-how of machines and some general technical skills. B. K. Sarkar, "Naya Banglar Ishkoolmastar" (1927), *Puratani Granthamala* 3: *Magajmeramater Hatiyar,* Seriban, Kolkata, 2009, 85.

[51] Bose, "Promotion of Advanced Study of Physics in India", *ibid.*

[52] This was similar to the hierarchical relation between the illustrator and the scientist imagined in the episteme of 'truth-to-nature'. L. Daston and P. Gallison, *Objectivity,* Zone Books, New York, 124. The status of the mechanic in our case shows a situation where the mechanic/operative, though recognised as a 'collaborator,' was subordinated to the scientist-innovator in the last instance.

[53] Bose described his instruments as "sukkhadarshi kal" on one occasion. Bose, "Vijnane Sahitya", in Samir Rakshit and Kamal Chowdhury, eds,

Jagadishchandra Sera Rachana Sambhar, 106. "Sukkhadarshi" in Bengali meant one that had an extremely delicate scrutinising power.

[54] "The peculiar economy of attention" that the Enlightenment science introduced was "pointillist, magnifying", Lorraine Daston points out. L. Daston, "Empire of Observation", in Lorraine Daston and Elizabeth Lunbeck, eds., *Histories of Scientific Observation,* University of Chicago Press, Chicago, 2011, 99. The microscope was the epitome of this economy.

[55] Anonymous, "Jagadish Chandra Basur Mahaprayan", 433; J. C. Bose, "Ahata Udbhid", in Samir Rakshit and Kamal Chowdhury, eds, *Jagadishchandra Sera Rachana Sambhar,* 140; "The Mechanism of Life", *The Modern* Review, Vol. 40, 1926, 667. Not only in the contemporary bhadralok press, but in the contemporary science journals of the west too, the Crescograph invoked comparisons with microscopes and ultra-microscope of Siedentopf and Ziegsmondy; *Machinery,* vol. 16 (1920), 396. Bose had made the same comparison before an audience in Calcutta on 10 January 1916 when he demonstrated the work of the Magnetic Crescograph; "The Magnetic Crescograph", in Anonymous, ed., *Sir Jagadisn Chander Bose,* 151-152.

[56] For Peter Galison, detectors were "the mediators between the production of phenomena and the production of evidence". Galison, *Image and Logic,* 3. We will see shortly that Bose's instruments of plant-researches shared similar epistemological foundation.

[57] Anonymous. "The International Physiological Congress, 1920: Summary of Papers", *Nature,* Vol. 2674 (106), 1921, 707.

[58] The final version of the machine was the outcome of five years of efforts. "The Magnetic Crescograph", 154.

[59] J. C. Bose and G. Das, "Researches on Growth and Movement in Plants by Means of the High Magnification Crescograph", *Proceedings of the Royal Society of London. Series B, Containing Papers of a Biological Character,* Vol. 90 (631), 1919, 366; "The Magnetic Crescograph", *ibid.*

[60] "The Magnetic Crescograph", *ibid.* The new system was found to be better than the jewel bearings which got clogged by dust particles from time to time.

[61] Bose and Das, "Researches on Growth and Movement in Plants", 368.

[62] Bose, "Ahata Udbhid", 121.

[63] Bose and Das, 'Researches on Growth and Movement in Plants', 368.

[64] Bose, "Ahata Udbhid", 138.

[65] J. C. Bose, "Reply to the Address of the Citizen of Calcutta", in Prantosh Bhattacharyya, ed, *Acharya* J. C. *Bose: A Scientist* & *A Dreamer,* Vol. 4, 96.

[66] "Tacit" forms of knowing, as sociologists and historians of science like Michael Polyani, Collins and others argue, are non-verbal, pre-logical and unarticulated means of knowing that are beyond the formal channels of knowledge transfer. The concept of "tacit knowledge", as Galison has pointed out, hints at the "craft aspects of scientific work". Galison, *Image*

and Logic, 52-53. The knowledge embodied in objects and transferred only through the circulation of them *also* constitutes "tacit knowledge" for us.

[67] D. Baird and T. Faust, "Scientific Instruments, Scientific Progress and the Cyclotron", *The British Journal for the Philosophy of Science,* Vol. 41 (2), 1990, 154.

[68] Anonymous, "The Measurement of Minute Motion", *The Journal of American Society of Mechanical Engineers,* Vol. 42, 1920, 308.

[69] A. Abrams, "Response of Metals to Stimuli", *Physico-Clinical Medicine,* Vol. 4 (1), 1919, 39-40.

[70] [M. K. Gandhi], "Prof. Bose's Invention", *Young India,* Vol. 3 (1), 1920, 21.

[71] L. Daston and E. Lunbeck, "Introduction : Observation Observed", in L. Daston and E. Lunbeck, *History of Scientific Observation*, 4.

[72] D. Baird, "Between Technology and Science", *Thing Knowledge,* 170-188.

[73] Geddes, *Life and Work of Sir Jagadis* C. *Bose, 129.*

[74] The indicator diagram inspired Carl Ludwig's pulse-recording Kymograph and Hermann Helmholtz's Myograph for recording muscle energy of a frog. see Wise, "Making Visible", 78. Bose acknowledged the influences of physiological researches on his own experiments with response curves on several occasions. Bose, *Responses in the Living and Non-living,* Longmans, Green & Co., New York and Bombay 1902, 190.

[75] Bose acknowledged the researches of Fritiof Homgren, James Dewar, McKendrick and others on the physiology of eye. Bose, "The Response of Inorganic Matter to Mechanical and Electrical Stimulus", *Collected Physical Papers: Bose Institute Transactions,* Longmans, Green & Co., London and Calcutta, 1927, 262. Curve-drawing instruments were also used by Waller and Sanderson in their physiological researches.

[76] For a short compendium of auxanometers, auxographs and similar instruments of plant-growth investigation in the early decades of the twentieth century, see W. F. Ganong, *A Laboratory Course in Plant Physiology,* Henry Holt & Co., New York, 1908, 199-205. Crescograph was also in the list. The *Botanical Gazette* wrote in its issue of August 1906, 'we have been content, for example, with magnifications of 10 or 20 times in the auxanometer, where Bose finds 1,000 or even 10,000 practicable with his crescograph'. C.R.B., "Plant Response", *Botanical Gazette,* Vol. 42 (2), 1906, 149.

[77] Bose, *Responses in the Living and Non-living, 190.*

[78] J. C. Bose, "Vijnane Sahitya", 106.

[79] *Ibid.*

[80] Anonymous. "Do Plants Have Feelings?", *Seattle Daily Times,* 22 February 1925.

[81] *Ibid. The Pioneer,* published from Allahabad, also compared Bose's instrument to a pen. Anonymous, "Unity of Life: Sir J. C Bose's Address", *The Pioneer,* 16 June 1907.

[82] R. Trivedi, "Adhyapak Basur Nababishkar", in Samir Rakshit and Kamal Chowdhury, eds, *Jagadishchandra Sera Rachana Sambhar,* 50-58.

[83] *Ibid, 53.*

[84] Bose sometimes borrowed images from others for purpose of this pattern-comparison. In the Responses in the Living and Non-living he used muscle-curve-drawings produced by other British physiologists. Bose, *Responses in the Living and Non-living, 16.*

[85] Bose sent photographic reproductions of curves to Rabindranath Tagore too. Letter from Bose to Tagore, London, 3 May 1901, Harun-ar-Rashid, ed, *Rabindranathke Lekha Jagadishchandra Basur Patrabali,* 49. Magic lantern slides were made of these response-curves and shown to various audiences. Bose, "The Unity of Life" (Lecture given at the Bombay University on 31 January 1918), in Anonymous, ed., *Sir Jagadis Chunder Bose,* 160.

[86] Geddes, *Life and Work of Sir J.* C. *Bose,* 244. Emphasis added.

[87] J. C Bose, *Plant Autographs and their Revelations,* Longmans, Green &Co., London, 1927, 220.

[88] Galison, *Image and Logic,* 4 and 19-31.

[89] In the history of the forms of visualizations employed in scientific investigations, Norton Wise argues, 'the historical space between maps and film' was occupied by 'another genre of image making [... J, one that used mechanical instruments to record graphically the invisible processes occurring inside man-made machines and the imagined machines of nature'. According to Wise, Watt and Southern's indicator diagram was the first of this kind. Wise, "Making Visible", 77-78.

[90] Anonymous, "Sir J. C. Bose's Researches", *The British Medical Journal,* Vol. 2 (3330), 1924, 770.

[91] Galison, *Image and Logic, 25.*

[92] Bose, *Growth and Tropic Movements of Plants,* Longmans, Green & Co., London and New York, 1929, 6.

[93] *Ibid,* 22 - 23.

[94] Anonymous, "Mysteries of Plant Life. Sir J. C. Bose's Wonderful Researches. Plant Autographs and What They Mean", *The Leader,* 8 December 1917, 7.

[95] J. C. Bose, "Nibedan" (1917), in Samir Rakshit and Kamal Chowdhury, eds, *Jagadishchandra Sera Rachana Sambhar, 131.*

[96] T. Ingold, *Lines: A Brief History,* Routledge, London and New York, 2007, 14.

[97] Ghosh, *Kaler Shahar Kolkata, 34-35.*

[98] Bose, "Ahata Udvid", 134.

[99] G. Pomata, "Observation Rising: Birth of an Epistemic Genre, 1500-1650", in L. Daston and E. Lunbeck, *Histories of Scientific Observation,* 45-80 and 81-113.

[100] Bose, "Bijnane Sahitya", 106-107.

[101] Tresch, *Romantic Machines, 3.*

[102] Baird and Faust, "Scientific Instruments, Scientific Progress and the Cyclotron", 148.

[103] Trivedi, "Abekshan O Parikshan", in Brajendranath Bandyopadhyay and Sajanikanta Das, eds, *Ramendra-Rachanabali,* Vol. 4, Bangiya Sahitya Parishat, Calcutta, [1950], 230-232.

[104] Bose and Das, "Researches on Growth and Movement in Plant", 372.

[105] With Crescograph one did not have to wait for several hours to detect the normal growth rate of plants as it was with auxanometers and other growth-recording instruments. Bose and Das, *ibid, 364.*

[106] Bose, "An Automatic Method for the Investigation of Velocity of Transmission of Excitation in Mimosa", *Philosophical Transactions of the Royal Society of London. Series B, Containing Papers of a Biological Character,* Vol. 204, 1914, 65.

[107] Bose, *Plant Autographs and their Revelations,* pp. 98-99.

[108] 'A loving glance allows many qualities to show, allows many words to be heard'. J. C. Bose, "Gachher Katha" (1895), in Samir Rakshit and Kamal Chowdhury, eds, *Jagadishchandra Sera Rachana Sambhar, 76.*

[109] The science of psychoanalysis in early twentieth century Europe was witnessing a debate around the validity of empathy as a tool of scientific observation, in which stalwarts like Freud and Ferenczi participated. E. Lunbeck, "Empathy as a Psychoanalytic Mode of Observation", p. 1. Daston and E. Lunbeck, eds, *Histories of Scientific Observation,* pp. 255-275.

[110] I borrow this term from A. Wetmore, "Sympathy Machines: Men of Feeling and the Automaton", *Eighteenth-Century Studies,* 43 (1), 2009, pp. 37-54.

[111] This is Bose's word. Bose, "Ahata Udvid", 134.

[112] Bose, "Udbhider Hritspandan" (1925), in Samir Rakshit and Kamal Chowdhury, eds, *Jagadishchandra Sera Rachana Sambhar, 155.*

[113] Daston and Gallison, *Objectivity,* 115 -190 and 139.

[114] Bose, "Bijnane Sahitya", 105.

[115] Schiefsky, "Art and Nature in Ancient Mechanics", in Bernadette Bensaude-Vincent and William R. Newman, eds, *The Artificial and the Natural: An Evolving Polarity,* The MIT Press, Cambridge, 2007, 77.

[116] Bose, "Adrishya Alok" (1921), in Samir Rakshit and Kamal Chowdhury, eds, *Jagadishchandra Sera Rachana Sambhar,* 85.

[117] Bose, *Plant Autographs and their Revelations: From the Smithsonian Report for 1914, pages 421-* 443, Washington, 1915, 425.

[118] Letter from Bose to Tagore, Kolkata, 6 March 1900, Harun-ar-Rashid, ed, *Rabindranathke Lekha Jagadishchandra Basur Patrabali, 26.*

[119] Lenoir, "Models and Instruments", 3.

[120] Schiefsky, "Art and Nature in Ancient Mechanics", 86.

[121] This was name of the section discussing Bose's growth-recorders in one of his popular lectures. Bose, "Surge of Life", in Prantosh Bhattacharyya, ed, *Acharya* J. C. *Bose: A Scientist & A Dreamer,* Vol. 4, 101.

[122] Bose, "Udbhider Hritspandan", 156. "Anubhab Yantra" roughly translates into a machine that *feels.*

[123] This imaginary continuum between the human/natural and the machinic/artificial abounds contemporary Bengali science-writing in general. Thus we find Jagadananda Roy explaining to his readers the mechanism through

which we were able to speak by citing the violin as an analogy. Roy, *Vijnanaer Galpo,* Indian Press Ltd., Allahabad, 1920, 32.

[124] Anonymous. "Plant Autographs: How Plants Can Record Their Own Story", 15.

[125] Bose, "Adrishya Alok", 88.

[126] Bose, "Convocation Address at the University of Punjab", 110.

[127] Geddes, *Life and Work of Sir J. C. Bose, 128.*

[128] Bose, *Plant Response as a Means of Physiological Investigation,* Longmans, Green & Co., London, 1906, 741-743. The text attached a diagrammatic representation of the windmill itself to illustrate its point.

[129] Bose, "Mechanism of Life", 226.

[130] Bose, "Snayusutre Uttejana-Prabaha", in Samir Rakshit and Kamal Chowdhury, eds, *Jagadishchandra Sera Rachana Sambhar,* 147; Bose, "Ahata Udvid", 136.

[131] R. Trivedi, "Jara Jagat", in Brajendranath Bandyopadhyay and Sajanikanta Das, eds, *Ramendra-Rachanabali,* Vol. 3, Bangiya Sahitya Parishat, Calcutta, [1950], 289.

[132] Bose, "Snayusutre Uttejana-Prabaha", *ibid.*

[133] For a discussion on the nineteenth century physics of interconvertible energy, ether, and animal electricity see Tresch, "The Machine Awakens", *French Historical Studies,* Vol. 34 (1), 2011, 87-123.

[134] Anonymous, "Khadyer Hisabe Shramajibir Barttan", *Bijnan,* Vol. 3 (5), 1914, 188 -191.

[135] Bose, "Unity of Life", 140.

[136] Geddes, *Life and Work of Sir J. C. Bose, 136.*

[137] R. Trivedi, "Adhyapok Jagadishchandrer Abishkar", in Samir Rakshit and Kamal Chowdhury, eds, *Jagadishchandra Sera Rachana Sambhar, 41.*

[138] H. Devi, "Udbhider Jiban Rakkhar Nababishkrito Upay", *Bharati,* 1294 B.S. [c. 1887], reprinted in Parthajit Gangopadhyay, ed, *Thakurbarir Bijnan-Bhabana,* Parul Prakashani, Kolkata, 2010, 169-171.

[139] M. Singleton, 'Yoga, Eugenics, and Spiritual Darwinism in the Early Twentieth Century', *International Journal of Hindu Studies,* Vol. 11 (2), 2007, 128-129.

[140] Roy translated the term "eugenics" as "Bangsher Unnatibidhan" or "Manabbangsher Unnatibidhan" (improvement of lineage or human lineage), J. Roy, "Bangsher Unnatibidhan", *Baijnanikee,* Indian Publishing House, Kolkata, 2003, 17-25.

[141] Trivedi, "Adhyapak Jagadischandrer Abishkar", 41.

[142] P. J. Pauly, *Controlling Life: Jacques Loeb and the Engineering Ideal* in *Biology,* Oxford University Press, Oxford, 1987, 5. Loeb was a student of Julius Sachs, whose researches influenced Bose a lot. Sachs, as we have already noted, also designed an improved version of auxanometer.

[143] *Ibid, 93.*

[144] Letter from Bose to Tagore, London, 30 August, 1901, in Harun-ar-Rashid, ed, *Rabindranathke Lekha Jagadishchandra Basur Patrabali, 63.*

[145] Bose, "Control of Nervous Impulse" (1918), in Prantosh Bhattacharyya, ed, *Acharya J.* C. *Bose: A Scientist* & *A Dreamer,* Vol. 4, 82-83.

[146] Anonymous, "Interview with J. C. Bose", *New India,* 26 January 1921, reprinted in Prantosh Bhattacharyya, ed, *Acharya* J. C. *Bose: A Scientist* & *A Dreamer,* Vol. 4, 318.

[147] J. A. Thomson, *The Control of Life,* Andrew Melrose, Ltd., London and New York, 1921, 5.

[148] Bose, "Convocation Address at the Punjab University", 114.

[149] Bose, "Bijnane Sahitya", 108.

[150] I. Mitra, "Experiencing the Social: The Physicality of Vernacularization", in "Modeling the Social: Vernacular Tracks of the Economic Discipline in Colonial Bengal", Unpublished PhD Dissertation: Department of Economics, Jadavpur University, 2013, 147-188.

[151] In another occasion, Bose emphasized the importance of external stimulus to the growth of "the intellectual life of a nation". "When, through narrow conceit", Bose held, "a nation regards itself self-sufficient and cuts itself from the stimulus of the outside world, then intellectual decay must inevitably follow". Bose, "Address to the Hindu University" (1916), in Anonymous, ed, *Sir Jagadish Chander Bose, 25-26.*

[152] Letter from Bose to Tagore, 8 June 1900, in Harun-ar-Rashid, ed, *Rabindranathke Lekha Jagadishchandra Basur Patrabali,* 3l.

[153] This "shock-therapy" metaphor was no doubt common to the twentieth century colonial elites. Jawaharlal Nehru, for example, in his Glimpses of World History, first published in 1934-35, considered India's colonial encounter with the west as generating a succession of unfortunate but necessary "violent shocks" that "could shake us out of our torpor". For Nehru, western science and technology was one such shock. "Without this 'great gift', India was 'doomed to decay.'" D. Arnold, "Nehruvian Science and Postcolonial India", *Isis,* Vol. 104 (2), 2013, 362.

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