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J C Bose: The Little Known Story of How India's First Biophysicist Proved Plants Have Life

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ABSTRACT

A famous experiment conducted by Bose at the Royal Society of London in 1901 demonstrated that just like humans, plants too have feelings. He placed a plant in a vessel containing bromide solution, which is poisonous. Using his instrument, he showed on a screen how the plant responded to the poison. "What happens if you take a rich magistrate's son and make him learn in a village school sitting besides the sons of servants and fishermen? He'll hear tales of birds and animals that make him curious about Nature. And that makes him one of India's first scientists." – Jagdish Chandra Bose

In 1914, a journalist for *The Nation* wrote about an experiment he witnessed in a small private laboratory in Maida Vale in London:

"An unfortunate creature is strapped to the table of an unlicensed vivisector. When the subject is pinched with a pair of forceps, it winces. It is so strapped that its electric shudder of pain pulls the long arm of a very delicate lever that actuates a tiny mirror. This casts a beam of light on the frieze at the other end of the room, and thus enormously exaggerates the tremor of the creature. A pinch near the right-hand tube sends the beam 7 or 8 feet to the right, and a stab near the other wire sends it as far to the left.

"Thus," the journalist concluded, "can science reveal the feelings of even so stolid a vegetable as the carrot."

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The carrot vivisector mentioned above was Sir Jagdish Chandra Bose, a scientist widely acknowledges as the father of modern Indian science. However to call Bose just a scientist would, however, be akin to calling Leonardo Da Vinci a mere painter. A man whose genius transcended boundaries, Bose was a quintessential polymath: a physicist, a biologist, a botanist, an archaeologist, an author, and a connoisseur of fine arts. He was the first person from the Indian subcontinent to receive a US patent and is considered one of the fathers of radio science, alongside such notables as Tesla, Marconi, and Popov. He was elected Fellow of the Royal Society in 1920, becoming the first Indian to be honoured by the Royal Society in the field of science.

Bose conducted most of his studies in plant research on *Mimosa pudica* and *Desmodium gyrans* plants. His major contribution in the field of biophysics was the demonstration of the electrical nature of the conduction of various stimuli (e.g., wounds, chemical agents) in plants, which were earlier thought to be of a chemical nature. In order to understand the heliotropic movements of plants (the movement of a plant towards a light source), Bose invented a torsional recorder. He found that light applied to one side of the sunflower caused turgor to increase on the opposite side. These claims were later proven experimentally. He was also the first to study the action of microwaves in plant tissues and corresponding changes in the cell membrane potential. He researched the mechanism of the seasonal effect on plants, the effect of chemical inhibitors on plant stimuli and the effect of temperature.

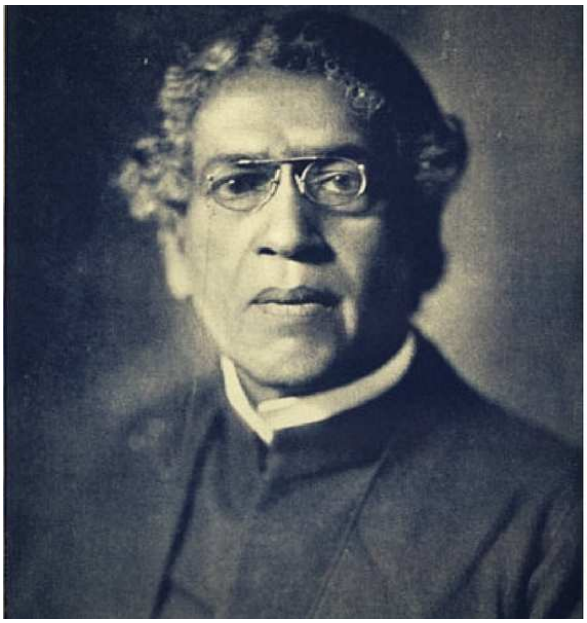
KEYWORDS: Jagdish Chandra Bose, nation, royal society, scientist, science, field, nature, plants

INTRODUCTION

Having graduated with a BA (Physical Sciences) from Kolkata University, Bose was teaching physics at the Presidency College while simultaneously pursuing his own research in electricity and

electromagnetic waves. In November 1894, for the first time in the world, Bose gave a demonstration of microwaves at the Kolkata Town Hall, where he ignited gunpowder and rang a bell at a distance by using microwaves.

He also developed an improved 'coherer' (a device that detects radio waves) – the first to use a semiconductor junction – but was unwilling to patent it. Bose believed that science should be for the benefit of humankind and one should not make money from it. However, under pressure from his friends, he finally submitted a patent application to the US patent office and on March 29, 1904, he became the first Indian to get a US patent for his "detector of electrical disturbances". Interestingly, Bose's coherer was the one used by Guglielmo Marconi to build an operational two-way radio.[1]



Between his experiments, Bose also found time to write science fiction in Bengali. His famous story *Polatok Tufan* (Absconding Storm) describes how a cyclone was stopped using a bottle of hair oil! It explained how oil changes the surface tension and holds water. His book *Niruddesher Kahini* (Story of the Untraceable) was the first major Bengali science fiction novel. Perhaps it was his work in radio waves that made Bose believe physics could go far beyond what was apparent to the naked eye. He had always been fascinated by the plant reactions seen in sensitive plants like the mimosa, which, when irritated, will react with the sudden shedding or shrinking of its leaves. So, curious about the secret world of plants, Bose switched his attention to investigating how plants respond to stimuli.

To do this, he invented the crescograph, an early oscillating recorder using clockwork gears and a smoked glass plate to measure the growth and movements of plants in increments as small as 1/100,000 of an inch. The plate caught the reflection of the plant and it was marked according to the movement of the plant. His first experiments were conducted with a leaf, a carrot and a turnip plucked from his garden.[2]

Bose performed a comparative study of the fatigue response of various metals and organic tissue in plants. He subjected metals to a combination of mechanical, thermal, chemical, and electrical stimuli and noted the similarities between metals and cells. Bose's experiments demonstrated a cyclical fatigue response in both stimulated cells and metals, as well as a distinctive cyclical fatigue and recovery response across multiple types of stimuli in both living cells and metals.

Bose documented a characteristic electrical response curve of plant cells to electrical stimulus, as well as the decrease and eventual absence of this response in plants treated with anaesthetics or poison. The response was also absent in zinc treated with oxalic acid. He noted a similarity in reduction of elasticity between cooled metal wires and organic cells, as well as an impact on the recovery cycle period of the metal

DISCUSSION

Bose strongly believed that plants had a sensitive nervous system, not unlike that of animals, and that their responses to external stimuli could be measured and recorded. His belief was strengthened by the results of his experiments. For instance, in one of his experiments, the plant was dipped in bromide (a poison). The pulse beat of the plant, shown as a light spot on the smoked plate, became unsteady once the plant started taking in the poison, proving that plants have life.[3]

Encouraged by the results of this experiment, Bose began studying how plants behave differently under different environmental factors such as temperature, chemicals, electricity, gases and humidity. The more responses he got from his plants, the more detailed his efforts became. Bose was astounded to discover that an electric death spasm occurs in plants when they die, and that the actual moment of death in a plant could be accurately recorded. As he later wrote:

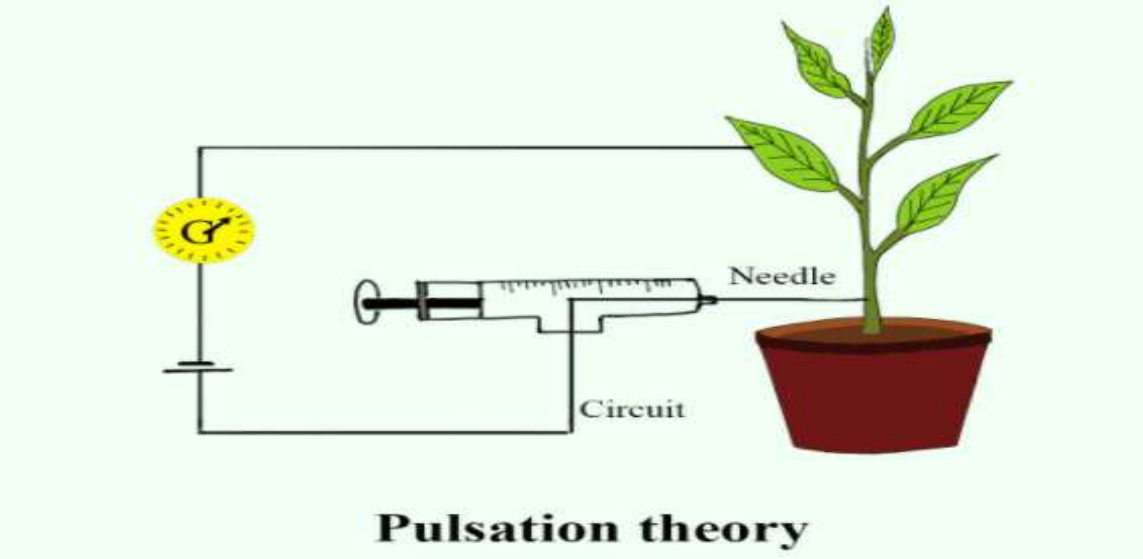
"All around us, the plants are communicating. We just don't notice it."

Determined to reveal the wonders of plant perception to the world, Bose described his experiments and their results in his 1902 paper,"Responses in the Living and Non-Living". He wrote how plants grew more quickly when exposed to nice music and gentle whispers, and poorly when exposed to harsh music and loud speech. He even mentioned how plants became depressed when exposed to polluted air and darkening skies. In short, his work showed that plants could feel pleasure and they could feel pain.

Though Bose's research had its usual share of naysayers, his invention of the crescograph received widespread acclaim, particularly from the Path Congress of Science in 1900. The publication of his paper by the Royal Society created greater interest and numerous invitations were extended to him. During his fourth scientific mission to Britain in 1914, Bose set up his private laboratory at Maida Vale which was visited by distinguished men from all walks of life.

Scientists from the Royal and Linnean societies came to see Bose's experiments with plant perception. In a famous incident, the ever-curious playwright George Bernard Shaw was seized with horror when subjected to the sight of a violently convulsing piece of cabbage gasping in a pot of boiling water. While Bose's work with plants was highly esteemed by some scientists, the disdain of the Western scientific circles for an Indian scientist's work can be seen in the way British journalists described Bose's work with plants in terms similar to Frankenstein-like experiments (like the account at the beginning of the story).

Sir J.C. Bose (1923) proposed a vital theory for the ascent of sap. He experimentally showed that the living cells of the innermost layer of the cortex were in a state of pulsatory motion, i.e., alternate expansion and contraction. This pulsation, according to him, caused the pumping of water from cell to cell in an upward direction. Of course, this idea is an elaboration of Godlewski's proposal of water translocation. He experimented with a self-made apparatus consisting of an electric probe, a galvanometer, an electric dry cell, and a thin copper wire. He took a potted plant to which one point, of the galvanometer was connected, the other point of which was connected with a probe[4]



The probe was inserted into the stem slowly. When it reached the innermost layer of the cortex the galvanometer showed momentary deflection for a longer period. No such deflection was observed on either side of this particular layer. From this observation Bose concluded that the cells of this layer were in a state of pulsation.

On expansion the cells absorbed water from the lower cells and on contraction water was pumped into the next higher cells. Bose also observed that for one pulsation (i.e., contraction and expansion) it took 14 seconds to several minutes. This pulsation was called by J.C. Bose as the „heart-beating of plants". Molisch showed that the movement of pulsation could be greatly increased by administration of heart-stimulating drugs and this supported the view of J.C. Bose. Many workers like Dixon, Shull, MacDougal, etc., have pointed out that there

is no relationship between such pulsatory movement and the rate of water translocation. It has been estimated that the sap must flow through 230 to 400 pulsatory cells per second to account for the normal rate of ascent of sap. But it was already estimated by Bose that for one pulsation it took a minimum of 14 seconds.[5]

RESULTS

However, his path-breaking experiments couldn't be ignored for long. In 1920, he was elected the Fellow of the Royal Society for his amazing contributions and achievements. Prior to his death in 1937, he also set up the Bose Research Institute at Calcutta (now Kolkata). He was greatly helped in this endeavour by his close friend Rabindranath Tagore, who contributed financially and also backed him in his efforts.

An avid supporter of Bose's researches and discoveries, Tagore had always found an essence of Indian scientific spirit, a reflection of Indian national culture, in Bose's work. In his poem for Bose, published in *Kalpana*, Tagore, addressing the scientist, was effusive in his praise:

"From the Temple of Science in the West,

far across the Indus, oh, my friend,

you have brought the garland of victory,

decorated the humbled head of the poor Mother …

Today, the mother has sent blessings in words of tears,

of this unknown poet.

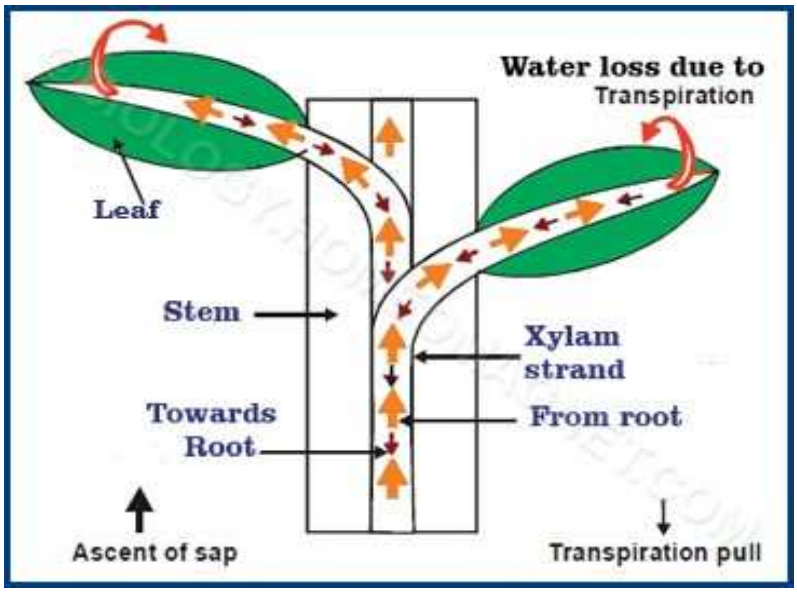
Amidst the great Scholars of the West, brother,

these words will reach only your ears."

As Tagore's words portray, for a country in the clutches of colonial rule, J C Bose was not just a scientist, he was a symbol of national pride. Bose too had always acknowledged his responsibilities as a scientist to revive the national pride of his country. In a letter to Tagore, he wrote:

"I am alive with the life force of the mother Earth, I have prospered with the help of the love of my countrymen. For ages, the sacrificial fire of India's enlightenment has been kept burning, millions of Indians are protecting it with their lives, a small spark of which has reached this country through me."

According to the vital force theory, the conduction of water up the xylem vessel is a result of vital action of the living cells in the xylem tissue. These living cells are involved in ascent of sap. Relay pump theory and Pulsation theory support the active theory of ascent of sap.[6]



Emil Godlewski (senior) (1884) proposed Relay pump or Clamberinh force theory (through xylem parenchyma) and Jagadish Chandra Bose(1923) proposed pulsation theory (due to pulsatory activities of innermost cortical cells just outside endodermis).

Jagadish Chandra Bose suggested a mechanism for the ascent of sap in 1927. His theory can be explained with the help of galvanometer of electric probes. He found electrical 'pulsations' or oscillations in electric potentials, and came to believe these were coupled

with rhythmic movements in the telegraph plant *Codariocalyx motorius* (then *Desmodium*). On the basis of this Bose theorized that regular wave-like 'pulsations' in cell electric potential and turgor pressure were an endogenous form of cell signaling. According to him the living cells in the inner lining of the xylem tissue pump water by contractive and expulsive movements similar to the animal heart circulating blood.

This mechanism has not been well supported, and in spite of some ongoing debate, the evidence overwhelmingly supports the cohesion-tension theory for the ascent of sap.

CONCLUSION

Today, the legendary scientist may no longer be with us, but his legacy shall endure forever. Over the decades, several scientists have given further weight to Bose's theories that plants may not be as different from animals as previously thought. It is only fitting that the team of scientists that hopes to complete and carry his work forward should choose to run their research at Kolkata's Bose Research Institute and call it, although informally, the JC Bose Legacy Project. At the Institute's Madhyamgram campus, work is on to decode the molecular mystery of plants (in terms of protein and genes) that show different responses to external stimuli such as touch, light or noise.[6]

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