

Experiments and Research Programmes. Revisiting Vitalism/Non-Vitalism Debate in Early Twentieth Century¹

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ABSTRACT

Debates in the philosophy of science typically take place around issues such as realism and theory change. Recently, the debate has been reformulated to bring in the role of experiments in the context of theory change. As regards realism, Ian Hacking's contribution has been to introduce 'intervention' as the basis of realism. He also proposed, following Imre Lakatos, to replace the issue of truth with progress and rationality. In this context we examine the case of the vitalism — reductionism debate in biology inspired by the works of Indian physicist-turned-biologist Jagadish Chandra Bose (1858–1937), in the early twentieth century. Both camps had their characteristic hardcores. Vitalists led by John S. Burdon-Sanderson and Augustus D. Waller accepted religious metaphysics to support their research programme, which ultimately degenerated. Bose worked more with the ideals of science such as Occam's razor, large-scale systematization of phenomena and novel prediction. I argue that his religious metaphysics, instead of acting as a protective shield, helped him to consolidate his position and allowed further problem shift resulting in a research programme that involved consciousness too. His research programme remains relevant even today.

KEYWORDS

Jagadish Chandra Bose, realism, theory change, research programme, hardcore, progress, vitalism, nervous mechanism of plants, Sāṃkhya, reformed Vedānta

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The most important debate in philosophy of science, which took place in the last century, centred around two themes: realism and theory change. Karl Popper (1902–1994) argued that science proceeds by conjectures and refutations. Thomas Kuhn (1922–1996) argued, in the context of scientific revolution, that experiment proves little. It is the new paradigm that settles the issue. Popper also held that “entities which we conjecture to be real should be able to exert a causal effect on the *prima facie* real things; that is, upon material things of an ordinary size” (POPPER and ECCLES 1977: 9). In the 1980s Ian Hacking infused some new blood into the debate. For him, realism is a matter of likeness. At the end of this discussion in the *Break*, Hacking proposed to discuss scientific realism under the heading of intervention. “We shall count as real what we can use to intervene in the world to affect something else, or what the world can use to affect us” (HACKING 1983: 146).

In what follows we study an experimental situation to understand how this construction and counter construction, actually took place in the early twentieth century. I am concerned here about the situation of Jagadish Chandra Bose (1858–1937), an Indian physicist turned biologist. Jagadish Chandra’s² situation was that of *Baconian Crossroad* (HACKING 1983: 249) facing two competing theories involving vitalism and reductionism. The question before us is what to make out of an experimental situation, including its reception among the scientists, and secondarily what is real. Let us take a quick look at the history of Jagadish Chandra’s success. But in subsequent appraisal, following Imre Lakatos (1922–1974),³ we concentrate on growth and not mere possibility of knowledge, showing that the vitalism is irrational.

INTO THE DOMAIN OF LIVING

The second half of nineteenth century saw great advance of research in electro-magnetism. And, as we all know, Jagadish Chandra proposed and perfected experiments to demonstrate various phenomena. His research came to its high around 1895 when he devised his coherer, demonstrated the controlled millimetre range radio wave propagation

² Using the first or second names interchangeably with a surname is quite common in Bengali language and does not mean any sort of an inappropriate familiarity. One of the reasons for calling famous personalities by their first names lies in a relatively small number of Bengali surnames which could often cause a confusion — editor’s note.

³ I am aware of methodological research involving research tradition instead of research programme. But I am concerned here with the research programmes only.

along with result of polarization involving nemalite etc. Little later he discovered 'electrical touch', symbolizing change in conducting power under radiation.

During this period it was also known to him that radio waves are a form of electromagnetic waves, and there is a range of it. We can perceive part of the spectrum but not the rest. Most important from our perspective was his treatment of fatigue of coherer, which he successfully dealt with. He then started to extend his research to other ranges. One such was photography without light. During this time he was preparing to extend his research to other fields and the first paper he wrote on *The Response of Inorganic and Living Matter*, presented in the International Congress of Physics in 1900. The paper was all about response of:

[...] living tissue, exactly as the curve of molecular reaction registers an analogous change in an inorganic substance. The two represent the same thing; in the latter the molecular deformation is evidenced by the change of conductivity; in the other the same deformation is manifested by the change of form (GEDDES 1920: 88).

But he did not stop there and the next sentence is important: "We have thus means of study of the molecular reaction produced by stimulus, of varying frequency, intensity and duration" (GEDDES 1920: 88). Still he thought that:

An abyss separates the phenomena of living matter from those of inanimate matter. But if we are ever to understand the hidden mechanism of the animal machine it is necessary to face numerous difficulties which at present seem formidable (GEDDES 1920: 88).

These quotations are well-known and even discussed in Bengal (India) dailies. The problem is with the interpretation of these claims. I want to emphasize that even at this stage there was a separation between living and non-living. Further, in his opinion, understanding of the 'animal machine' was found formidable. So the chasm, as he would say later, still remains. In the next phase comes his experiment on both living and non-living with toxic material to see the effect and he could detect continuity! So he concluded: "In all the phenomena described above continuity is not broken. It is difficult to draw a line and say, 'here the physical phenomenon ends and the physiological begins'" (GEDDES 1920: 90). But what is asserted, as an alternative in the next paragraph is source of some controversy!

We may attempt on the basis of this common property an explanation of different phenomena, which at first seem so very different. And in favour of this latter view we may

invoke general tendency of science to seek, wherever facts permit, a fundamental unity amidst the apparent diversity GEDDES (1920: 90).⁴

This is obviously a methodological step. Here he first considers two possibilities — different hypotheses explaining different phenomena or one hypothesis explaining different phenomena and then settled for the simpler. In physics this is obvious — amply demonstrated, for example, by great systematization using inverse square law. But in physiological context we are bound to be reminded of Sanderson's dictum: "Plurality of functions with unity of structure". Still the difference is formidable. However, Sanderson hastens to add that such unity must be represented by a simple structural element like retinal cone or cell (BURDON-SANDERSON 1889). For Jagadish Chandra, this search for fundamental unity comes in the form of a search of excitability in all forms of matter — living as well as non-living. A series of experiments were devised to test effects of different reagents, including toxic agents, on metals like iron, tin and platinum as well as in plants. The effects were remarkably similar. For the Royal Institution discourse on May 10, 1901, his attitude takes a better shape — he now formulates his proposal thus:

We have seen response sinking under fatigue, becoming exalted under stimulants, and being killed by poisons, in the non-living and in living. Among such phenomena, how can we draw a line of demarcation, and say, here the physical ends, and there the physiological begins? [...] Do not these records tell us [...] — that the physiological is related to physico-chemical? — that there is no abrupt break, but a uniform and continuous march of law (GEDDES 1920: 97).

From these he:

[...] understood for the first time a little of the message proclaimed by my ancestors on the banks of the Ganges thirty centuries ago — 'They who see but one, in all the changing manifoldness of this universe, unto them belongs Eternal Truth — unto none else, unto none else!' (GEDDES 1920: 98).

Apparently what he was doing here seems to be methodologically sound. If there are strong correlations then look for a common cause which gives rise to these correlations. If we, for the present, bracket the last sentence about Eternal Truth, there is no doubt that he found

⁴ Though the paper is now reprinted in BOSE 1927 I shall use Geddes. Several authors find that Jagadish Chandra is invoking an Indian ideology: *unity in diversity* or even *Upaniṣadic monism*. But these are completely unnecessary factors introduced in the context of science. These authors fail to note his explicit statement that he was in fact invoking an 'age old principle of science'.

that common cause in the physico-chemical. It was a resounding success but an elaborate paper was presented in the Royal Society on June 6, 1901. John Burdon-Sanderson (1828–1905) also attended the lecture. After the presentation was over Burdon-Sanderson commented: “It was a great pity that he should leave his own sphere of study, in which he attained such acknowledged distinction, for other fields which properly belongs to physiologist” (GEDDES 1920: 99).⁵ He also suggested that the title of the paper should be changed from *The Electric Response to Certain Physical Reactions*. The effect was disastrous. His paper was not printed at all but sent to the Archive. Naturally Bose got very depressed but did not give up. Geddes saw a problem of authority against knowledge dominating the then atmosphere in the Royal Society and he notes that it was an opposition based on no scientific ground. In his interpretation, Jagadish Chandra felt that as a physicist he was regarded as an intruder in the domain of physiology and so in effect facing a kind of hierarchy akin to that of caste system prevalent in India.

A year later Jagadish Chandra came to publish *Response in the Living and Nonliving*. Much later in 1914 he again gave a lecture on this subject and the paper was published in the journal of the Royal Society of Medicine.⁶

SCIENCE AND IDEOLOGY IN LATE 19TH CENTURY ENGLAND

Before we go further we should take a look at the general attitude of scientists in matters intellectual as well as ideological prevalent in late 19th century Britain. For, to understand why Burdon-Sanderson raised such an objection it is essential to know the state of the science of physiology and its ideological moorings. In 1873, Charles Darwin (1809–1882) was quite preoccupied with the behaviour of *Drosera* which was a “wonderful plant or, rather, a most sagacious animal” (BURDON-SANDERSON 1911: 106). He reached the conclusion that the excitable cells of the plant may show essentially similar response to that of the animal tissue. Burdon-Sanderson picked up this suggestion from Darwin and started serious work but with *Dionea* instead. He demonstrated that there was an electromotive change in the leaf whenever it comes into active state. It was also shown that even if the leaves are not allowed any mechanical

⁵ Emphasis mine. Geddes’ “Another well-known professor of physiology” seems to be Augustus D. Waller. Interestingly, both Geddes and Waller worked in Burdon-Sanderson’s laboratory (BURDON-SANDERSON 1911: 97). For other interesting discussions, see SENGUPTA, ENGINEER and SHEPHERD 2009; SHEPHERD 2005.

⁶ Best technical summary of Bose’s work may be found in SHEPHERD 2005.

movement, whenever the excitable hairs are touched, an excitatory response in the form of electromotive change occur.

He continued his work on this aspect of plant response and published a detailed account in 1882 (BURDON-SANDERSON 1882). He concluded that the excitatory disturbance, "by the mode of its suddenness of its incidence and the rapidity of its propagation, is distinguished from every other phenomenon except the corresponding process in the excitable tissues of animals" (BURDON-SANDERSON 1911: 107). He actually thought of two distinct possible ways of excitation: one short rapid and propagating fast. The other is the relatively long effect 'often of different sign'. The first one was identified with the electrical change as the visible sign of an unknown molecular process.

But as an explanation of the second, like Wilhelm Pfeffer (1845–1920), he thought that "the diminution of the turgor or water-charge of the protoplasm of the excitable cells" (BURDON-SANDERSON 1911: 107) may cause this. In 1888 he came up with another paper where behaviour of 'modified leaf', i.e. a leaf which was subjected to weak current, was investigated. He found that:

The modification reveals itself as a permanent alteration in the amount, and even the sign of the electric state of the inactive leaf-surface. It is localized to the part to which the modifying current has traversed, and is associated with a remarkable diminution in the high electrical resistance of the tissue, this diminution being strictly confined to the modified region (BURDON-SANDERSON 1911: 109).

Around the same time he has also been working on frog's heart and later with tortoise. So he should not have had any difficulty in identifying the current as the sign of conscious response of living being. Still something made him to keep a distance from this conclusion. In this connection his observations made in a letter to Miss Florence Buchanan, are instructive:

i) By measurement a complete knowledge of what happens electrically (intensity, localization, and time-relations), may be obtained but that does not enable us to conjecture the nature of the excitatory process of which these phenomena are the concomitants.

ii) The excitatory process can best be defined as a sudden transition from less functional (the so-called rest-state) to greater.

iii) "It is not a measurable physical state but a vital one which cannot be measured, and which therefore lies outside the scope of scientific knowledge" (BURDON-SANDERSON 1911: 109).

iv) The two acts, which seem to constitute the excitation and response, are not continuous, but are joined together by a non-measura-

ble link. This link is a subject of scientific conjecture, not of scientific knowledge.

v) This he called 'organismal' as something which is involved in organisms only.

Then he reiterates that neither the physical effect of the stimulus nor that of the response constitutes the excitatory process. It is constituted only when these two are coupled by the organismal nexus. Therefore this process is not measurable. He further observed that the "electrical machinulae⁷ are acted on by the organismal stuff and not by their neighbours. Propagation is a vital process, not a physical one" (BURDON-SANDERSON 1911: 168–169). As it is well-known, around that time some distinguished physiologist like Hermann von Helmholtz (1821–1894), Emil du Bois-Reymond (1818–1896), Claude Bernard (1813–1878) and Max Karl Ernst Ludwig Planck (1858–1947) revolted against this vitalism and tried to explain⁸ everything related to life in terms of inorganic phenomena (BURDON-SANDERSON 1911: 164).

However inclined he might have been to include the plants within the domain of living the nature of reaction of plant to external excitation and the then debate about the explanation of it forbade him from including the plants within the domain of conscious organisms. In the beginning of the paper he however noted two great objections to his earlier attempt to interpret the change in electromotive phenomena observed in the plants.

In 1876 Professor Munk [...] published an elaborate paper on *Dionaea*, in which, while he admitted that the facts which have been recorded were in the main true, and that a real relation existed between the electrical disturbance which follows excitation in *Dionaea* and the so-called 'negative variation' of animal physiology, he charged me with having entirely misinterpreted and misunderstood that relation (BURDON-SANDERSON 1911: 174).

In the same page, he also noted that according to another physiologist Henry G. Kunkel (1916–1983):

⁷ I have no doubt that he was referring to the mechanical theorists who sought explanations of all living processes in terms of mechanical effects. A very interesting summary can be found in LODGE 1905. Here it is reasonable to assume that Jagadish Chandra knew about this and had this controversy in mind when he said if we are "ever to understand the hidden mechanism of the animal machine it is necessary to face numerous difficulties which at present seem formidable".

⁸ DASGUPTA (1999: 130–133) offers an excellent summary of this programme.

[...] all electromotive phenomena observed in plant, are dependent on changes in distribution of water in their tissues, and consequently have nothing whatever in common with the electromotive phenomena of muscle and nerve (BURDON-SANDERSON 1911: 174).

In the preparatory part of the paper he also noted that there is time lag between transmission of excitation and also difference between transmission through nerves and the subsequent mechanical effect. Even in this context he discussed two models of nerve and transmission of excitation, those already proposed by Haller and Newton. He in fact gave an analogical model of transmission of excitation in terms of transmission of effect of excitation within nerve, taken as a tube. It's the wave train that propagates not the liquid contained. In this context he sought to explain why the effect would be retarded when the tube is partially blocked — an analogy used by Jagadish Chandra in his book *Plant Response*.

Another important physiologist, Augustus D. Waller (1856–1922), was a professor of physiology who authored quite a few books. Jagadish Chandra in fact quoted from one of his books *Brain*. His book *Introduction to Human Physiology* (WALLER 1891) was a standard for quite some time and widely used in Britain. In this book he observed:

It is necessary, in order to define the scope of the foregoing analysis, to add a few words of limitation. We have followed an idea to the borderland of physical phenomena, which can be measured by our senses. We have glanced across the limit into regions where questions and opinions cannot be measured by objective means, although they have been fearlessly broached, freely pronounced upon by schoolmen and churchmen. We desire not to trespass upon those regions. The question why? Is not answered by positive science, but only the question how? And sometimes how much? Physiological problems are limited to the tangible and measureable phenomena of living bodies. The physiologist cannot say why a muscle contracts, nor define 'life', 'free will', 'moral responsibility'; his professed task is limited to an objective study of the essential particulars in which living differs from inert or dead matter [...]; the original cause of the property termed contractibility is beyond our knowledge (WALLER 1891: 300).

Needless to say, he left the question of life as well as vital force to philosophers and churchmen. But the above quotation makes it clear that he was not at all for reductive mechanistic philosophy. All he would accept was the 'how' part which can be measured and described in mechanistic terms.

DEFINING PROBLEMS OF ELECTRO-PHYSIOLOGY

Between them Sanderson and Waller have raised and discussed almost all the relevant questions related to excitation: That of vital process, transmission of signal from the organ of will, that is brain within the nerve, two types of transmission of effect of excitation, electrical and mechanical and, especially by Waller, the phenomenon of fatigue. Similar effects were observed in plant and in animal tissues. Both were aware of debates regarding the problem of explaining 'plant response' and debates about nature of transmission. And thirdly, they were aware of the debate related to 'vital process' *vis-à-vis* mere 'mechanical disturbance' theories of life-processes.

In animals of course there was no problem of conceiving of a vital process, which acts upon the electrical machine to produce response. These reactions, generated in nerves, propagate through nerves to other regions so that the organismal stuff responds. Nothing like nerve is found in plants — neither is it possible to conjecture that there are nerves in the metal etc. Besides, assuming that there is some substance in Kunkel's claim that the reaction of nerves and reaction of plant parts are completely different is actually a matter of explanation and not about observation. Therefore, Burdon-Sanderson thought that, till the matter is resolved, it would be inappropriate to make any claim about 'response' just from the observation of similarity. So came his strong words of disapproval for Jagadish Chandra's use of the term.

CONTEMPORARY OBJECTIONS

But for the time being let us ponder on an issue raised by Subrata Dasgupta. He claims that Jagadish Chandra's argument was a flawed argument as it relied on a false premise. He failed to distinguish between necessary and sufficient conditions and mistook the former for the later (DASGUPTA 1999: 130). In other words, Dasgupta's argument is that it may be true that living matter produces electricity (under certain conditions) but because something is producing electricity (under certain conditions) need not be regarded as living.

What was this electrical activity? Dasgupta, whose book is perhaps the most serious investigation about Jagadish Chandra's achievements, discusses it clearly. The question of animal electricity was quite well known since the results of Luigi Galvani and Alessandro Volta in 1790's. Moreover, the two types of electricity were discussed by Augustus Waller

whose article was referred by Jagadish Chandra himself (BOSE 1902). As Dasgupta noted, Waller claimed that an isolated nerve shows no sign of life through chemical or thermal change but it does manifest an electrical response. Using this argument Bose concluded, as Dasgupta reads him, that electrical activity is defining characteristics of life.⁹ But did not he have other things in mind also, that is, the relation of physiological to physico-chemical? Dasgupta hardly takes any interest in this aspect.

According to Dasgupta the central thesis of Bose was that there is continuity between living and non-living (DASGUPTA 1909), which he contests as not established at all. This claim has recently created some controversy but I shall not get into that.¹⁰ Instead, I shall prefer to rectify that Jagadish Chandra had two basic and independent theses: the first was actually a form of physicalist reductionism, i.e. physico-chemical theory, and the second one was that there is continuous march of law.

In the context of the late 19th century England we might say, substance was defined as the entity of two types: non-living or living. In the latter case, living behaviour is physiological and all physiological is actually physico-chemical. At the physico-chemical level everything is molecular behaviour and so — “ultimately there should not be any substantive difference”.¹¹ This was the substance of Jagadish Chandra’s two theses. One may argue that if Jagadish Chandra accepted the logic of ‘sufficient condition of life’ then he would not have repeatedly referred to the living *vis-à-vis* the non-living. If the non-living could respond, and if, as he assumed, electric response was sufficient to entail life then the non-living would no longer remain nonliving because he himself demonstrated that non-living can also respond. This is proof enough that he did not treat the ability to respond as the ‘sufficient condition’ of life. Rather he was talking of the universality of electrical stimuli to measure response in the living as the title of the subsection of his article *Universal Applicability of the Test of Electric Response* shows. His choice of electrical response as the criterion of life was not an attempt to establish the

⁹ DASGUPTA 1999 also talks about ‘sufficient condition’. At this level of generality we do work with sufficient conditions only. For example existence of field is sufficient condition of the production of the field quanta. This point does not merit serious considerations.

¹⁰ Cf. CHATTERJEE 2008. Though she demonstrated the problem in Dasgupta’s argument, she ultimately finds an authority in Nilratan Dhar to say that Jagadish Chandra merely found similarity of response in living and non-living and nothing more! By the way, I would like to thank to Ms. Chatterjee for sending me a copy of her paper.

¹¹ In his summary of Jagadish Chandra’s work in this phase, Tagore also expressed similar view and Jagadish Chandra never protested. Cf. TAGORE 1901: 149–151.

universality of electric response as a condition of life but to demonstrate the universal applicability of electrical stimulus merely to measure response in life.¹²

Though I think this to be an altogether unwarranted conclusion, it forces us to spell out some details. Did Jagadish Chandra stop at merely demonstrating universal applicability of electrical stimulus to measure response in life? To say this will be the most unfortunate reading of Jagadish Chandra's intension. Here I think the greatness of Geddes' interpretation comes in. When he made a distinction between two arguments he knew that in the first stage Jagadish Chandra was demonstrating just the similarity and retained the divide between the living and non-living (CHATTERJEE 2008). But if Jagadish Chandra stopped at that he would have been at most a second rate scientist. Jagadish Chandra actually understood that his demonstration of similarity showed a serious anomaly in the vitalist theory. He therefore went for a problem shift — first by reformulating his observations as a *reductio* against vitalism and then by proposing an alternative in terms of existence of the level of the physico-chemical, and the second by reinterpreting that in terms of molecular strain theory.

But one question still needs to be answered. In spite of demonstrating this similarity, why did not he extend his argument to claim that there is no divide between the living and non-living? My answer with hindsight is that Jagadish Chandra knew very well that he did not have a knock-down argument. For the vitalists like Sanderson or Waller would simply block his argument — as they indeed tried to do — by saying that these are separate domains and mere similarity does not establish anything more than mere similarity!

Following Burdon-Sanderson, one may ask: why should the molecules behave in a way so as to produce the electrical activity? Here we must, as claimed by Waller, invoke metaphysics to answer because there is some more basic reality that is intervening, but that level is 'beyond the scope of science'. For Burdon-Sanderson and also for Waller, that reality was the vital force. For Jagadish Chandra, that reality was physico-chemical and at least in this context, not the Ultimate Truth he learnt from his forefathers! The 'ultimate truth', by his own declaration, he merely understood after he reached this conclusion.

I find no reason to believe that in 1900 he was not aware of the positions of Burdon-Sanderson and Waller that animals do respond to external stimuli and that they do so by virtue of the nervous system. The

¹² CHATTERJEE 2008 following Nilratan Dhar asserts this.

response has a definite pattern and that can be influenced by various external factors like temperature, can die under action of poison and can get fatigued under prolonged excitation. Presumably he also knew of Darwin's work and subsequent work of Sanderson that some plants respond to stimuli. It is also a good guess that he knew about Sanderson's position that only *Dionaea* — and not all the plants — responds like animal tissues/nerves. As it is well-known he was also aware that non-living substances respond in a particular way and show effect of fatigue. It is therefore natural to extend the domain to that on which he was already an authority and try to see if there is a similarity. As we all know, he did see the similarity in response curves of all three kinds of substances. Moreover he already had his molecular strain theory. Thus, the obvious step is to look for an explanation within his own work — in the domain of the physico-chemical.

His ideas firmed up after facing the criticism in England. Result of contemplation and further experiment led to more detail formulation and appropriate treatment of the phenomena concerned. Though Dasgupta and others took note of this fact, they never tried to look at the progressive problem shift effected by Jagadish Chandra and therefore got involved in naïve methodological appraisal. Ultimately, following Lakatos, I feel that the result degenerates into naïve history.

MORE ABOUT SIMILARITY

Let us now look at what Jagadish Chandra showed in innumerable experiments. The book he published a year later *Responses in Living and Non-living*, is actually an elaboration of his view expressed in the abovementioned papers. The preface of the book is dated May 1902. He also mentioned that the work commenced in India but he joined and worked in Davy–Faraday Laboratory during the intervening period. The first chapter he reviews mechanical response of living substances in the form of 'response curve'. But, as many have discussed it before, he notes at the end:

Thus these response records give us a means of studying the effect of stimulus, and the modification of response, under different varying external conditions, advantage being taken [by earlier theorists] of the mechanical contraction produced in the tissue by the stimulus. But there are other kinds of tissues where the excitation produced by the stimulus is not exhibited in a visible form. In order to study these we have to use altogether independent method, the method of electrical response (BOSE 1902: 4 [emphasis and insert B.M.]).

He also clearly mentioned that a living substance may be put into an excitatory state by either mechanical, chemical, thermal, electrical, or light stimulus (BOSE 1902: 2). Therefore, *contra* Dasgupta, *electrical response* is only an alternative and not taken as a defining characteristics of the living. The next chapter, however, comes up with some experimental set up but also an explanation of nerve current and its conditions. Here he claims that if an excitation occurs somewhere in the nerve, while two ends are connected by a conductor and through a galvanometer, no current will flow. For, whatever electrical changes occur in the two ends because of this stimulus, they will be almost the same in both ends and the galvanometer will show no deflection. But if one side is made insensitive by action of a cut or poison, then the other side would produce electricity but the dead side would not. So there will be an electrical activity.

Following Ian Hacking, we may ask what is manipulated here? The answer, by construction — it is almost a phenomenological theory though — is the nerve (which is injured) and therefore it is real. But we can, as Jagadish Chandra did, accept the *well-understood* theory that the nerve is made up of molecules. So he concludes: “the physico-chemical conditions of the uninjured A and the injured B are now no longer the same, it follows that their electrical conditions have also become different” (BOSE 1902: 6). If nothing happens further the current will be constant — the current of rest. But if there will be further injury and/or use of chemicals, it would *show* that in the form of increase or decrease of electrical activity.

In the next page he comes to non-living system comprising of two different metallic strips, zinc and copper connected by cloth ‘moistened with salt solution’ and shows that even there we can find an electrical activity similar to that of nerve including the effect of manipulation by creating similar injuries. In the section, *Electrical Response: A Measure of Physiological Activity* he briefly discusses these electrical responses as physiological, or characteristic of living tissue, for, conditions, “which enhance physiological activity also, *pari passu*, increase their intensity” (BOSE 1902: 13). But in the next paragraph we clearly find his intention:

From these observed facts — that living tissue gives response while a tissue that has been killed does not — it is concluded that the phenomenon of response is peculiar to living organism. The response phenomena that we have been studying are therefore considered as due to some unknown, superphysical ‘vital’ force and are thus relegated to a region beyond physical inquiry (BOSE 1902: 13).

The first sentence ends with a footnote citing a passage from Waller's book (BOSE 1902: 3–4). But Waller was arguing for vitalism, while Jagadish Chandra was actually fighting against it. I want to inquire: on what methodological ground Jagadish Chandra reached the conclusion? Jagadish Chandra's argument is simple use of Occam's razor, or as the Indians would say, an argument using *gaurava doṣa*, which means that if you can explain a phenomenon using a concept and can also explain it without using that concept, then the latter explanation is preferable. At bottom it is the age-old demand of simplicity which even Popper accepted and argued for. But one may ask here: why should the simple theory be true? Hacking's suggestion of intervention does not help in our case directly. But it does indirectly. We may wonder then, if one uses vitalism to produce any effect regularly. If there is an explanation which shows superfluity of a concept then, I suggest, it can be taken as a proof that it was not used and so it was not real. But, as Popper would say, a theory in terms of vitalism has less empirical content than a molecular strain theory and the latter is more refutable and so more scientific.

It should be noted that Jagadish Chandra devotes two full pages in the conclusion to clarify that his fight is actually against vitalism and for scientific — in his sense, physico-chemical — study of life in which vitalism plays no role in explanation and in understanding the human machine. Thus, he makes a clear reference to Sanderson, just raising the possibility:

It may however, be that this limitation is not justified, and surely, until we have explored the whole range of physical action, it cannot be asserted definitely that a particular class of phenomena is by its very nature outside that category (BOSE 1902: 14).

Moreover, he thinks that similarity of electrical response of animal, plant and non-living is due to a molecular disturbance, the stimulus causing a distortion from a position of equilibrium. So from our point of view he effectively proposes a general theory of response while looking for an appropriate reductive framework.

PROGRESSIVE PROBLEM SHIFT

We have earlier remarked that Jagadish Chandra effected problem shift. The first is negative by demonstrating the anomaly but the second part is positive — through proposing a molecular strain theory of response.

Even though Lakatos (1995 [1978]) claimed that there is no such thing as crucial experiment, Jagadish Chandra believed that he performed some 'crucial' experiments to prove the physiological character of electrical response (BOSE 1902: 30). It was an intermediate step. Later he would explain this in terms of the molecular strain theory proposed in 1902 (BOSE 1902: 97). But Lakatos also brought in another interesting idea. According to him a problem shift may be degenerative as opposed to progressive. For him what we apprise is a series of theories only rather than an isolated theory. Such a theory change is actually a progressive one or "constitutes a theoretically progressive problem shift" (LAKATOS 1995 [1978]: 33) if it can predict some novel fact in excess of its predecessor. So is the necessity of such a big array of experiments. Again and again, for every claim of peculiar nature of living organism as claimed by his predecessors like Burdon-Sanderson or Waller, Jagadish Chandra would devise an experiment, to show that similar effects exist in non-living, e.g. metal. If there be a peculiar response of nerve under certain conditions, which manifests itself as electrical activity, he would show that such activity is present in plant or in metal wire as well. If there was a peculiar effect shown by optic nerves and retina, he would show that there is nothing special about it by showing a similar activity in, say, a silver cell. His theory therefore showed that a peculiar form of phenomenon could be observed in metals and in plants too. Therefore, his theory comes up with novel predictions and then got them verified experimentally.

One particular case, that of retina, deserves special mention. He first proposed that the eye is actually a photo-electric cell. Next he compares the electrical response curve of retina with that of a silver-bromide cell to show that they are very similar. In *résumé* of the chapter XVIII of *Response* he concludes that the response of the sensitive inorganic cell to the stimulus of light, is in every way, similar to that of the retina. For, in both we have a positive variation, that is the intensity of response up to a certain limit increases with the duration of illumination; it is affected in both alike, by temperature; in both there is comparatively less fatigue:

[...] finally of the effects produced by stimulus of light, we find that there is not a single phenomenon in the responses, normal or abnormal, exhibited by the retina which has not its counterpart in the sensitive cell constructed of inorganic material (BOSE 1902: 178–179).

THE POSITIVE THESIS

Now, I want to discuss the positive thesis proposed in the penultimate chapter of the book referred above. In his theory then light impinges on the retina and produces the visual effect. The visual effect is essentially living activity. But, as the well-known and well understood theory says, and demonstrated by experiment, light also produces electrical impulse in the adjoining nerves due to the electro-physiological properties which are at bottom results of molecular disturbances in the membrane and molecules in the nerves. Can these two be different?

Bose begins with the hypothesis that they are not different. In other words, the visual effect of light, which is living phenomenon, and the electrical impulses it produces are identical. Support from this thesis comes from the fact that:

[...] varying intensities of light give rise to, [...] the curves which represent the relation between the increasing stimulus and the increasing response have a general agreement with the corresponding curve of visual sensation (BOSE 1902: 170).

In the next sentence he notes that the electrical phenomena not only explain but also are 'deeply suggestive' with respect of others. Here he was clearly hinting at novel prediction of his theory. The formulation of evidence here is fully couched in the psychological language, that of stimulus and response. In ordinary circumstances, in darkness, there will be a feeble sensation of light known as the intrinsic light of the retina. The effect of external light superposes on this light and produces some curious results. Among these curious results there is the oscillation he observed in binocular vision.

The situation may be roughly described as follows. Think of a stereoscope consisting of a slanting cut on the left and another on the right with some distance between them. If we look through it when the left cut is open we can see a slanting opening on the left and on the right when the other is open. But when this plate is 'turned towards the sky' we will see two openings superimposed like a cross. But one arm of the cross begins to be dim alternately. After looking through the stereoscope, for ten seconds or more, the eyes are closed. First there is darkness due to rebound. "Then one luminous arm of the cross first projects [...] slowly disappears after which the second [...] shoots out suddenly in a direction athwart the first" (BOSE 1902: 170).

He likens this with the oscillatory after-effect of light observed in case of sensitive 'silver cell' in the form of response current. There can be no

question of any 'objective cause' as the eyes are closed — still there can be no doubt of the 'objective' nature of the strain impression on the retina. One possible explanation may come from 'memory' as some of the undoubted phenomena of memory are also recurrent. But he takes for granted Edward Wheeler Scripture's formulation:

Certain sensation for which there is no corresponding process outside the body are generally grouped for convenience under the terms [memory]. If the eyes be closed and the picture be called to memory, it will be found that the picture cannot be held, but will repeatedly appear and disappear (BOSE 1902: 170).

So recurrence is recurrence of after-effect and not any curious effect of memory peculiar to the living alone but only some effect arising out of some physical law. This memory, for him, is an after-effect stored as a kind of delayed reaction in the nerves alone and by his theory this, like a spring, is also a physical reaction. So from molecular strain theory he is now on the verge of another problem shift — Explanation of Consciousness.¹³

THE UNCONSCIOUS VISUAL IMPRESSION

Next comes *Unconscious Visual Impression* and that is most exciting. He describes an experiment where he is the subject. When he was looking at a particular window, his attention was concentrated on a particular window creating an after-effect. This was repeated for a number of times. But on some occasion, he found after closing the eyes, that owing to weariness of the particular portion of the retina he could no longer see the after image of the window. Instead a circular opening appears. Then follows his explanation:

I was not aware of the existence of a circular opening higher up in the wall. The image of this had impressed itself on the retina without my knowledge, and had undoubtedly been producing the recurrent images, which remain unnoticed because my principal field of after-vision was filled up, and my attention directed to the recurrent image of the window. [...] It thus appears that, in addition to the images impressed in the retina which we are conscious, there are many others which are imprinted without our knowledge (BOSE 1902: 179).

¹³ To the best of my knowledge D.M. Bose first raised this possibility of interpreting Jagadish Chandra's work in terms of consciousness. Cf. BOSE 1947–1948: 73–84. Dasgupta also noted this but did not develop it further.

Here he comes close to formulating multiple draft model,¹⁴ albeit talking in empiricist language. The explanation is entirely physical and includes a suggestion that phenomena of ocular phantoms, which do not have objective causes, may also be explained in terms of this kind of recurrent after-effects. Given all these one may conclude that he was a thoroughbred empiricist speaking in the then psychological language and in fact, pleaded for a multiple draft model of visual perception.

ANOTHER METHODOLOGICAL STEPS

We have till now presented a very short summary of the results in the book and also discussed methodological ground for his most general conclusion that there is a continuous march of law both in living and non-living. Questions have been raised about his extra emphasis on fatigue. However it is not only true that some extra emphasis was there, it was also necessary for Jagadish Chandra's argument.

As we briefly raised the matter the attitude and ideology of the then leading physiologists were dominated by vitalism, which was at the root of philosophical appreciation of the living process. Both took for granted that the last word in this respect would come from the Church. Burdon-Sanderson actually presided over a congregation of students' Christian association at University College of London (BURDON-SANDERSON 1911: 160). Waller on the other hand tried to explain some of the phenomena (though in the form of conjecture) in terms of vital force producing CO₂ in the human (living) tissue as a result of which fatigue occurs (WALLER 1895–1896: 312). Jagadish Chandra quoted from Waller:

Considering that we have no previous evidence of any chemical or physical change in tetanised nerve, it seems to me not worthwhile pausing to deal with criticism that it is not CO₂ but 'something else' that has given the result (WALLER 1897: 59).

Then he adds: "That this phenomenon is nevertheless capable of physical explanation will be shown presently" (BOSE 1902: 123). To reach this conclusion what he does is to show that even the metals have those effects of fatigue but in a metal like tin there is no question of generating CO₂. Hence there is no question of invoking vitalism.

What is worth emphasizing, he was resorting to an alternative but simpler theory which allowed him an entirely physico-chemical explana-

¹⁴ Proposed by DENNETT 1991.

tion. Here he was in fact facing Baconian crossroad. But his experiments and belief in physico-chemical led him to proceed further through various other research programmes resulting in construction of 'nervous mechanism' of plants. Simplicity did not 'settle' everything — as we have said before, vitalism was not knocked out. So he expected that a f e r t i l e r e s e a r c h p r o g r a m m e would settle things.

EXPLANATION OF PLANT RESPONSE

Since both plants and animals are living, he believed there should be a similar kind of explanation to all of them. Hence the explanation of responses in both should be in terms of nervous reactions. Though he had been working all along in this vein he came to publish his most mature book *Nervous Mechanism of Plant Response* in 1926. In the *Introduction* he notes:

The results indicated that the response of the more complex and unstable living matter is ultimately, the expression of physico-chemical reactions. I next tried to find whether ordinary plants, meaning those usually regarded as insensitive, exhibit the characteristic electrical response already known in 'sensitive' plants. [...] My next investigation was directed towards obtaining evidence of responsive mechanical movement in these plants [...]. The most important fact established in plant response was the nervous character of the impulse transmitted to a distance. [...] My discovery of the excitatory polar action of an electrical current and its transmission to a distance, proved that conduction of excitation in the plant is fundamentally the same as that in the nerve of animal (BOSE 1926: vii).

Even in this project he established that the existing two theories, more mechanical in nature, those of hydro-mechanical theory of transmission of excitation — proposed by Wilhelm Pfeffer (1845–1920) and Gottlieb Herberlandt (1854–1945), as well as the theory of Transpiration-Current Conduction — were wrong as they were unable to explain directional nature of propagation of signal. He in turn proposed that phloem bundles do the job. Theorization in terms of phloem bundles did have the character of manipulation but he did need a construction in terms of phloem bundles as nerves. By this construction he now completed his project.

It is a pity though that he gave up, possibly on the face of the resistance from Waller and Sanderson, any serious research on propagation of signals in animals and refrained from construction of models of signal transmission as a combined electrical as well as physico-chemical process for even plants. It should be apparent that he was not very far from

such a model. In fact he came up with the idea of action current in plant, that is in phloem. Later direct evidence was found in “demonstration of the existence of two separate nerves for the motor and the sensory impulses, the characteristic of the motor nerve being that conduction takes place in it at a much quicker rate than the sensory” (BOSE 1926: 216). As we all know contemporary works on transmission of signals in plants actually began from where he left.¹⁵

WHY ‘MESSAGE FROM THE ANCESTORS’ THEN?

There is widespread belief that Jagadish Chandra was invoking Indian mysticism, when he said that there is no discontinuity between living and non-living. I take the following definition of mysticism provided in the *Stanford Encyclopedia of Philosophy*:

A (purportedly) super sense-perceptual or sub sense-perceptual experience granting acquaintance of realities or states of affairs that are of a kind not accessible by way of sense perception, somatosensory modalities, or standard introspection (GELLMAN 2010).

If we take Vedānta doctrine to be relevant in the context of Bose’s worldview and require *brahman* to be either super sense-perceptual or sub sense-perceptual experience then there is a problem. The operative part of the definition is realities or states of affairs that are of a kind not accessible by way of sense perception etc. But if *brahman* is everywhere, as claimed by Vedānta, then why should not it be accessible by sense-perception, especially if we include the experimental verification? Though, it may happen that some aspects of *brahman* are not so accessible and would require special intuition.

Although this is not a proper place to get into a comprehensive discussion on Vedānta philosophy, before proceeding further a few general remarks seem necessary, especially because there are several references to these views while explaining the genesis of Jagadish Chandra’s ideas.¹⁶ Vedānta is one of the most influential systems of Indian philosophy. Like all other orthodox *darśana*-s, in particular the systems of Sāṃkhya and Yoga, it also deals with the nature of ultimate reality, origin and nature of the universe, relation of the universe and the ultimate reality and

¹⁵ For some frontline research which cites him cf. FROMM and LAUTNER 2007. A very illuminating summary of the relevant contemporary results in plant physiology is available in SHEPHERD 2005.

¹⁶ See DASGUPTA 1999; BOSE 1947–1948; GOSLING 2011, to name a few.

many other issues. Vedānta and Sāṃkhya both accept that world of experience is composed of the elements (*bhūta*), among others, and also recognize the faculty called *buddhi*, i.e. intellect. But the crucial difference between these two schools lies in the generation of the *bhūta*-s (elements) and the intellect. Sāṃkhya also accepts that all the individuals come into being thanks to the contact (*saṃyoga*) of two basic realms: *puruṣa* and *prakṛti*, or the self and nature.¹⁷ Thus, this system formulates the theory of natural evolution and believes in the existence of many individual selves (*puruṣa*-s), who alike nature (*prakṛti*) are not created since both the basic realms are the primordial and eternal possibility of spontaneous creation.

Whereas Vedānta also accepting existence of the five elements (*bhūta*-s) and intellect (*buddhi*) as far as the world of experience is concerned, strongly rejects the Sāṃkhya claim of evolution based on a distinction between spontaneously creative nature (*prakṛti*) and the self (*puruṣa*), being the passive principle of consciousness. For Vedānta there is only one *brahman*, the primordial eternal absolute reality, which does not evolve to produce anything different than itself. The elements (*bhūta*-s) are merely transformations of/within *brahman*. However, they cause no real change in it. The philosophers of Vedānta argue that *brahman* transforms itself through its delusive inner power (*māya-śakti*) which makes the elements and individuals perceived.¹⁸ In fact, the One (*brahman*) is not marked by the existence of elements or atoms. Yet, the latter ones, called in Sanskrit *aṇu*-s, are accepted in Nyāya and Vaiśeṣika schools who found their world view on such entities. A meticulous refutation of their claims is provided by *Brahmasūtra* (BS 2.2.1–2.2.17), the most ancient text of Vedānta tradition attributed to Bādarāyaṇa, a sage of the 1st century BCE, but probably compiled in its final form several centuries later.

With these brief introductory remarks let us now come to Jagadish Chandra's situation. His father, Bhagaban Chandra Bose, was one of early dedicated members of the Brahma religious movement¹⁹ even though

¹⁷ Seal's book is one of the most interesting expositions of Sāṃkhya doctrine and Gosling thinks that it might have influenced Jagadish Chandra.

¹⁸ One of the later texts of Vedānta, *Pañcadaśī* of Swami Vidyāraṇya (chapter I: 59), categorically says: *sattattva māśritā śaktiḥ kalpayet sati vikriyāḥ, varṇā bhitti gatā bhittau citraṃ nānā vidhaṃ tathā* (BANESHANANDA 2001).

¹⁹ Brahma Samaj was a very influential religious, social and reformist movement responsible for initiating the Bengal Renaissance. It was formed in Kolkata in 1843 by Dwarkanath Tagore (1794–1846) by merging his Tattwabodhini Sabha with the Brahma Sabha founded ten years earlier by Rammohan Roy (1775–1833).

he was then living in Mayenmansingh (now in Bangladesh), far from Kolkata. As early as in 1854 he, with three others, started the Brahmo prayer meeting there. The real architect of the Brahmo movement, Devendrananth Tagore (1817–1905) did not accept any of the books of the Hindus, like *Brahmasūtra*. Neither did he accept Śankara's (8th c.) Advaita Vedāntic interpretation according to which there is no difference between the universal substance (*brahman*) and the individual self (*jīva*) or the claim that the manifested world is an illusion. Instead he compiled the Brahmo Dharma, which came to be accepted as the book of the Brahmos. This book is actually a compilation of the verses from various *Upaniṣads*. In late 19th century, it was a matter of pride for the Brahmos to possess a copy of this book. Being a son of Bhagaban Chandra, it is only to be expected that Jagadish Chandra knew a little about the contents of this book. The book is silent about any contention neither did I find any mention of *Sāṃkhyakārikā* or anything like intellect distinct from consciousness. Therefore, it is unlikely that he was concerned with intelligence as it is defined in Sāṃkhya system.

We should also take note of one of his Bengali articles which he wrote in 1895²⁰ and later collected in a volume *Avyaktya*. Interestingly, he began with a statement that the world of experience is composed of the five elements, exactly as it is claimed in Sāṃkhya. But in the next sentence he asserts that this may be understood metaphorically. Actually there are only three elements: *padārtha* (matter), *śakti* (energy) and *vyoman* (space). Later in the same article he reaches the conclusion that there are only two causes of this universe, namely space (*ākāśa*) and its vibration (*spanda*) (BOSE 1958: 11–12). The next claim is even more interesting:

Matter is only vibration of the *ākāśa*. At certain point of time, the unknown *mahāśakti* created infinite number of vibrations and which resulted in creation of the atoms. [...] The vibration of this *ākāśa* is floating in the same *ākāśa* as this universe (BOSE 1958: 12 [translation B.M.]).

Does the term *ākāśa* as used here have the same meaning as *vyoman* in this doctrine? I think to take this for granted would be a mistake as Jagadish Chandra categorically said in the beginning. *Brahmasūtra* actually identifies *ākāśa* with *brahman* itself (BS 1.1.22; 1.3.41).²¹ Some commentators also read with the same attitude the following verse from *Chāndogya Upaniṣad* (8.14.1):

²⁰ Seal's book was published in 1915 but it is not known that Jagadish Chandra had much contact with Seal.

²¹ *Brahmasūtra* 1.1.22: *ākāśastallīṅgāt*; and also 1.3.41: *ākāśoharthāntaratvādivyapadeśāt*.

He, who is known as *ākāśa*, creates *prāṇa* (the vital energy), *nāma* (name) and *rūpa* (form or shape). That, in which reside *nāma* and *rūpa*, is *brahman*, the immortal (*amṛta*), the self (*ātman*).

Further *Brahmasūtra* infers that *prāṇa* is *brahman* from the fact that the whole universe is vibrating (BS 1.3.39).²² This proves beyond reasonable doubt that Jagadish Chandra was not talking about Sāṃkhya. His intention was to incorporate the metaphysical position of Vedānta to the modern world view.

The next point I want to discuss is the Brahma component and the basic empirical attitude. As I said before the Brahma Dharma was compiled by Devendranath. Three verses were regularly chanted by the Brahmos. Two of them are really defining characteristics of *brahman*: *satyam jñānam anantam brahman* and *sat, cit, ānanda*. While the first characterizes *brahman* as pure existence, ultimate Truth, and omniscience, the other directly characterizes *brahman* as consciousness. The same *brahman* is also identified with space (*ākāśa*) from whose vibration (*spanda*) the universe is created. Therefore, if everything is generated from *brahman* which is all-knowing (*jñāna-svarūpa*) and has the character of consciousness (*cit*), then these two together say that the conscious being pervades everything and that it produces the universe.

Bose accepted physicalism while explaining the possibility of uniform laws as effect of the power of the eternal. The Brahma form was an oft-quoted verse from *Śvetāśvatara Upaniṣad*.²³ Rabindranath Tagore (1861–1941) translates it as: “I bow to God over and over again who is in fire and in water, who permeates the whole world, who is in the annual crops as well as in the perennial trees” (DAS 1996: 287). To be a physicalist about the world does not necessarily entail being an empiricist. As far as I can see this is a consistent metaphysics by itself and also consistent with Vedānta.

Coming back to the issue of mysticism, I want to emphasize that it was quite a popular view among the Bengali intellectuals during the late 19th century and early twentieth century. Such a general mystical attitude is expressed by Rabindranath Tagore in 1903 as:

For me, Religion is something very concrete. [...] I feel the existence of God in everything. The dust is not only dust, a tree is not only a tree, a flower is not only a flower; there seems to be a deeper significance in all these. I feel his touch in space, in water, everywhere. At times the whole world talks to me (ROY 2007: 51 [translation B.M.]).

²² *Brahmasūtra* 1.3.39: *kampanāt*.

²³ *Śvetāśvatara Upaniṣad* 2.17: *Yo devo'gnau yo'psu, yo viśvam bhuvanam āviveśa, ya ośadhīṣu yo vanaspatiṣu tasmai devāya namo namaḥ*.

Therefore, I suggest, the attitude involved was not that of supra sense perceptual or subsense perpetual. Having said all these it would be fair to say that there were many attempts to synthesize Sāṃkhya and Vedānta and reach one unified system. In such a system there would be only one *puruṣa*, as Vedānta claims, but the individual *puruṣa* of Sāṃkhya feature as reflections (*pratibimba*). About the causal mechanism that created the universe Sāṃkhya metaphysics is almost entirely accepted. Within the Brahmo fold, Dwijendranath Tagore (1849–1926), the elder brother of Rabindranath and the reigning philosopher of the Brahmo movement started work with such a project in 1886. The result was philosophy which he called Dvaita-Advaita *vāda* (MUKHERJEE 2012). The view retains the distinction between *brahman* and the individual self (*jīva*) as desired by Devendranath.

The main intention of the present author is to address the issue of what and how far experiments can be important stepping-stone of a scientific revolution, if at all. With this intention I study a historically given situation of Jagadish Chandra Bose. It is commonly agreed that he did extraordinary work in the field of electromagnetism and propagation of electromagnetic wave. For the first time his experimental set up actually used semiconductor. However, he then shifted to study of plants and tried to demonstrate that plants are ‘living’ organisms. This part of his scientific activity is highly controversial. There are at least two interpretations of his later work. The first, popular among majority of Indians, is that he performed something great which the West failed to understand. According to the other interpretation Bose’s departure from physics unmade him as a scientist or made him a ‘marginal figure’. In this paper I briefly discussed his experiments and resistance from his famous contemporaries to accept his interpretation exploring how the debate actually got built up. Evaluation of a scientist’s work needs to be done in the background of reigning philosophy and culture. In Jagadish Chandra’s case, commentators choose Western paradigm. The western paradigm was firmly entrenched in the ideology of mind–matter dualism on the one hand and living (vital) and non-living on the other, along with the undefended premise that only the living are endowed with consciousness. So they found, that his interest in the plant life as well as his attempt to extend his work from the domain of matter (electromagnetism) to the domain of living (animal and plants) is at best contentious. It has been argued that such conclusions and/or skepticism were actually the product of prevalent western scientific paradigm with its basic belief in mind/matter divide and ascribing mind only

to the animals.²⁴ We need not subscribe to that. In fact, Virginia A. Shepherd, following Anthony J. Trewavas, famous for his recent research in the fields of plant physiology and molecular biology, argues just that. She points out:

How biased is the usual concept of intelligence, where behaviour is usually associated with the rapid movements made by animals. Applying the definition of intelligence from D. Stenhouse (adaptively variable behaviour during the lifetime of an individual) Trewavas gives numerous examples of intelligent behaviour involving growth and the development in plants. These include roots navigating the maze of the soil. [...] Plants can learn through trial and error, which requires have goals, assessing and modifying growth behaviour. A kind of memory enables plants to anticipate difficulties, and to grow around them. Plant behaviour is intentional (SHEPHERD 2005: 616).

CONCLUDING REMARKS

Jagadish Chandra Bose's attitude was firmly rooted in Indian paradigm and its philosophy of reformed Vedānta. He believed that reality is *jñāna-svarūpa*, that is of the nature of cognition (MUKHERJEE 2012). The infinite *puruṣa* is like Greek Logos — active and pervading everything. Therefore, consciousness should be perceived as residing everywhere and so in plants as well as in the inanimate matter. Consciousness research must proceed through the properties of the mental. But the current paradigm of psychology, which Jagadish Chandra accepted, was working in terms of stimulus and response and propagation within the system as electrical signal. As a matter of fact the 'hard core' of his later research programme included this thesis as hypothesis. Therefore, the research programme, inspired by his philosophy, was looking to produce evidence in favour of this thesis. The confusion was created by his use of word 'living', while he was actually working on consciousness, as it is clear from the title of his major work of 1926, *The Nervous Mechanism of Plants*, dedicated to Rabindranath Tagore. The progression was in the following order. Consciousness is everywhere — including plants — and it should implement itself in psychological processes. Psychological processes need to be studied in terms of stimulus and response by current paradigm. Most objective (measurable) stimulus was electrical in nature. The effect also travels physiologically and the most important fact established in plant-response

²⁴ DASGUPTA (1999: 124) briefly touches this interesting point but did not spend more than two sentences!

was nervous character of the impulse transmitted. By that time the transmission of nervous excitation through synaptic junctions was already proposed. Nevertheless, there were no nerves or synapses in the plants. So a theory was sought to be developed in terms of transmission of excitations in the fluid of phloem and xylem tissues, that is conduction of sensory impulse by the external and motor by the internal phloem.²⁵

The mechanistic philosophy was prevalent in France and Germany under influence of Helmholtz, Du Bois-Reymond and others, subscribing to reductionist-mechanistic explanation in science eliminating God as well as vitalism from its domain. Jagadish Chandra Bose subscribed to reductionist-mechanical view of explanation but also accepted *brahman* as the all-pervasive and participating consciousness. Still, his was not monism — for world was also real existent and not illusion — behaving according to the ‘law of nature’.

I conclude with an observation that his research programme was progressive both theoretically and empirically and through progressive problem shift at least twice — proposing alternative to vitalism in terms of molecular theory and then bringing in a theory of non-vitalist concept of consciousness. I believe, even today some fresh research programmes can be generated from his work as far as his concern for consciousness is appreciated and shared (FROMM and LAUTNER 2007).

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²⁵ For elaborate discussion of this issue see SHEPHERD (2005: 614–617), especially the section entitled “Bose’s work in Today’s Context”. See also sections 3.5 and 3.6 of SENGUPTA, ENGINEER and SHEPHERD 2009: 125–151.

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