# THE COLONIAL "MODEL" AND THE EMERGENCE OF NATIONAL SCIENCE IN INDIA: 1876-1920

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Basalla's three stages "model" for the spread of modern, Western science has in recent years come under serious criticism[1]. The inadequacy of this diffusionist "model" to reflect sufficiently upon the socio-cultural and politico-economic relations of Western science with recipient cultures continues to draw the attention of scholars. In doing so, the analysis of individual scientists, scientific institutions and the practice of science is increasingly brought within the ambit of sociology of knowledge in a historical mould[2]. Such an approach enables us to penetrate beneath the contours of the colonial science "model" of Basalla to enquire how recipient cultures perceive and respond to Western science and how the experience of one society varies across other cultural contexts. Recognizing that a justification for such an exercise requires a larger work than the present paper, an attempt is made here to focus on the scientific enterprise in India during 1876-1920. It focuses largely on the period prominently categorized as colonial science by Basalla. Further, this paper attempts to examine Basalla's inescapable conclusion that *"colonial science contains in an embryonic form, some of the essential features of the next stage"* through the definition of colonial scientist.

## Who is a "Colonial Scientist"

Basalla's "model" has been critically examined for its conceptual clarity by a number of scholars. One feature of the "model" considered here as fundamental to the understanding of independent scientific tradition is the definition of a colonial scientist. Basalla, and for that matter the writings on colonial science, make no distinction between native and transplanted scientists or settler scientists. In the Indian context, the latter category calls for a further distinction between committed missionaries, who participated in the promotion of modern science, and government scientists, who merely executed the policies coming from above. Such a distinction, which in fact is empirically valid in the Indian case, is indeed an important basis upon which to understand the dynamics of colonial science and therefore its continuity and change.



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Without such distinctions the understanding of phase transition becomes problematic, particularly when we compare the emergence of national scientific communities across cultural contexts. Inkster[3] who draws attention to the spread of modern science to Japan and Australia, meant for the former *"the penetration of indigenous science and culture by Western science, culture and technique"* and for the latter, *"the spread of science in the Western scientific community"*. In contrast to the settler societies such as Australia or Canada, a closer examination of the composition of scientists in late 19th century India shows broadly three categories of scientists.

First, the practice of research activity in a large measure was limited in about a dozen survey research organizations under the control of colonial administration. The image of science in the periphery, categorized by historians as colonial or "low science", identified with fact gathering was a division of labour[4]. This image of science in fact was kept intact by the colonial administration by blocking the advancement of scientific research. These features could not have been possible without institutions and persons who were basically the **"gate keepers"** of colonial science. Native Indian Scientists were highly discriminated against in the colonial scientific enterprises[5]. In 1920, P. C. Ray, father of the Indian School of Chemistry, could count only 18 Indians out of 213 scientific personnel in eleven colonial scientific enterprises, including the Indian Educational Service[6]. H. B. Medlicott, Head of Geological Survey, held that Indians were incapable of any original work in natural science. Medlicott[7] wanted to wait till the *"scientific chord among the natives"* was touched and added that *"if indeed it exists as yet in this variety of human race so let us exercise a little discretion with our weaker brethren, and not expect them to run before they can walk"*. Supercession of P. N. Bose by a junior scientist, T. Holland, for the position of Director, Geological Survey of India, and the negative attitude of Alfred Croft, Director of Public Instruction, Bengal, towards J. C. Bose and P. C. Ray - are a representative sample of the gate keepers of colonial science. "Gate keepers" operated on several fronts including education, industry, finance and science departments.

In the second category, both within and outside the colonial administration there were professionals who did their best in the given circumstances. These professionals came to India either through government channels or commerce. They were **"scientific soldiers"** both of Indian and European origin for whom the work ethic was of paramount importance and who would not normally dabble in the "gate keeping"

business. William Brook O'Shaughnessy, who was instrumental in laying about 12,000 miles of telegraphy between 1857 and 1860 (period noted for the first war of Indian independence) is a good example of this category[8]. The bulk of the scientific personnel in this category were of European origin. Even though these scientists spent long periods of time in India they were psychologically tuned to their mother country and lived in a world of isolation among native Indians. When these European scientists attained the age limit, they returned to their country, taking in their baggage a vast treasure of experience which was simply lost to India for ever. William Pole (1814-1900), who taught engineering at the Elphinstone College, Bombay, helped in the "Survey of Great Indian Railway". On his return to England he was employed in railway engineering and consulted by de Lesseps on the proposal to dig a canal through Suez. Pole went on to become consulting engineer to the Japanese Government and hold a chair of engineering at University College, London. Colonel Alexander Strange (1818-76) returning to England from the Trignometrical Survey of India in 1861, established a large department on scientific instruments inspection. Strange was elected as a F.R.S. in 1864. *Nature* in March 1876 observed that *"to him belongs the credit of appointing Royal Commission in Scientific Institution and the Advancement of Science"*. Strange was also instrumental in the establishment of the Ministry of Science[9].

The third category of scientific personnel was native Indians in majority and a small number of Western settlers, mostly missionaries and Jesuits. David Hare, Father Eugene Lafont, William Carey and Marshman of Serampore missionaries, P. C. Ray, J. C. Bose, C. V. Raman, M. N. Saha, Ashutosh Mukherjee, M. L. Sircar, Visvesvaraya and many others may be included in the third category[10].

Basalla, and many other scholars, do not distinguish the roles performed by Meldicott, O'Shaughnesy and M. L. Sircar or P. C. Ray. They are lumped together to define a colonial scientist. In actual terms, the three categories of scientists had their respective constituencies of operation with their respective goals, purposes and network of relationship. What role did the third category of scientists play? What kind of institutions did they established? And what were their ideological and intellectual objectives?

These scientists were basically part of the emerging nationalism and were as much partners in the freedom movement as Gokhlae, Ranade, Joshi, Dutt and others. Even though most of the scientists did not directly participate in the political struggle, ideological und-

erpinnings to their scientific pursuits reflected a definite form of "struggle". Their struggle meant to accord an international status to science in India and thereby reassert their national scientific identity. J. C. Bose, India's eminent scientist held that[11] the *"highest expression in the life of a nation must be its intellectual eminence and its power of enriching the world by advancing the frontiers of knowledge"*. His mission, as he often said, was not to introduce science to India, but to revive Indian science. There were others such as P.C. Ray who declared[12], in the midst of his scientific career, that *"science can afford to wait, but Swaraj cannot"*. In concrete terms what this struggle sought was to transform the structures of colonial science in the national interest. More importantly, the struggle was directed to create alternative support structures towards the establishment of independent national science as pursued by J. C. Bose and others referred to earlier. What I mean by support structures are: institutions for the dissemination of scientific and technical knowledge; national views on science and technology; institutions and research programmes geared to the advancement of scientific knowledge; and the constitution of specialist or scientific communities. It is to these support structures, in which the third category of scientists was involved, that the rest of the paper will be devoted.

## Early Institutional Efforts

If the establishment of the Asiatic Society of Bengal in 1784 is considered as the landmark for the institutionalization of Western science in India, the inauguration of the Indian Association of Cultivation of Science (IACS) on 15 January, 1876, inaugurated the national science. The man behind this institution was Mahender Lal Sircar (1833-1904), an allopathic doctor by training but a strong advocate of homoeopathy. The uniqueness of this institution was the vision of its national objective in science and autonomy from government laid down as early as in 1875. Sircar[13] stated that

> "the object of the Association is to enable natives of India to cultivate science in all its departments with a view to its advancement by original research, and (as it will necessarily follow) with a view to its varied applications to the arts and comforts of life".

Despite a modest collection of Rs. 61,000 for the establishment of IACS, in 1875, Sircar[14] pleaded that *"we should endeavour to carry on the work with our own efforts, unaided by the government. I want it to be solely native and purely national"*. Sircar envisaged the combination of the character, scope and objectives of Royal Institution of London

and British Association for the Advancement of Science (BAAS) in the IACS. Seven sections were organized within few years after IACS establishment. These were general physics, chemistry, astronomy, systematic botany, systematic zoology, physiology and geology. Sircar, Lafont, Tara Prasanna Roy, Nilratan Sarkar, Chunnilal Bose, J. C. Bose, Ashutosh Mukherjee and P. N. Bose were some of the Indian scientists who delivered lectures at the IACS. Even though the efforts of these people went a long way to generate mass interest in science in Bengal, original investigations in science had to wait till C. V. Raman's association with the IACS in 1907.

Above all, the greatest contribution of IACS during this period (1876-1901) was its development of the idea of nationalism in the cultivation of science. A direct spin-off from the IACS was the emergence of at least four institutions to promote the cause of national technical education. Paramnath Bose, a member of IACS, established Indian Industrial Association in 1891. The Association arranged popular lectures on coal and fibres. Its members experimented with indigenous raw materials. The Association for the Advancement of Scientific and Industrial Education (AASIE) was founded in 1904 by Jogendranath Ghosh. This Association played an important role in sending Indian students abroad in the Swadeshi movement. Satishchandra Mukherjee, a leading educationist of Bengal, launched the Dawn Society, in 1902 to promote the idea of national education. The Society's magazine, *The Dawn,* provided an important platform for promoting applied science literature and popularization of science[15].

In 1904 and 1905 Lord Curzon's attempts to invoke government control over education followed by the Bengal partition brought the question of technical education into sharp focus. The Dawn Society became the National Council of Education (NCE) in 1906 to organize parallel structures of education[16] on *"national lines under national control"*. But crises struck the NCE. As a direct fallout of the splits in NCE over the question of higher technical education, two institutions were established. Tarak Nath Palit and Nilratan Sarkar launched the Society for the Promotion of Technical Education in 1906, which established the Bengal Technical Institute[17]. The other group of NCE, involving Satish Mukherjee, Goorudas Banerjee and Aurobindo Ghosh, established the Bengal National College and School in the same year to promote science along with literary courses in the universities[18]. The split of NCE lasted only four years and in 1910 both the rival camps merged. What survived out of this national movement in education was

the nucleus of the present day Jadavpur University and the establishment of the University College of Science, Calcutta University, which received rupees 2.4 million rupees from Taraknath Palit and Rash Behari Ghosh along with the assets of the Bengal Technical Institute in 1914[19]. As a part of the national education movement, P. K. Roy and M. L. Sircar were demanding separate science courses in physics, chemistry, botany and math at the Calcutta University in the 1890's. Through the efforts of Nitraian Sircar, J. C. Bose and M. L. Sircar, the Science Degree Commission was set up in 1898 and recommended it. Ashutosh Mukherjee, taking over as the Vice-Chancellor of Calcutta University in 1912, further boosted science by starting post graduate research and teaching at the Calcutta University. This development, in a way, weakened the NCE split. The colonial government opposed the department and refused to finance it for advanced training. It was at this stage that the donation of Palit and Ghosh made it possible the organization of advanced scientific research at the Calcutta University.

The efforts of the national education movement in the promotion of science education and research was, however, not confined to Bengal. Poona Sarvajenik Sabha's demand of 1882 to strengthen technical education was later taken up by the Indian National Congress after 1885[20]. About two decades before the idea of the Bengal Technical Institute, the princely states of Baroda and Travancore established technical institutes in the 1880s, of which Baroda's Kala Bhavan Technical Institute was the first and biggest institute established by the native Indian states[21]. The roots of the present day Faculty of Technology and Engineering, M. S. University, Baroda, goes back to Kala Bhavan. The phenomenal growth of Baroda as a manufacturing and industrial centre between 1890 and 1910 is related to the engineering schools of Kala Bhavan[22]. Taking the lead from Baroda, 57 "industrial and arts schools" or "technical institutes" were established by native Indians and missionaries in the states of Baroda, Mysore and Travancore[23].

Between 1880 and 1919 the native Indian and missionary contribution for the establishment of colleges and the initiation of science teaching in them was at par with British contribution. But for the universities established at Bombay (1857), Madras (1857), Calcutta (1857), Allahabad (1887), Banaras (1916), Mysore (1916), Patna (1917), Hyderabad (1918), non-governmental contribution was substantial. In the three presidency regions and Punjab, 45 affiliated colleges were established where 91 lecturers, mostly of Indian origin, were teaching graduate and post-graduate subjects in science and engineering[24].

To counter the literary bias of the British educational policy and to motivate Indian students to science and engineering, wealthy Indian elites instituted a number of scholarships and endowments. The famous Premchand Roychand offered 5 scholarships of Rs. 1400 per year from the endowment of Rs. 200,000 in 1879 to the Calcutta University[25]. The Rajabhai Tower and Library at Bombay University were established by the generous grant of Rs. 400,000 given by Roychand. Dadabhai Naroaji offered Rs. 50,000 and collected Rs. 175,000 for Canning fellowships at the Bombay University[26]. J. N. Tata's contribution of Rs. 3.0 million and the donation of Rs. 500,000 by Sheshadri Iyer, Dewan of Mysore Maharaja, along with the offer of 300 acres of land for the establishment of Indian Institute of Science had no parallel in 1910. The AASIE founded in 1904 by J. Ghosh was to raise Rs. 100,000 per year to provide scholarships for Indian youth going abroad for technical training. From 1905 to 1908 the Association offered 236 scholarships for study abroad[27]. In Bengal, private aid to education from 1878 exceeded the government aid by a considerable margin[28].

## Scientific Societies and Vernacular Literature in Science

Between the University Departments in Science and Engineering and specialized institutions such as IACS and Kala Bhavan, there were half a dozen societies whose main objective was to popularize science and create a base for modern science among Indians. Besides the Dawn Society (1904) and AASIE (1904), the Aligarh Scientific Society founded by Syed Ahmad in 1864, the Bihar Scientific Society, Muzaffarpur, founded by Syed Imdad Ali in 1868 and Punjab Science Institute, Lahore established in 1886, were the main societies[29]. The main thrust of these societies was activities to create a base for modern science in vernacular language. Translation of science books and launching of newspapers were therefore undertaken by these societies[30]. Aligarh Society translated 40 books dealing with electricity, algebra, arithmetic, agriculture and social sciences. It launched the *Aligarh Institute Gazette* to promote Western arts and science. Bihar Society started a fortnightly *Akhbar-ul-Akhyar* and established five schools in 1870s to popularize Western science[31]. The Punjab Society's lectures were organized by Lala Ruchi Ram Sahni.

The Anglicist-Orientalist debate of the 1830's in Bengal had a definite influence on the national education movement, particularly on science education. Ram Mohan Roy relegated classical languages to the pre-Baconian form in favour of English education in English medium[32]

*"to instruct the natives of India in mathematics, natural philosophy, chemistry, anatomy and other useful sciences"*. On the other hand, Debendranath Tagore established Tattwabodhini Patnashala (school) in 1840 for imparting education in vernacular language. This was supported by Rabindranath Tagore in the late 19th century[33]. Compromise between the two positions and yet, not snapped link with our own culture through the use of vernacular was the only way out. P. C. Ray realized this problem and pleaded[34] that

"although there is a diversity of language among the European nations, there is uniformity in the use of technical terms. The Japanese have fully realized and have thus adopted the middle course. We should also follow in their footsteps".

Others, like Gurudas Bandopadhyaya, the first Indian Vice Chancellor of Calcutta University, and J. C. Bose, supported the middle course. Serampore missionaries like William Carey and Marshman are to be credited with the first introduction of science into Bengali literature. Bengal had given the lead in the late 19th century for science magazines and books in the vernacular. Between 1868 and 1900, 10 journals and magazines in science alone and 47 in technology were reported from Bengal[35]. *Vigyan Rahasya* (1871), *Vigyan Vikas* (1873), *Vigyan Darpan* (1876), *Sachitra Vigyan Darpan* (1882), *Chikitsa Darshan* (1887), *Tatvabodhini Patrika* and *Bengal Spectator* were some of the important periodicals in Bengali dealing with science and technology[36].

**TABLE 1**
**Publications on Science in Indian Vernacular Languages in the Indian Provinces between 1875 and 1896**

| Provinces | Medicine | Maths | Natural Sciences | Total |
|---|---|---|---|---|
| Bengal | 472 | 180 | 124 | 776 |
| Madras | 83 | 35 | 43 | 161 |
| Bombay | 210 | 101 | 102 | 413 |
| Punjab | 264 | 183 | 17 | 464 |
| NWP Oudh | 116 | 174 | 20 | 310 |
| Total | 1145 | 673 | 306 | 2124 |

Efforts invested in creating a base for modern science in Indian languages were however not confined to Bengal. These activities stretched to other parts of India, as is evident from table 1[37]. Of the 2124 publications, 306 are in Bengali languages. Whilst these publication were concerned with the graduate and under graduate level, the

Calcutta School Book Society in 1875 published a catalogue of Bengali titles. Of the 1544 titles, 333 were on science and technology[38].

## Individuals, Institutions and Programmes to Advance Science

When J. C. Bose and P. C. Ray joined the Presidency College in 1885, and C. V. Raman the IACS in 1907, the "cultivation of science" was extended to mean the contribution to the advancement of sciences. Father Lafont at St. Xavier College established an excellent observatory for meteorological and spectrotelescopic investigations[39]. The Indian Institute of Science came into existence by 1909, and before the close of 1920, the University College of Science, Calcutta University (1914) and Bose Research Institute (1917) were established. In effect, these institutions gave a new "identity" to Indian science. Even though the scientific elite of this era were the product of the Western education, advancing science did not mean aping the West passively. As J. C. Bose observed[40],

"impulse from outside reacts on impressionable bodies in two different ways. So the first impetus of Western education impressed itself on some in a dead monotony of imitation of things Western while in others it awakened all that was greatest in the national memory".

J. C. Bose often said that his purpose was not to merely introduce science, but to revive Indian science. By this he meant to revive the experimental tradition and not the speculative tradition. The assertion that the method of science was Western, and hence alien to national culture, was rejected as groundless by J. C. Bose[41]. Thus advancing science also meant achieving a new status for the self and for national prestige. Eminent Indian scientists of J. C. Bose's era widely shared this view.

The constitution of research activity to advance science in the above institutions enabled the leading scientists to make a significant departure from the era of colonial science. For instance, Indians could only publish 18 papers in the *Journal of Asiatic Society* for the sixty year period from 1836 to 1895. The European settlers in contrast accounted for 1021 papers[42]. In the next quarter century (up to 1920) research output from the above five institutions alone accounted for 304 papers, the bulk of it concerning original investigations[43]. In every branch of science Indians contributed to the advancement of knowledge and earned professional recognition from the world bodies.

J. C. Bose's work on micro-wave (1895) and plant physiology (1900) earned him world recognition: he was elected to the Royal So-

ciety in 1920[44]. On Radio receivers, Patrick Geddes, biographer of J. C. Bose, accords him priority over Marconi who patented it[45]. P. C. Ray discovered Mercurous nitrite in 1896. No branch of chemistry was left untouched with his original papers. He published about 107 papers by 1920 and was elected vice-president of the Edinburgh University Chemical Society as early as 1888. C. V. Raman entered IACS in 1907 and published about 35 papers by 1920. The areas of research covered by Raman and his colleagues included sound and vibration, theory of musical instruments, viscosity, colloid studies, wave optics and molecular scattering of light[46]. Basic research in these areas which were further developed earned Raman the Nobel Prize after fifteen years and the fellowship of the Royal Society in four years. Another genius was S. Ramanujan, a Port-Trust clerk at Madras who never entered the University. His theory of numbers earned him the Fellowship of the Royal Society in 1918. Ashutosh Mukherjee, a lawyer by training, contributed 16 original papers on differential equations. Similarly Dr. Ganesh Prasad, Hardinge Professor at Calcutta University, contributed to applied mathematics in the theory of potentials[47]. Satyendranath Bose joined Calcutta University in 1916 along with M. N. Saha. Bose was the first to translate Einstein's original German paper on the generalized theory of relativity into English in 1915; it was published as book by Calcutta University in 1920. S. N. Bose's interest in Einstein's work led him to the famous Bose-Einstein statistics of 1924 paper wherein he gave a logical derivation of Planck's law of blackbody radiation.

While Indian scientists achieved world recognition in many scientific fields, technologists made their presence felt at the national level[48]. P. C. Ray's Bengal Chemicals and Pharmaceutical Works (BCPW), established in 1892 with the assistance of S. C. Sinha, is a direct example of his economic nationalism. There were a number of independent innovators in Bengal[49]. However, J. C. Bose, C. V. Raman, P. C. Ray and others were not isolated individuals. They constituted the embryoes of what is known as the Indian scientific community for the first time. The Indian School of Chemistry under P. C. Ray encouraged and trained a generation of students, who immensely contributed to the development of chemistry departments in the universities and gave at least four generations of chemists[50]. The base for the Indian Chemical Society (1924) was in fact provided by the students of P. C. Ray and its genesis goes back to the dream P. C. Ray shared with J. C. Ghosh, J. N. Mukherjee and S. S. Bhatnagar in London. The second school was the School of Physics which emerged

at Calcutta. C. V. Raman, J. C. Bose and M. N. Saha constituted this school but until 1920, C. V. Raman was its leader. The Centenary Volume of IACS identified the school as "School of Raman"[51].

Another group which became active during 1900 and 1920 was the group on plant physiology under J. C. Bose. Following his paper in 1900 on the generality of molecular phenomena produced electrically in living and non-living matter, J. C. Bose published four monographs through Orient Longmans, which contained the details of 650 experiments in plant physiology[52]. With this base, J. C. Bose organized a research group at his Bose Research Institute from 1917. N. N. Neogi, S. C. Das, Gurupudaswamy Das, Jyotiprakash Sircar, S. C. Guha and Lalit Mohan Mukherji worked with J. C. Bose and published about 20 papers on life movements in plants, which received world recognition.

Reviving the Indian tradition of mathematics, the Calcutta Mathematical Society was established in 1908 with Ashutosh Mukherjee as president. Ashutosh Mukherjee, known for his legal profession and the vice-chancellorship of the Calcutta University, contributed 16 original papers on differential equations. Through the efforts of V. Ramaswami Iyer, the "Analytical Club" at Fergusson College, Poona was upgraded to the Indian Mathematical Society in 1911. Dr. Ganesh Prasad founded the Banaras Mathematical Society in 1918. Other societies which were established by 1920 are the Bihar and Orissa Research Society (1915) and lastly the Institution of Engineers (India) in 1920. There were however other researchers with small teams and scientific societies spread all over India which needed the common platform provided by the launching of the Indian Science Congress Association in 1914. As Rutherford[53] observed,

"the congress was founded at a time when the universities were becoming the centres of original research, it afforded to a widely scattered scientific community a much needed common meeting ground".

## Concluding Remarks

An attempt has been made in this paper to critically examine a part of Basalla's colonial "model" in the context of scientific enterprise in India for the period 1876-1920. It is erroneous to construct the definition of colonial science delinked from its social context - namely colonialism and rising nationalism - to extract its "regenerative" features by grossly undermining the "exploitative" features. The colonial science used by Basalla reflects its political unreality in the Indian context.

A closer examination of the institutions and scientists between 1876 and 1920 begs a finer definition of a colonial scientist. I have argued that three categories of scientific personnel and institutions make sense for the period after the 1870s, if one is to understand the constitution of (Basalla's Third Phase) what I term as national, independent science. The first category is the "gate keepers" of colonial science who helped to keep science dependent and practiced discrimination against the native Indian scientists. Second, there were "scientific soldiers" who merely executed their occupational and professional roles. The third category consisted of scientists who struggled to create support structures for the cultivation of modern science and its advancement in the framework of emerging nationalism. The term "national" is interpretatively derived which manifests widely in the writings and views of the third category scientists. This categorization is put forward as an alternative to the homogeneous colonial scientist used by Basalla and others for the period after the 1870s. Explicit to stratification is also the recognition that scientists in each stratum had different constituencies of operation with respective goals and purposes. It is held that the third category was responsible for the emergence of national science or a "independent" scientific phase and that the other two categories were not. The empirical support which is brought to bear on this argument is that scientists and institutions established by the third category neither had any intellectual collaboration with nor received the barest minimum economic support from the other two categories in the constitution of national science.

The research groups constituted by the third category of scientists may be accredited with this historic role in that they established for the first time schools in physics and chemistry, "specialized groups" and professional bodies in plant physiology and mathematics. To this category may be added the group on spectra-telescopic investigations at Saint-Xavier's College, organized by Father Lafont. All these groups constituted the genesis of the Indian scientific community formalized by the establishment of the Indian Science Congress in 1914, which created a common platform for scientists from different parts of India.

The role of Indian scientists in the constitution of national science began with the creation of support structures from 1876. This effort of creating support structures was however not confined to Bengal: within the constraints of limited sources and time, I have shown the spread of support structures in various other parts of India. Technical institutions such as Kala Bhavan, college departments in science sub-

jects, scholarships and endowments for science subjects, popularization of science and the creation of base for modern science in vernacular language - all institutionalized by native Indian scientists, constitute the support structures. In the midst of colonial economic exploitation technical training centres in minor trades have played a very important role without which thousands of artisans might have been converted into landless labourers.

By the 1890s, Indian scientists first achieved world recognition in modern science from the Indian soil. An altogether different view, which follows from the stratification of scientists, is that the constitution of national or independent science was outside the structures of the colonial scientific enterprise. Basalla's hypothesis that phase III in its embryonic form is contained in colonial science is questionable. Further, the paper suggests that national science was not constituted just because it is financed by natives of the country. It needed a "calling" by which it was intellectually integrated into the national interests aided by political and economic efforts. Emerging nationalism after the 1870s and the ideological role of scientists in it is in no small measure unconnected to the struggle of Indian scientists to achieve international recognition. Limited to their sphere of influence, they believed that advancing the frontiers of knowledge also meant giving a distinct national identity to their intellectual production. This "cultural nationalism" in science was however not completely devoid of economic relevance. The generation of skilled persons, chemists and technologists who managed swadeshi based industries (such as - The Bengal Chemicals and Pharmaceutical Works of P. C. Ray, - Calcutta Chemicals, - Duck-Back Waterproof, - Bengal Potteries), received their training in the Bengal Technical College, a product of the national education movement. What happened in Bengal also happened elsewhere. Kala Bhavan Technical Institute is the best example of the development of Baroda as a manufacturing town. By 1920, although some infrastructure was laid down, the forging of structural connections between science, technical education and production was greatly constrained by colonial policies. Scientific excellence on the other hand did not require such an elaborate umbrella of connections. With an optimum support structure, scientific excellence could be developed at the laboratory level with brains, so Indians could contribute.

By all means the national science was "stemming" out of its embryonic form by 1920. The support structures created up to this period were to prove to be a great boon for science in India in the next

15 years and enabled further consolidation of the base of national science. C. V. Raman won the coveted Nobel prize and two more fellowships of the Royal Society were added to the Indian list. S. N. Bose, M. N. Saha and S. K. Mitra were making original contributions. Twelve professional societies such as the Indian Chemical Society, the Society of Biological Chemists, the National Institute of Science, and the Indian Academy of Sciences were established in this period. All these accomplishments by the mid 1930s were the result of the support structures created before 1920. The continuity and change in the national science tradition calls for further research.

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## Notes

[1] G. Basalla, "The Spread of Western Science", in *Science,* **vol.156,** n°3775, 1967, p.611-622; for critical examination of Basalla's "model" see Ian Inkster," Scientific Enterprise in Historical Context", *Social Studies of Science,* **Vol.15,** 1985, p.677-706; and Roy MacLeod, "On Visiting the Moving Metropolis: Reflections on the Architecture of Imperial 'Science'", *Historical Records of Australian Science,* **vol.5,** n° 3, 1982, p.1-16.

[2] See D. Raina and I. Habib, "Cultural Foundations of a 19th century Mathematical Project" *Economic and Political Weekly,* 16 Sept., 1989; R. M. Young, "The Historiographic and Ideological Context of the 19th Century Debate on Man's Place in Nature", in M. Teich and R. M. Young (eds), *Changing Perspectives in the History of Science,* London: Heinman, 1972.

[3] *Op. cit.,* note 1.

[4] See MacLeod, *op. cit.,* note 1

[5] Deepak Kumar, "Racial Discrimination and Science in 19th century India", *Indian Economic and Social History Review,* 1983, **vol.xix,** n° 1, p.63-82.

[6] P. C. Ray's Presidential address to the seventh Indian Science Congress (ISC), see *Proceedings of the 7th ISC,* Calcutta: Royal Asiatic Society of Bengal, 1920.

[7] Review of agriculture, *surveys,* n°25, September, l88O.

[8] Sarjoj Ghose, "William O'Shaughnessy - an Innovator and Entrepreneur", paper presented at a seminar on "Calcutta and Science", December 21-23, 1989, Birla Industrial & Technological Museum (BITM), Calcutta.

[9] These examples are taken from an excellent study by W. H. G. Armytage, *A Social History of Engineering,* London: Faber and Faber, 1961, p.164-167.

[10] In contrast to "scientific soldiers", some foreign scientists and missionaries were attached to India. Father Lafont joined St. Xavier College in 1865 and died in Calcutta in 1908. He was in fact one of the founders of the IACS. David Hare, a watch maker, came to Calcutta in 1800 at 25, later founded the Great Hindu College in 1817 with R. M. Roy and died in Calcutta in 1842.

[11] Dibakar Sen and A. K. Chakrabarty (eds), *J. C. Bose Speaks,* Calcutta: Puthipatra, 1986, p.97-105.

[12] S. Chatterjee and A. Sen, *A. P. C. Roy - Some Aspects of his Life and Work,* (125th Birth Anniversary volume) Calcutta: Indian Science News Association, 1986, p.105.

[13] *A Century: IACS,* (centenary volume of IACS), Calcutta; IACS, 1976, p.9.

[14] *Ibid.*

[15] For little more details of the associations, see Sumit Sarkar, *The Swadeshi Movement in Bengal 1903-1908,* New Delhi: People's Publishing House, 1977.
[16] *Ibid.*
[17] The staff included N. Sircar, M. Nandi, P. C. Ray, B. N. Seal and J. C. Basu. The emphasis was laid on promoting swadeshi products. It had 124 students in 1909.
[18] NCE drew curriculum of 3 years of primary, 7 years of secondary and 4 years of collegiate course. Many eminent persons taught at the college including Dharmanand Kosambi, father of D. D. Kosambi. In 1908 there were 450 students.
[19] Shiv Visvanathan, *Organizing for Science: The Making of an Industrial Research Laboratory,* Delhi: Oxford University Press, 1985.
[20] At its third session in 1887 the Indian National Congress demanded that the government *"elaborates a system of technical education"*. Later in 1888 it demanded the constitution of a commission to enquire into the state of technical education. See Congress Resolutions VII, X, XII & XV for the years 1887, 1888, 1891 to 1893 respectively.
[21] *The Dawn Magazine,* Calcutta, from September 1910 to February 1911 traced a detailed history of the Kala Bhavan. Material used here is drawn from these sources.
[22] *Ibid.* See also Dhruv Raina and S. Irfan Habib's paper, *this volume.*
[23] *Ibid.*
[24] K. R. Kirtikar, "The Study of Natural Sciences in the Indian Universities", Part I to V, *The Modern Review,* Calcutta, 1909. Kirtikar studied the native Indian contribution to the development of science education in affiliated colleges.
[25] *Ibid.*
[26] *Ibid.*
[27] See Sumit Sarkar, *op. cit.,* note 15.
[28] In 1879-80, private aid was 54% of the total expenditure on education in Bengal which was increased to 56%. Bengal Administration Report, 1880-81 p.53 quoted in D. Kumar, *Science Policy of the Raj,* 1857-1905, Ph. D. thesis, Delhi University, 1986.
[29] *Report on Industrial Education,* Part II, National Archives of India, New Delhi, 1903. This report covers Punjab Science Institute, Lahore. For detailed studies on Aligarh and Bihar Scientific Societies, see Irfan Habib, "Institutional Efforts: Popularization of Science in the mid-19th Century", *Fundamenta scientiae,* **vol.6** n° 4, 1985, p.299-312.
[30] 17 Books on pure mathematics by Tod Hanler, Bernard Smith, Galbraith and Haughton were translated. A model farm of agriculture to cultivate modern methods was created by Aligarh Society. Foreign varieties of wheat, cotton and vegetables were imported. Bihar Society established five schools in which Western sciences were taught.
[31] Deepak Kumar, *op. cit.,* note 28.
[32] Address from R. M. Roy to the Governor General protesting against the establishment of the Calcutta Sanskrit College, Dec. 1823, see J. K. Majumdar (ed), *Raja R. M. Roy and Progressive Movements in India: A selection from Records (1775-1845),* Calcutta: Art Press, 1941.
[33] Sumit Sarkar gives an excellent exposition of this debate in his book swadeshi movement, *op. cit.,* note 15. See also J. F. Hilliker, "The Creation of a Middle Class as a Goal of Educational Policy in Bengal 1853-54, in C. H. Phillips, M. D. Waivwright (Eds), *Indian Society and the Beginnings of Modernization: 1800-1850,* School of Indian and African Studies, University of London, 1970.
[34] P. C. Ray, "The Place of Science in the Vernacular Literature", in P. C. Ray (ed), *Essays and Discourses,* Madras: G .A. Natesan & Co. 191 8, p.136-137.
[35] D. P. Bhattacharya, R. Chakravarty and R. D. Roy, "A Survey of Bengali writings on Science and Technology", *Indian Journal of History of Science,* 24 (1) p.8-66, 1989.
[36] *Ibid.*
[37] Selected from excellent survey conducted by D. P. Bhattacharya et al., *ibid.* Delhi.

[38] *Ibid.*

[39] A. K. Biswas, "Eugene Lafont and the Scientific Activity of Saint Xavier College, Calcutta (1860-1910)", paper presented at a seminar on "Calcutta and Science", December 21-23, 1989, BITM, Calcutta.

[40] J. C. Bose, "The History of a Failure that was Great", in Dibakar Sen and A. K. Chakrabarty, *op. cit.*, note 11.

[41] See D. Bose's article on "J. C. Bose and the Indian Tradition of Science" in D. Sen and A. K. Chakrabarty, *op. cit.*, note 11. Pr. Sathianadhan interviewed J. C. Bose in 1896, J. C. Bose who mentionned two assistants: "My young assistant not a graduate has within a short time developed great originality and has rendered me very efficient help in the construction of my apparatus. Lastly, a bearer, employed as a menial servant, now arranges for me the most difficult experiments, manages the Dynamics-Machine and is a good photographer", reported in *The Dawn,* October, 1902, p.115. C. V. Raman shared many of J. C. Bose and M. L. Sircar's views. See, G. Venkataraman, *Journey into Light: Life and Science of C. V. Raman,* Bangalore: Indian Academy of Sciences, 1988.

[42] See Shiv Visvanathan, *op. cit.*, note 19, p.27.

[43] The 261 papers are from J. C. Bose and co-authors 87; P. C. Ray and co-authors, 107; C. V. Raman and co-authors 46; S. N. Bose, 5; and A. Mukherjee, 16 from IACS, Presidency College, University College of Science, Bose Research Institute and St. Xavier College only. Remaining papers are from the Indian School of Chemistry.

[44] Lord Kelvin, commenting on the papers of J. C. Bose on polarization of the Electric ray, observed "I have found time to look all through the pamphlet although not to learn all its contents but I have seen enough to fill me literally with wonder and admiration", reported in *The Dawn,* under J. C. Bose interviewed in 1896, November 1902, p.113.

[45] Bose gave an experimental demonstration at a public function Calcutta town hall in 1894-95 in the presence of Lieutenant-Governor of Bengal. Marconi patented his discovery in England in 1896. The improved version of coherer, the electric wave receiver was patented by Sister Nivedita and Mrs. Ole Bull in USA on behalf of Bose. Unwilling to use his rights the patent lapsed.

[46] See G. Venkataraman, *op. cit.*, note 41.

[47] S. N. Prasad, *Progress of Science in Indian during the Past 25 Years,* Calcutta: Indian Science Congress Association, 1938.

[48] M. Visvesvaraya, *Memoirs of my Working Life,* Delhi: The Publication Division (NBT), 1951.

[49] See Sidharth Ghosh, "Some Eminent Bengali Pioneers in the Field of Technology", paper presented at a seminar on "Calcutta and science", BITM, Calcutta, 21-23, Dec. 1989.

[50] Rasiklal Datta, Nilratan Dhar, Jitendranath Rakshit, J. C. Ghosh, J. N. Sen, Jnanendranath Roy, Pulin Bihari Sarkar, A. C. Ghosh, P. C. Bose and G. C. Chakravorti are few of those chemists who achieved national recognition. For further details see P. C. Ray, "Essays and Discourses", *op. cit.*, note 34.

[51] A. Dey, S. K. Banerjee, S. Appasamyar, S. K. Mitra, D. N. Ghosh, D. Banerjee, T. J. Chinmayanandan K. S. Rao are some of the scientists who constituted the "Raman's School of Physics" up to 1920. See, A Century: IACS, *op. cit.*, note 13.

[52] These four monographs are: *Response in the Living and Non-Living (1902), Plant Response as a Means of Physiological Investigation (1906)* with 315 experiments, *Comparative Electro-Physiology (1907)* with 321 experiments, *Researches on Irritability of Plants (1913).* See, Dibakar Sen and A. K. Chakrabarty, *op. cit.*, note, 11.

[53] Rutherford's presidential address to the silver jubilee session of the Indian Science Congress. See, *Proceedings of the 25th Indian Science Congress,* 1938, Part II, Calcutta: Royal Asiatic Society of Bengal, 1939.