HU3101: History and Philosophy of Science

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Question 1. Jagadish Chandra Bose left microwave research and opted for plant physiology. Do you think nationalistic sentiments coupled with revivalist Hindu philosophy had a role to play in this change over?

Answer. The following is an extract from Jagadish Chandra Bose's discourse at the Royal Institution, May 1901. We highlight its significance as Bose's first real foray into the world of physiology. After demonstrating each of his results by a series of experiments, he concludes —

> I have shown you this evening autographic records of the history of stress and strain in the living and non-living. How similar are the writings! So similar indeed that you cannot tell one apart from the other ...
>
> Amongst such phenomena, how can we draw a line of demarcation, and say, here the physical ends, and the physiological begins? Such absolute barriers do not exist.
>
> Do not these records tell us of some property of matter common and persistent? Do they not show us that the responsive processes, seen in life, have been foreshadowed in non-life? – that the physiological is related to the physicochemical? – that there is no abrupt break, but a uniform and continuous march of law?
>
> ...
>
> It was when I came upon the mute witness of these self-made records, and perceived in them one phase of a pervading unity that bears within it all things the mote that quivers in ripples of light, the teeming life upon our earth, and the radiant suns that shine above us it was then that I understood for the first time a little of that message proclaimed by my ancestors on the banks of the Ganges thirty centuries ago —
>
> 'They who see but one, in all the changing manifoldness of the universe, unto them belongs Eternal Truth, unto none else, unto none else!'

In order to explain Bose's seemingly sudden change in scientific interest, we must first look at earlier events. Bose was perhaps the first true experimental scientist of India, given full recognition by his peers. This was extremely impressive, given the prejudices of the 'Western world' regarding the capacity of an Indian to carry out exact science.

> Intellectual acuteness in Metaphysics and Languages had always been frankly acknowledged, but it was assumed that India had no aptitude for the exact methods of science. For science, therefore, India must look to the West for her teachers.

Bose had indeed completed his studies abroad, and even worked under the illustrious Lord Rayleigh; soon after returning to the Presidency College, University of Calcutta however, he began pursuing his original work. Seemingly unhindered by a lack of proper laboratory equipment, he designed and built his own. His experimental work pioneered the field of 'electrical waves', revolutionising radio and microwave optics[1]. His work brought him international acclaim in the scientific circles; there is an anecdote in which after Bose delivered a discourse on

[1] Bose showed that these electrical waves obeyed all those properties of a beam of ordinary light: reflection, refraction, total reflection, polarisation, etc. Another notable aspect of his research was that he was the first to use semiconductor junctions to detect these waves.

his paper, Lord Kelvin himself "not only broke into the warmest praise, but limped upstairs into the ladies' gallery and shook Mrs. Bose by both hands, with glowing congratulations on her husband's brilliant work."

During his work on electrical wave receivers, Bose observed a curious anomaly; the receiver (essentially metallic springs) gradually lost its sensitivity over time. This was analogous to 'fatigue'. Indeed, allowing the receiver to rest for some time restored its sensitivity. However, there was an even more perplexing discovery: letting the receiver rest for too long (several days) would render it insensitive again! The only was to restore its sensitivity was by applying an electric shock. This required entirely an entirely new theory to explain. Bose began testing the electrical sensitivities of metals, non-metals, and metalloids in various combinations to build up some sort of classification. This 'electric touch' was found to be periodic (with respect to atomic weight). Some metals like potassium stood out, acting precisely in the opposite way of others like iron. Bose deduced that this phenomenon was governed by the chemical nature of the substance, and arose from molecular changes[2]. This culminates in the paper *On the Strain Theory of Photographic Action*, tying up many apparently unrelated phenomena. The action of electrical waves on his receivers was exactly that of light on a photographic plate. In his investigations, Bose also developed his 'artificial retina', showing that the range of human vision is based on precisely this electrical sensitivity of the retina, like in a photographic plate.

In the above experiments, we note a certain parallelism between the metallic and the living (the concept of fatigue for instance) in the context of electrical response. Soon, Bose began investigating living tissue directly, and the first step was the *Response of Inorganic and Living Matter*. Here, he compares the reaction curve of muscle tissue in response to an electrical stimulus, with that of ferric oxide. Both exhibit the same phenomena of fatigue, rest, recovery, and reactivation. He also drew an analogy with poisoning of muscles with the introduction of impurities in metal like potassium.

> In all the phenomena above described continuity is not broken. It is difficult to draw a line and say 'here the physical phenomenon ends and the physiological begins' or 'that is a phenomenon of dead matter, and this is a vital phenomenon peculiar to the living.' These lines of demarcation would be quite arbitrary.

Bose's work seemed to draw appreciation from physicists, but not from physiologists. Undeterred he continued his research and the idea came to him that in order to establish this 'continuity' between the inorganic and the organic, he ought to be looking at plant matter. Bose gathered leaves from his garden, vegetables from the greengrocers, and repeated his experiments on them. Now, he observed similar electrical responses in metal, plant, and animal. The responses in the living tissues would disappear on applying poisons, and it could be revived up to a threshold (beyond which the tissue dies). Bose now did something strange: he introduced these poisons to various metals, and tested their responses. Lo and behold, their behaviour was extremely similar to that of living tissue!

> So striking was this correspondence, that one day when Bose was beginning to show his records to Sir Michael Foster, the veteran physiologist of Cambridge, the latter picked one up and said,
>
> "Come now, Bose, what is the novelty in this curve? We have known it for at least the last half-century."
>
> "What do you think it is?" said Bose.
>
> "Why, a curve of muscle response, of course."
>
> "Pardon me; it is the response of metallic tin."
>
> "What!" said Foster, jumping up – "Tin! Did you say tin?"

[2]Today we might recognize these phenomena as belonging to semiconductor electronics.

> On explanation, his wonder knew no bounds; and he hurried Bose to make a communication to the Royal Society, which he (then Secretary) offered to communicate.

Bose presented these very findings in his Friday Evening Discourse at the Royal Institution, May 1901; we have quoted an extract from this in the very beginning.

The above events have been presented to demonstrate that Bose's interest and research into plant physiology seem to arise naturally from his work on electric waves in physics. Besides, there doesn't appear to be any need to justify one's research subjects since scientific curiosity ought to suffice; what is most important (but out of the scope of this topic) is that the results should stand for themselves. Still, this picture would be incomplete without accounting for Bose's personal philosophy, the driving force behind his work.

The reference to the Vedas in Bose's speech represents his affinity towards ancient Indian spiritual tradition. Indeed, many thinkers of the time, say Swami Vivekananda and Rabindranath Tagore to name the most influential, encouraged this revivalism of Hindu philosophy. This was meant to support nationalistic sentiment during this period of India's freedom struggle. Bose himself came to subscribe to the Advaita Vedanta philosophy, which described an all-pervading consciousness, the Brahman. This explains his (increasingly frequent with time) allusions to the 'unity of life and the non-living' or 'unity in apparent diversity' in the various phenomena he observed. In the words of V.A. Shepard,

> Bose's insistence on the unity of the living and non-living arose from a deeply held philosophical position, Vedanta in inspiration, a monism that regarded the world as a single unified entity, where mind and matter were aspects of the same thing.

Thus as Bose's scientific claims began to dip into metaphysics over the years, this question of philosophical bias or loss in objectivity arose. The idea of consciousness is perhaps the heaviest topic in philosophy, but here too Bose made bold claims.

> ... even a speck of protoplasm has a faculty of choice.

> ... all matter was one, how unified all life was ... there was no such thing as brute matter, but that spirit suffused matter in which it was enshrined.

> Consciousness and sensation are thus regarded as inseparably associated with the nervous system and nervous reaction. If this be so, then my recent scientific results prove beyond a shadow of doubt that many plants possess not merely a rudimentary, but a highly elaborated nervous system.

There is another sense in which Bose searched for unity in his work — the unity of scientific disciplines. He emphasized that science is in search of knowledge which is ultimately whole and entire, requiring an interdisciplinary approach to fully comprehend. Bose said

> ... in the West, the prevailing tendency at the moment is, after a period of synthesis, to return upon the excessive sub-division of learning. The result of this specialisation is rather to accentuate the distinctiveness of the various sciences, so that for a while the great unity of all tends perhaps to be obscured.

Thus, the general sentiment was that the 'Eastern' approach of scientists like Bose was better suited to the development of science. In this pursuit, Bose spoke

> There will soon rise a Temple of Learning where the teacher cut off from worldly distractions would go on with his ceaseless pursuit after truth, and dying, hand on his work to his disciples. Nothing would seem laborious in his inquiry; never is he to

> lose sight of his quest, never is he to let it go obscured by any terrestrial temptation. For he is the Sanyasin spirit, and India is the only country where so far from there being a conflict between science and religion, knowledge is regarded as religion itself.

These efforts were realized with the establishment of the Bose Institute, Kolkata in 1917.

Bose's work and ideas were greatly admired by the aforementioned scholars, Vivekananda and Tagore, who sent addresses of praise soon after Bose revealed his first results (on the unity of metal and animal tissue). Sister Nivedita, a disciple of Vivekananda, worked closely with Bose editing his book *Responses in the Living and the Non-Living*. Vivekananda must surely have had some influence on Bose, with his declaration that

> It seems to us, and to all who care to know, that the conclusions of modern science are the very conclusions the Vedanta reached ages ago; only in modern science they are written in the language of matter.

In conclusion, we can identify three factors behind Bose's investigations into plant physiology. First, his research in physics combined with natural curiosity lead him along this line of enquiry. Second, his struggles with Western prejudice in the field of science motivated him to push back and uphold Eastern ideas such as unity among the science (hence his complete lack of hesitation towards his interdisciplinary research). Third, support from revivalists of Vedanta philosophy inspired him to continue his work in plant physiology with renewed confidence.