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SCIENCE IN BRITISH INDIA*

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The first part of this article sets up a nested three-stage model for the advent and growth of modern science in India. The first part deals with the colonial-tool stage, where science was used by the British to further their colonial interests. The second part discusses the remaining two stages: the peripheral-native stage, in which Indians were trained and hired to provide assistance to the government science machinery; and the Indian-response stage, in which Indians took to scientific research on their own initiative. Note that we use the term native to refer to Indians in a subservient role. The term Indian is used only when there is exercise of free will or desire thereof.

I

A major accomplishment of the Renaissance in Europe was the 1498 discovery of the direct sea route to India. The great commercial success of the Portuguese spurred the Dutch, the English, and the French to venture out to the sea. The overseas trade was extremely profitable[1]. Cloves purchased for only £ 2048 in the Spice Islands sold in London in 1609 for £ 36,287. The first 12 voyages to East Indies from England yielded an average profit of 138%. By 1621, one man in 2000 in England was working for the East India Company[2]. The navigational needs of the traders acted as a great incentive for development of science in Europe. The best scientists of the time applied their minds to 'discover the longitude'[3]. In the early seventeenth century, professors at Gresham College, London took up navigational problems in the national interest, eg. Henry Briggs[4] (1560-1631) whose introduction of logarithm to the base 10 greatly simplified mathematical calculations. English as well as French companies started compiling sea charts and keeping records of voyages. Observatories were opened at Paris (1667) and Greenwich (1675) to solve the problem of the longitude. The Astronomer Royal supplemented his meagre salary by giving tuition to young men seeking employment with the East India Company[4]. It paid to join the Company, and it paid to know astronomy.

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The European climate was now extremely conducive to scientific innovation. The 1731 invention and use of a sea quadrant by a young American glazier Thomas Godfrey was a dead end because neither the inventor nor America at the time had any use for it. But the next year, when it was independently invented in England (by John Hadley), it was immediately accepted as a valuable navigational aid and developed further[5]. As early as 1736, Hadley's octant 'when it was definitely regarded as an English instrument', was used in India by a French navigator, Apres de Mannevillete (ref. 6a, p. 151 = 6a: 151].

Maritime trade transformed not only European economy but also its state of mind. For the first time in history of mankind, production of wealth depended not upon the courtesy of God and the King, but on human endeavour. Merchants and artisans now became respectable and influential members of the society. And since the new rich class owned its wealth to science, it became patron of science.

The new experiences weakened the hold of the past authorities. Thus the French physician Julien La Mettrie wrote in 1747 in *The Man-Machine:* 'We are no more committing a crime when we obey our primitive instincts than the Nle is committing a crime with its floods, or the sea with its ravages'[7].

Modern science came to India in tow with the Europeans. The very act of reaching India from Europe showed a sense of adventure and competence. It was natural for these early visitors to try to acquaint themselves with their new environment, for survival as well as for profit. Early European scientific endeavours in India consisted of two disciplines, geography and botany. In the early days, the Europeans were confined to the coastal areas and had no reason to venture into the interior. Geographical exploration therefore fell to the Jesuit priests. The Society of Jesus was set up in 1540. The first Jesuits arrived in India in 1542 and remained active for more than 200 years. In 1759 the King of Portugal banished all Jesuits from his colonies; and in 1773 the Pope banished the order altogether. It was revived in 1814, with the first English Jesuits arriving in Calcutta in 1833. The Jesuits had the time, scientific training and the opportunity of criss-crossing the country. Thus in 1580 Father Monserrate (1536-1600) on a mission to Emperor Akbar took observations for latitude from Surat to Fatehpur Sikri [6a:11]. The next year when Akbar marched to Kabul against his half-brother Mirza Hakim, he took Monserrate along as a tutor for his second son Murad, and for making observations on the way. The Jesuits sent their observations and diaries to Europe where they were faithfully preserved and ignored. Europe was not yet ready for India. It is only in the 18th century when knowing India became a paying proposition that Jesuit data were dug up and put to use. (Monserrate's observations were first noticed 200 years later, in 1784). The 34 volumes of Jesuit observations from all over the world published at Paris between 1702 and 1741 were avidly read by the colonialists, and a 26-volume edition appeared in 1780-83, of which six volumes were devoted to India [6a:11].

While geography was left to the missionaries, botany did interest the traders. This is not surprising. After all, it was the lure of the culinary plant that had brought Europeans to India in the first place. But plants had other uses also. They provided drugs in the treatment of diseases and had in addition exotic value. It was only natural that visiting seamen should take interest in plants for reasons of their own health, and for their medicinal, commercial and curiosity value back home. The first western botanist in India was the Portuguese Garcia D' Orta (1479-1572), a physician and professor at Lisbon, who came to India in 1534 and stayed till his death. D'Orta , said to be a converted Jew, moved in 1538 or 1541 to the island of Bombay which the Portuguese had acquired in 1528 and which they now leased to D' Orta in perpetuity at an annual rent of £85. Obviously D' Orta could not hold on to his estate, but in 1563 he wrote a book called *Dialogues on Samples and Drugs*[8].

The next dabblers in botany were the Dutch[9], who opened a factory (a fortified warehouse) at Cochin in 1663. The material collected from Malabar was published at Amsterdam as 12-volume *Hortus Malabaricus* and illustrated by 794 plates 'some of which are so good that there is no difficulty in identifying them with the species which they are intended to represent.' Such work had a curiosity value, but fulfilled no pressing need, as can be seen more clearly from the work of Rumphius whose manuscript on the flora of Spice Island of Amboina completed in 1690 was published years later between the years 1741 and 1755. Another work with delayed but influential response was by Paul Hermann who spent seven years (1670-77) exploring the fauna of Ceylon at the expense of the Dutch company. Since this 600-species collection was sent to Europe, it was used by that great systematist Linnaes in 1747 to publish his *Flora Zeylanica.*

We have seen that the early use of modern science in India was sporadic and desultory, and motivated by localized curiosity. Most of it had no contemporaneous significance and was incorporated into the main body of science much later. Additionally, it left the Indians themselves untouched. Of far greater significance was the medical expertise of the British doctors [10:37]. This expertise was sought by the Indian rulers who paid for it in terms of goodwill and trading concessions[10]. Thus Gabriel Boughton, a surgeon on the East India Company's ship Hopewell, was sent to Emperor Shahjahan's court at Agra in 1645. He served between 1645 and 1650 as a surgeon to Shah Shuja, Emperor's second son and Viceroy of Bengal, from whom he got a farman for free trade issued in favour of the Company. Then in 1716, when the Company sent an embassy under John

Surman to the Mughal Emperor Farrukhsiyar, it included a surgeon William Hamilton, who came in handy in curing the Emperor of a painful disease, which had delayed his marriage [10:110]. The surgeon's skills brought the English party into high favour not only with the Emperor but also with his powerful Vazir. The embassy returned with three farmans confirming the right to trade free of all duties. Ironically, this gave Company as well as the traders a big advantage over their native competitors. Surman's embassy has been hailed as a landmark in the history of the Company's settlements'[11].

With the post-Aurungzeb (1707) collapse of the Mughal Empire, India became available for grabs. The European vaishya outfits developed kshatriya ambitions. The 1757 battle of Plassey laid the foundation of the British colonial empire[12]. Earlier scientific activity by the Europeans in India had been motivated by commerce and curiosity. Now science was pressed into the cause of empire-building and institutionalized. (It is not without significance that Robert Clive, the founder of the British Empire in India, was made Doctor of Laws in 1760 by the Oxford University, a full year before the King made him a baron[13]). We present here a model to act as a framework for discussing the advent and growth of modern science in India[14]. The model distinguishes between three nested stages of development.

The first stage, called 'the colonial stage', consists of introduction and use of science, especially by the British, as an imperialist tool, with incidental benefits to science. The second stage, the 'peripheral-native stage', came into being when the British were well entrenched in India. In it, the Indians were assigned the peripheral role of providing cheap labour to the colonial science machinery. The third stage, 'the Indian-response stage', arose as a reaction to the second stage, and is characterized by scientific activity by the Indians themselves and on their own initiative. We use the term native to refer to Indians in a subservient role, using Indian itself only when there is exercise of, or desire to exercise, free will. We shall now discuss each stage separately, drawing illustrations mostly from the Survey of India[6] which represented science in the most dedicated service of the state.

The colonial-tool stage

The gold coins minted by the Portuguese for use in India depict the artillery sphere, the pre-telescopic basic navigational instrument used for determining the latitude. This was Portugal's way of paying tribute to science to which it owed its power. The Portuguese arrived in India even before the Mughals did. Their love for Christianity and hatred for Muhammedans far exceeded their desire for Indian territory. Moreover, given their small population they did not quite know how to successfully deal with the scurvy deaths on the sea. The Portuguese introduced navy as a parameter in India's geo-political equations, placing the Indians rulers at a disadvantage. Even when its power was at its peak, the Mughal Empire had to seek the help of the religiously neutral British to thwart the Portuguese attempts at preventing Indian Muslims from sailing to Mecca. When the Portuguese first arrived in India, Copernican heliocentrism had not yet made its appearance. But by the time the Mughal Empire collapsed, Europe was already on the verge of industrial revolution, so that science and colonialism could feed each other.

Filling the political vacuum in India required as a first step knowledge about its geography. The French were more successful on the scientific front than on the colonial. The first worthwhile map of India was compiled in 1752 by the French geographer Jean-Baptiste Bourguignon D'Anville at the request of French East India Company, who based it on Jesuit data and on whatever geographical information he could lay his hands on. The value of D'Anville's *Carte de l'Inde* can be judged from the fact that it was reprinted in England in 1754 and then again in 1759, along with the annotated translation of his memoirs [6a:33].

Astronomy was the first modern science to be brought to India, as a geographical and navigational aid. Its early use was however sporadic and mostly out of personal curiosity. Systematic scientific effort became essential when the 1757 battle of Plassey transformed the British East India Company into Jagirdar. The Company Bahadur was fully conscious of its needs: survey of its present and future lands; safety of navigation, increased revenue; and proper administration. The first need was geographical knowledge. In 1757 itself when Clive was still at the Nawāb's capital Murshidabad, he proposed that 'an exact and useful survey may be made which will enable us to settle beneficial boundaries'. Accordingly a 'Surveyor of the New Lands' was appointed in 1761, and in 1767, two years after the Company received divani rights over Bengal, Bihar and Orissa. Maj. James Rennel was made the 'Surveyor-General of Bengal'. Rennel's Bengal and Behar Atlas appeared in 1779-81, and the Map of Hindoostan in 1782-92 [6a:369;15].

Surveys were continually required for military purposes. Geographical location of important places in the country was determined with alacrity by 'borrowing a sextant here, a watch there, and a quadrant in another quarter, from different officers at Calcutta who happened to possess them'. Surveyors were sent out with every army to prepare route maps. The importance of 'military geography can be gauged from the fact that in 1790 when the Governor General took the command against Tipu, the Sultan of Mysore, he appointed the Surveyor-General to his personal staff. In 1793 the Company paid the fabulous amount of Rs. 6000 to a surveyor, Lt Robert Hyde Colebrooke, for a map of

Mysore accompanied by a memoir [15:57]. Colebrooke served as Surveyor-General of Bengal in 1794-1808 [6a:326].

The destruction of Tipu in 1799 extended the Company's territories from the east coast to the west. Just as Plassey had produced its Rennell, Seringapatam produced its Lambton, only more quickly. Unlike Rennell's survey which was run in traditional, route survey style, Maj. William Lambton (1753/6-1823] modelled his on the lines of the recently started surveys in France and England. The Trigonometrical Survey of Peninsular India was started in 1800 with second-hand instruments bought within the country. Expectedly, its history is also the history of the entrenchment of the British in India. In 1817 the Mahrattas were finally crushed. On 1 January 1818 the survey was renamed the Great Trigonometrical Survey of India (GTS) and extended to cover the whole country. It even surreptitiously covered trans-Himalayan region. The GTS came to its own in 1830 under Lt. Col. Sir George Everest (1790-1866) who was appointed the Surveyor - General. The GTS fixed with great accuracy the longitude and latitude of a large number of places. The details were then filled in by the Topographical and Revenue Surveys. In 1878 the three were merged under the name Survey of India. (The name GTS is often retroactively applied to include Lambton's survey, and the Survey of India to its predecessor constituents.). Uniformly accurate data from such a huge landmass as India led to the important geodesical theory of isostasy by Archdeacon John Henry Pratt (1808/9-71) and to a mathematical model of the earth, known as Everest geoid[6,15].

As early as 1787, General William Roy, the founder of the British survey, wrote how desirable it was to determine the length of a degree of latitude on the Coromandel coast and in Bengal. It was too early for the Company to bother about the shape of the earth when its ships were getting wrecked. Rennell and Alexander Dalrymple, the Company's hydrographer at London, made a joint reply: 'Whatever advantage to science may be derived from the exact determination of the figure of the Earth, we conceive no other benefit can possibly attend the Admeasurement in Bengal; but that proposed on the Coast of Coromandel will contribute towards the construction of an exact chart of the Coast' [6a:164].

The Coromandel coast is rocky and full of shoals and without a natural port and was a graveyard for the Company's ships A survey of the coast was thus literally a matter of life and death, and eventually in 1785 a professionally trained surveyor-astronomer Michael Topping (1747-96) was brought from England, on free passage and equipped with his instruments [6a:389]. Since his work required a reference meridian, an Astronomical Observatory was set up at Madras in 1790. It was the first modern public observatory outside Europe. While pleading for it, Topping reminded the Company Directors that they now had a chance of 'affording their support to a science to which they are indebted for the sovereignty of a rich and extensive empire'. Although the Company had grandiosely declared that the purpose of the Observatory was to 'promote the knowledge of astronomy, geography and navigation in India', it was clear that the main aim was to promote the Company's profitability"[16]. Science was only a part of the duties of the Company's officers. The value of various services can be gauged by the price placed on them. Topping's monthly salary as the 'Company's Astronomer and Geographical Marine Surveyor' was 192 pagodas (1 pagoda=Rs. $3^1/_2$; £1=Rs. 8). He got double this amount (400 pagodas) as the 'Superintendent of Tank Repairs and Water Courses'. An additional 100 pagodas came from the superintendence of the Surveying School. In the early years, the Observatory was no more than a surveying outfit. This role ended with the 1830 reorganization of the GTS, but navigational need was still outstanding. Increased sea-trade activities of the British required familiarity with the southern skies. In 1844 after 14 years of labour, Thomas Glanville Tayor (1804-48) produced the celebrated Madras catalogue giving positions of about 11,000 southern stars. It was hailed by the Astronomer Royal as 'the greatest catalogue of modern times' and revised in 1893 with funds from the India Office and the Royal Society[16].

The Observatory was now redundant. Even the British astronomers who had now observatories in South Africa and Australia lost interest. The Astronomer Royal wanted it abolished but could not succeed against the assertion of the local British pride, succinctly expressed in the letter written by the Madras Director of Public Instruction to his Chief Secretary (16 January 1867)[17].

> 'Here I beg to call special attention to the fact that the views of Mr. Airy (Astronomer Royal] are based simply upon the question as to what work is absolutely required to support the work done at Greenwich and other first class Observatories. I earnestly hope that the Ruler of India will take a higher and most extended view of the matter, and consider what is due to this country.'

The rhetoric saved the Observatory, but no new equipment was sanctioned. Fortunately, there were workshops of the Public Works Department that could maintain the ageing instruments. India's astronomical fortunes revived with the advent of the new field of solar physics. India was ideal for extensive photography of the sun, which was not possible in cloudy Britain. Also, it was then believed that a study of the sun will help predict the failure of the monsoons. In 1878 solar photography was started at Survey of India, Dehra Dun, and photographs were sent to England for analysis. A solar observatory was established by the Imperial Government at Kodaikanal in 1899 (which still exists)"[16].

Once the Trigonometrical Survey was begun, the Government lost interest in Madras Observatory. In 1801 Madras Astronomer was getting a monthly salary of Rs. 672, whereas the Superintendent of the Trigonometrical Survey was slightly better placed at Rs. 980. Seven decades later, in 1877, while the Astronomer's salary had crawled upto Rs. 800, the Survey Chief's had jumped to a substantial Rs. 2565. Fifteen surveyors were getting more than the Astronomer, three of them being Fellows of the Royal Society. All surveys were manned by military officers. Whereas meteorological and magnetic observations were considered legitimate military duty, pure astronomy was not.

The last word on where pure science stood up *vis-a-vis* the applied belongs to the irrepressible Everest. In 1834, on orders from the Government, astronomical instruments from the Survey were issued to enable the former Bombay Astronomer to observe the phenomenon of the opposition of Mars. This happened when Everest was out on field tour. On his return Everest made a strong protest against the loan, saying... 'The discoveries which the late Astronomer of Bombay is likely to make in science would hardly repay the inconvenience occasioned by retarding the operations of the Great Trigonometrical Survey...' [6d:137]. It should however be noted that John Curnin, the first Director of the Colaba Observatory, was dismissed from service in 1828.

From geography to geology was but a natural step. The survey of the Himalayan region naturally brought forth interest in its legendary mineral wealth. The Governor-General wrote (1817): 'We have been duly sensible of the want of professional enquiry into the mineral produce of the hill country lately acquired by us. The remedy now offers itself'. The remedy consisted in the person of Mr. Alexander Laidlaw 'Mineralogist and Investigator of Natural history' though 'lacking in liberal education'. He was sent out by the Court of Directors. His pay was consistent with the wealth he was to explore: a salary of Rs. 600 plus Rs. 200 for his carriage, and free issue of instruments and stores, to say nothing of an advance of Rs. 2500 in cash'. He was attached to the survey of Kumaun. The Governor-General wanted him to look for metals but added, 'To copper or iron I would not point Mr. Laidlaw's attention, as I think the working either might injuriously affect important articles of British export'. Mr. Laidlaw did not pay attention to anything and was dismissed after two years [6b:266].

In 1818 Dr Henry Voysey a surgeon who doubled as a geologist was attached to the GTS so that he could draw 'attention to anything that might influence geometrical and astronomical observations'. Voysey's reports included one on the stone used in building the Taj at Agra. He also reported on diamond mines of South India. Industrial revolution meant the realization that coal was more important than diamond. As the steamer ships were pressed into use, the Government became interested in coal fields. This led to the appointment of a Geological Surveyor to the Company, and in 1851 to the Geological Survey of India. (The Survey of India, the Geological Survey, and the Medical Service, were the only science services in the pre-1857 British India). Geological evidence in support of the continental-drift hypothesis came from India; this fact is commemorated in the name 'Gondwana' for the ancient southern super-continent. The name, Gondwana System, was introduced in 1872 by Henry Benedict Medlicott (1829-1905), from 1854, professor of geology at Roorkee and later superintendent of the Geological Survey of India[18].

Systematic study of botany[9] in India was pioneered by John Gerald Koenig, a native of the Baltic province of Courland, who came to the Danish settlement at Tranquebar (150 miles south of Madras). Koenig was a pupil of the celebrated Linnaes and at once initiated many enthusiasts into botanical studies. The workers included Sir William Jones, the well-known oriental scholar, who in 1784 established Asiatic Society of Calcutta. Most workers were however content with collecting the samples and sending them to Europe. Rottler, a missionary, was the only member of the band who himself published in Europe descriptions of any of the new species of his own collecting; they appeared in *Nova Acta Acad. Nat. Curiosorum* at Berlin. All these efforts were individual.

A recognised centre for botanical activity was provided by the East India Company in July 1787 with the establishment of a 300-acre botanical garden at Sibpur on the bank of Hooghly, near Calcutta. The reasons for Company's initiative were described at the 69th Meeting of the British Association for the Advancement of Science by Sir George King, president of the section of botany, and director of the garden during 1871-97:

> The East India Company was still in 1787 a trading company, and a large part of their most profitable business was derived from the nutmegs and other spices exported from their settlements in Penang, Malacca, Amboina, Sumatra, and other islands of the Malayan Archipelago. The Company was also in those days the owner of a fine fleet of sailing vessels, and the teak of which these ships were built had to be obtained from sources outside the Company's possessions. The proposal to found a Botanic Garden near Calcutta was thus recommended to the Governor of the Company's settlements in Bengal on the ground that, by its means, the cultivation of the teak and of the Malayan spices might be introduced into a province near one of the Company's chief Indian centres[19].

(Years later decline in availability of timber for ship building in the Malabar coast made the Government wise to the destruction of forests and led to appointment of Dr Alexander Gibson (1800-67) as Conservator of Forests for Bombay Presidency during 1847-60).

At the fall of Mysore, the botanical garden at Bangalore (the Lal Bagh) was appropriated by the Company 'as a depository for useful plants sent from different parts of the country'. The Company's botanist at Madras (Dr Benjamin Heyne) was ordered by the Governor-General to accompany the Surveyor, with the following instructions:

> A decided superiority must be given to useful plants over those which are merely recommended by their rarity or their beauty, to collect with care all that is connected with the arts and manufacturers of this country, or that promises to be useful in our own; to give due attention to the timber employed in the various provinces of his route, ... and to collect with particular diligence the valuable plants connected with his own immediate profession [i.e. medicine][6a:113].

An important task assigned to the colonial botanical gardens was dealing with malaria, the scourge of the tropics and the biggest obstacle to colonial expansion[19]. The bark of the cinchona tree as a cure for malaria was introduced in Europe from South America in 1640 by a Spanish lady Countess del Cinchon [20:28]. In 1820, two French chemists Pierre Joseph Pelletier and Joseph Bienaime Conventou succeeded in extracting the alkaloid of quinine from cinchona bark, and commercial production of quinine began in 1827. Until the 1850s all the world's cinchona bark came from the forests of Peru, Bolivia, Ecuador and Colombia, where the trees grew wild. The British and the Dutch interests then decided to grow the trees in Asia[19]. In 1858-60, Clements Robert Markham (1830-1916) assistant secretary at the India Office aided by a gardener at the Royal Botanic Gardens at Kew secretly travelled to Bolivia and Peru and brought back seeds of the *Cinchona calisaya* tree; while English botanist Richard Spruce brought seeds and young plants of *C. succirubra* from Ecuador. (Curiously, Markham's[15] own 1878 *A Memoir of Indian Surveys* makes no mention of cinchona). Intense experimentation at the Indian botanical gardens made India self-sufficient in quinine. Dr. Thomas Anderson (1831-70), superintendent of the Calcutta Garden since 1860, died at Edinburgh of 'disease of the liver, contractered during his labours to establish the cultivation of the quinine-yielding species of cinchona'[9]. Almora-born British physician Ronald Ross (1857-1932) discovered in 1897 that the germ of malaria is carried by Anopheles mosquito, and received the 1911 Nobel prize. Not unexpectedly, he could carry out his research only intermittently 'during his spare time when he was not on duty as regiment doctor' and entirely at his own expense, which included payment of an anna per mosquito given to the patient (Husein Khan) who permitted Ross's 10 mosquitoes to have a good meal from his malaria-infected blood [20:40]. Later, in 1904 Ross served as a consultant at Panama where the long-needed canal could finally be built only when malaria was eradicated.

The botanical gardens carried out' systematic, geographical and economic studies' of Indian flora, and finally in 1891 Botanical Survey of India was constituted[9]. The Company did not mind enrichment of science as long as it took place in the normal course of its own activities. But the moment it was asked to extend patronage to science for the sake of science, it baulked. In 1851, not withstanding a memorandum from the British Association, the Company refused to promote a project on *Flora Indica* by Dr (later Sir) Joseph Dalton Hooker of Kew and his collaborator Dr Thomas Thomson (1817-78), later the superintendent of Calcutta Garden 1854-61. Hooker's monumental seven-volume *Flora of British India* (1875-97) had to wait for orders from the Secretary of State.

The British desire for exploration and increased revenue led to the epoch-making discovery of fossil fauna in the Shivalik hills. The story deserves to be told in some detail, because it brightens a particularly dark period at Delhi [6b:67; 6c:23; 15:210]. As early as AD 1357, Ferozeshah Tughlaq cut through a hill with the help of 50,000 men to dig a west Yamuna canal. East Yamuna, or doab canal, was dug up later, during the Mughal period. Both these canals had ceased to flow by the middle of the eighteenth century. The British government took up the question of restoring these two old canals. After preliminary survey in 1810-11, work on the Ferozeshah canal was begun in 1817, and on the doab canal in 1822. The head of the canals, Shaharanpur, was also the seat of a public garden that was established in 1779 by the Rohilla Fauzdar, Zabita Khan, who appropriated the revenue of seven villages for its maintenance. His son Ghulam Qadir, who pitilessly blinded the hapless Mughal emperor Shah Alam in 1788, continued the arrangement, and so did the Mahrattas after him. In 1823 Marquis of Hastings converted it into a 400-acre botanical garden, to which was later added a nursery of trees for canal banks.

Dr Hugh Falconer (1808-65) of the Bengal Medical Service, who in 1832 became the director of the Saharanpur garden, was aware of a report by Ferozeshah's historian Farishta where he described unearthing of three yard long bones of giants while digging the east canal. In 1831, Falconer along with Sir Proby Thomas Cautley (1802-71), in charge of the doab canal, discovered fossil bones. On 16 November 1834 Lt (later Sir) William Erskine Baker (1808-81) superintending engineer, received a present of a fossil of an elephant's tooth from the Raja of Nahan. He sent a sketch to the secretary of the Asiatic Society Calcutta. On hearing this Dr Falconer made enquiries, and had a fragment of a similar tooth presented to him also. 'I got a hint where they (the teeth) came from and on going to the spot I reaped a rich harvest' collecting more than 600 specimen of bones within six hours[21]. These discoveries proved that in the remote past a sea occupied the valleys of the Indus and Ganga. The well-known pattern of the Company's attitude towards science is repeated here. Dr Falconer wanted to devote his full time to his great work *Fauna Antiqua Sevalesis,* but as a 1878 Memoir[15] puts it he 'was not spared to complete it'. This work was edited and published after his death.

Steam navigation, telegraph, and railways helped tighten British grip over India. The practice of government-sponsored science to serve the practical need of the administration continued throughout the British rule. Thus there came about India Meteorological Department (1875); Imperial Bacteriological Laboratory (1890) at Poona, later shifted to Mukteswar; Imperial Agricultural Research Institute (1903) at Pusa in Bihar, later shifted to Delhi; and Zoological Survey of India (1916). The last scientific act of the British Indian government was dictated by the second world war which in turn brought about its exit from India. In 1942 Council (then called Board) for Scientific and Industrial Research was set up for providing scientific support for the war effect. Note that the actual number of scientific officers was very small. In 1920 the biggest of the scientific services, Survey of India, had a total of 46 imperial grade officers, while the Botanical Survey had only two[22].

We have seen that the British rulers were not interested in science as such, but in using science to further their interests. Whenever their practical needs pointed a finger towards a particular branch of science, attention was paid to that science. Harnessing science enriches it also. Thus in the process of empire building, India was added as a laboratory to the edifice of modern science. Introduction of Indians to science came about when they were assigned the role of laboratory assistants. They soon graduated to respond to science on their own initiative.

II

The first part[1] describes the colonial tool stage. Now we will deal the peripheral native stage and the Indian response stage.

The peripheral native stage

Just as the British in India needed science, they needed Indians also. The first task assigned to the natives was to educate the foreigners about the lay of the land, without which knowledge their military might would be useless. In 1774 'Golam Mohamad, a Sepoy Officer' was sent to 'explore the roads and countries of the Deccan' and 'to gain intelligence about the Mahratta powers' (2a:30). In the 1780s, Thomas call, surveyor-General of Bengal, while working on his Atlas of India employed 'Munshys to survey some roads between places well ascertained in the Map' and procure 'some very useful information'. The Company reimbursed his expenditure of Rs. 12000[2a:286]. In 1791 the Bengal surveyor Reuben Burrow while budgeting for his journey asked for 'a Moonshy at Rs. 25 a month' adding, 'The last article is more necessary than at first sight may appear, as it is often requisite to send a Moonshy to make enquiries and to take bearings, and to get copies of routes etc' [2a:286]. 'A properly instructed native' Mirza Mogul Beg collected data between 1786 and 1796 that went into 'A map of the countries to the West of Delhi, as far as Cabul and Multan', prepared by Francis Wilford in 1804 [2a:234].

The most spectacular use of the native surveyors was by Col. (later Lt. Gen.) Charles Reynolds, Surveyor General of Bombay, who employed them for 12 years from 1795 to 1807 to collect data for a large-scale map of western India, especially of territories outside the Company's control. He even offered to pension them off on his own. As a part of this work, Reynolds discovered that Ghaggar does not cross the desert to reach the sea as had been supposed by earlier geographers, but instead loses its way in the sands near Sirsa. Reynolds received the princely sum of two lakh rupees for his valuable map [2a:378].

On the other end were Company Surveyors who hired 'Native Assistants' or 'harkaras' (messengers) to do the legwork. The Company refused to reimburse these expenses. It was one thing to pay for inside information on the Mahrattas, but the Company had no intention of spending its hard earned money on such useless piece of information as that the rivers Sone and Narmada do not spring from the same place as Rennel had supposed but arose 40 miles apart [2b:354]. The Company not yet sure of itself was never very comfortable with the use of the Natives, which though convenient and economical, was risky. While adding to the knowledge of the Europeans they might become knowledgeable themselves, or worse, sell the information to the French or Dutch rivals. For the later reason, half-castes were not employed. Madras Presidency solved its problem of manpower shortage in a far sighted way. Madras Observatory ran a surveying school from 1794 to 1810 to train teenager European orphaned boys as practical revenue surveyors. Note that this school was not for Indians. Those were the days—over by 1830— when the word native denoted India-born irrespective of the ethnicity. Finally in 1813, the use of harkaras for survey work was banned, 'as Government were anxious to prevent the Natives from obtaining, or being taught, any knowledge of the kind' [2b:355]. Only the Company's own covenanted or military officers could carry out surveying and map making. The role of the Pandits ('educated Hindus' regardless of the caste) and Munshis ('educated Muhammadans') was over for the time being.

Simultaneously, native help was commissioned to acquaint the new rulers with the people, and their customs and laws. A 'Muhammadan Madrasa' was opened at Calcutta in 1781 and a 'Sanskrit College' at the Hindu holy city of Banaras in 1791, so that bands of young Hindus and Muslims could separately collect the traditional information from their elders and pass it on to the British. Note that English was not taught at these institutions. This phase of native education in which non-English knowing Indians were pressed into service may be called 'the moon-shee phase', advisedly using the old spellings to underline the intended meaning.

Once the East India Company became a ruling power, the question of English education for the natives was bound to arise. In 1792, one of the Company Directors bluntly expressed the argument against educating the natives[3]. 'We had just lost America from our folly in having allowed the establishment of schools and colleges, and that it would not do for us to repeat the same act of folly in regard to India ... if the Natives required any thing in way of education, they must come to England for it.' With the final defeat of Mahrattas in 1817-18, the British hold on India became complete and unassailable, and the British could afford to relax. The Governor-General, Lord Hastings, could now loftily announce that the Government did not consider it necessary to keep the Natives in a state of ignorance in order to retain its own power[3]. As a matter of fact, services of Indians were now required in running the administration. This was the beginning of what we may call the 'baboo phase' of native education under British auspices. As befits a cautious and clever ruler the transition from the moonshee phase to the baboo phase was to be effected in an unobtrusive manner, and with the full and active support of the native leadership. On 20 January 1817, Hindu College was opened at Calcutta. Its prime mover was Raja Ram Mohun Roy (1772/74-1833), who however kept out of the picture for fear of 'alarming the prejudices of his orthodox country men.' Earlier the Company had hired Hindu and Muslim boys to attend oriental colleges. Now, upper-class Hindu boys paid from their own pocket to receive English education. The college started receiving Government grant in 1824, and science classes were started. (Finally in 1855 Hindu College was converted into government-owned Presidency College).

Once the British supremacy was established and survey work expanded, need for involving the Indians themselves was increasingly felt. After all, you cannot entirely dispense with the natives in their own country. A major factor in their favour was the climate: 'their service will prove of the greatest use in exploring the wilds... of Bustar, etc., whose dreadful climate no European constitution could possibly sustain for any length of time' [2c:388]. The British surveyors naturally argued for the use of the natives: 'The advantages derived to Government are... apparent... opening a new field for... natives, teaching them a profession hitherto unknown to them in this Presidency... and allowing Government to take advantage of the cheapest agency... obtaining correct surveys of the land, on which the principle revenue of the State depends... and a properly authenticated survey, so necessary to the due administration of justice' [2c:389].

The policy found support at the highest level. In 1829, Lord William Bentinck, Governor-General of India, wrote in a minute on the organization of the survey: 'It is by a more enlarged employment of the native agency that the business of a Government will be at once more cheaply and efficiently transacted' [2c:388]. The 1830 reorganization of

Survey with George Everest at the helm required immediate use of the 'native agency'. Although field data were being collected by the British surveyors themselves, they had no time to sit down and reduce the data. Arrears had in fact piled up for the previous eight years. It was therefore decided to set up a computing office as distinct from the field staff. When the Government expressed the hope that 'all requisite computers may be drawn from existing establishments under this Presidency', Hindu College was ready to fulfil it.

Offer of employment as Computers was sent to a number of students; salary was to be Rs 30 p.m. during a 6-month probation, then Rs. 40. Radhanath Sickdhar (his spellings) and six other students of Hindu College joined at the end of 1831. Sickdhar's case is well known. Exceptionally brilliant, he was made a Sub-assistant at GTS after his probation at a salary of Rs. 107 p.m. He was then 19 years old. He rose to become Chief Computer when he was transferred to Calcutta in 1849 to hold charge of the Computing Office. He retired in 1862 and died in 1870. A bachelor, Sickdhar became thoroughly European in outlook, and began to take English food. 'Col. Everest was at first dissatisfied but afterwards admitted me in his own table' [2d:461]. A legend has grown that the height of Mount Everest was computed by Sickdhar. This is no doubt an attempt to push the most deserving peripheral native into a nuclear role. Unfortunately, the story is not true; the height was calculated at Dehra Dun, after Sickdhar had been posted at Calcutta.

The career-graph of other Computers is instructive [2d :342]. After seven years of service, six were still getting only Rs 40. Five of them quit in 1838 to accept the newly established post of Deputy Collector in the revenue department. The seventh one, Nil Comul Ghose, who was getting Rs 100 p.m, also left. The GTS recruited another Indian, Ram Dayal De as a Subassistant in 1840, but dismissed him in 1844.

The Surveyor-General's Office naturally took interest in science teaching at Hindu College. A European computer and sub-assistant, Vincent Louis Rees, was entrusted with the task of helping in the training of the Bengali Computers. He also taught mathematics at Hindu College, from where he earned a salary of Rs 300 in addition to his GTS salary of Rs 318 p.m. [2d: 462]. The science teaching was apparently not substantial. Twenty years later, in 1855, Mahendralal Sircar, much interested in science, left the Presidency college to join the Medical College, saying that the principal object of education was to teach the pupils how to read and write the English language [4 :11].

While in general Indians were kept out of actual field survey work, there was one type of survey which they alone could do. And that was the surreptitious survey of the trans-Himalayan regions, where Europeans would have been immediately spotted and killed. This work was of great strategic importance, and necessary to fill the gap between the Indian and the Russian surveys. With characteristic British thoroughness and disdain these surveyors were only taught how to take the observations; they were not taught how to reduce the data lest they cheated. When exceptionally useful, they were rewarded with scientific medals, khitabs, and jagirs. Otherwise, even their names are not recorded; they are indicated merely by capital letters.

It will appropriate here to give some details [5 : 148; 6]. 'During the year 1876 one of the trained native explorers of the Great Trigonometrical Survey named the Mullah ascended the Indus river from the point where it enters the plains of the Punjab at Attock to the point where it is joined by the Gilgit river'. In 1877 'M-S-, a native gentleman of the Muhammadan faith, and of much repute among his co-religionists' explored the areas beyond Hindu Kush. He was presented with one of the two medals which were placed at the disposal of the Surveyor General of India by the Venice International Geographical Congress for award to meritorious Native explorers. We do not know the name of this gold medalist but the case of Nain Singh and Kishan Singh is well known. They were called Pandit brothers. They are however neither Pandits (in the sense of caste appellatoin) nor brothers (they were cousins). A native officer of the Survey, Sub-surveyor Imam Baksh Bozdar took part in eight different expeditions during 25 years of his service. On his retirements in 1884 he was given a grant of 250 acres of land in the Dera Ghazi Khan district (now in Pakistan), and the title of 'Khan Bahadur'.

The establishment of astronomical observatories at Lucknow (1834), Trivandrum, and Hyderabad (1901) by Indian aristocracy also rightly belongs to the peripheral native stage, because although the ownership was Indian, the control was European. There was no attempt to introduce the Indian to modern astronomy. Lucknow Observatory closed down as soon as the instruments and novelty wore off. Trivandrum met similar fate as far as astronomy is concerned. But being close to the magnetic equator, provided valuable magnetic data. Nizamiah Observatory at Hyderabad was attached to the Osmania University and had a rather unspectacular existence. It however did participate in the international Carte du Ciel to prepare a photographic star map of the sky[7].

Except for clandestine activites outside the boundaries of British India where ethnicity was a crucial factor, the role of Indians in the scientific pursuits remained peripheral. However, as the needs of the Empire grew so did its perception of the abilities of the natives. The scientific content of the British administration in India increased steadily ; and with it increased the role assigned to the Indians. As a first step, the natives moved from being coolies to calculators. In the second, they graduated to become doctors and engineers to work on the network and engineers to work on the network of railways, telegraph, roads and canals.

It is noteworthy that the first Indian fellowship of the Royal Society of London belongs to this stage. Ardaseer Cursetjee (1808-77), marine engineer at Bombay, was elected FRS on 27 May 1841. The present image of the Royal Society as a club of distinguished scientists does not go back to the early half of the 19th century when it was also a club of gentlemen curious in natural history, well acquainted with mathematics and engineering or conversant in various branches of experimental philosophy.

Cursetjee belonged to the famous Parsi family of Wadia shipbuilders.[9] Cursetjee was brought up and educated in the Hon. Company's service. He was however more interested in the newly introduced steam machinery than in shipbuilding and fortunately for him his interest converged with the Company's need. Cursetjee was requisitioned by the newly established Elphinstone Institution to teach practical sciences. The Company funded his one year visit to Britain from December 1839 to November 1840 during which he visited various royal dockyards and private foundaries while in England, he was selected for the post of Chief Engineer and Inspector of Machinery in the Company's steam factory and foundry at Bombay. His salary was to be 600 rupees a month, more than seven times his then salary as an assistant builder[8]. Cursetjee took his appointment on 1 April 1841. He was the first native to be placed over Europeans. His staff consisted of 'one chief assistant, four European foremen, one hundred European engineers and boiler makers, and about two hundred native artificers'.

He was elected a fellow of the Royal Society on the recommendation of James Walker, the President of the Institution of Civil Engineers. Cursetjee's certificate of nomination refers to his journey to England, 'to acquaint himself with the arts and manufactures of Europe with the view of improving his own country and his countrymen, his being a gentleman well versed in the theory and practice of Naval Architecture and devoted to scientific pursuits.....and having otherwise promoted Science and the useful arts in his own country to which he has just returned, ...' In terms of the directions issued by the Royal Society in 1839. Cursetjee would have been classified 'as a distinguished engineer' and as 'one who is attached to science and anxious to promote its progress'. His fellowship however remained a strictly private honour. It did not advance his professional career in any manner, nor did it make any impact on his countrymen. Cursetjee retired in 1857 at a specially sanctioned pension of two thirds of his salary. He died on 16 November 1877 at Rickmond England, where he had eventually settled.

The British timed their operations well. When upper Ganga canal was being dug, an engineering college was set up at Roorkee. When wood was needed for the railways, a forest school was opened at Dehra Dun. It is no wonder that the British emphasized higher education among selected Indians rather than removal of mass illiteracy, which would harm their interests. The Sahib's faith in the Baboos was fully justified. During the 1857 upheaval, it was an Indian, Seebchunder Nandy (1824-1903), who kept alive the vital telegraph link between Calcutta and Bombay.

Nandy was born in a poor family in Calcutta, in 1846, he jointed government service in the refinery department of the Calcutta Mint under Dr William Brooke O' Shaughnessy (1809-89) who was also the professor of chemistry at the Medical College. When in 1852, the Company authorized the construction of the first telegraph line in India under O' Shaughnessy, he placed Nandy in charge of the work. It was Nandy who sent the first signal from the Diamond Harbour end of the telegraph line. The message was received at Calcutta in the presence of the Governor-General Lord Dalhousie and O' Shaughnessy. Immediately afterwards Nandy was appointed Inspector in charge of the line and entrusted with the task of training other signallars. In 1853, O' Shaughnessy became the Director-General of Telegraphy. Two Englishmen were appointed Superintendent and Assistant Superintendent, but Nandy continued as Inspector. Nandy became Assistant Superintendent in 1866, retired on special pension in 1884 when he was made Honorary Magistrate. On 28 February 1883, he was made Rai Bahadur. He died of plague on 6 April 1903 during the Calcutta epidemic. Note that while the Government kept him in his place in its hierarchy, he was given honours which will raise him in his social hierarchy.

Interestingly, on retirement Nandy changed the spellings of his name from the anglicized Seebchunder to the phonetically more correct Sib Chandra. When the Calcutta corporation decided to name a lane in his honour, it bypassed the problem of the spellings by opting for the colloquial Sibu Nandy. Even in the post-independence India, the harnessing of the native by the colonial Government has not been a topic of much comment. An official history of Indian telegraph written by Krishnalal Shridharni in 1953 (with a foreword by Jawaharlal Nehru) gushes about Nandy's role in the first telegraph line: 'History was made with an Indian at one end of the line and an Englishmen and Irishman at the other'. The incongruity of this can be seen from an imperialist comment on what the Indians prefer to call the First War of Independence. Sir John Laird Mair Lawrence (1811-79) who as Chief Commissioner saved Punjab during the mutiny and later (1864-59) served as Viceroy of India said 'The telegraph saved India' [for the British, that is][11]. If the Mutiny had come 10 years previously when the railways and the telegraph had not yet been introduced it might have succeeded.

The simultaneous use by the British of science as well as the natives brought the two into contact. This point is tellingly brought out by the contrasting case of two 19th century Indian astronomers[7]. Samanta Chandrasekhar (1835-1904) was born in the small village Khandpara, some 50 to 60 miles west of Cuttack. The only astronomy he could learn was the pre-telescopic one. Following in the footsteps of Bhāskara (b. AD 1114) and using primitive instruments he completed at the age of 30 his *Siddhānta Darpaṇa*, containing 2500 Sanskrit ślokas of various metres, including 2284 of his own composition. He was looked down upon by his kshatriya clansmen including his nephew, the King, for taking to a brahminical profession . The Raja of Puri bestowed on him the title Harichandana Mahapatra. In 1893 the Viceroy issued a Sananda conferring on him the title of Mahamahopadhyaya, a title normally reserved for Brahmins. A year before his death, he was sanctioned a monthly pension of Rs 50 'in view of the high social position of the Mahamahopadhyaya' with the Vicerory explaining to the Secretary of States for India:

> The case being a curious and interesting one of devotion to learning for its own sake, and the Lieutenant-Governor believes that Government in honouring such a student will honour itself... the grant of a pension to such a student would be entirely in consonance with native felling...... we regard the Pandit's work as no means devoid of interest, and even value since it throws light upon the beginning of Astronomy, by showing what can be done by primitive instruments.

In later years, Samanta Chandrasekhar did see through a telescope and bitterly regretted that he had not had the advantage of such an instrument in his younger days.

In sharp contrast stands the case of Chintamani Ragoonatha Charry (1828-80), who was the son of an Assistant at the Madras Observatory. Joining the Observatory as a daily-wager when still a teenager, he rose to become the First Assistant with a monthly salary of Rs 150. His 1867 discovery of a variable star R Reticuli is the first recorded discovery by an Indian: this earned him the fellowship of the Royal Astronomical Society. He set out to update the element of traditional *panchangs*. He compiled a work in Tamil entitled *Jyotisa Cintāmaṇi* (he did not know Sanskrit). He also published an almanac Dṛg-*gaṇita Pancāṅg* with the help of the Nautical Almanac. Charry gave public lectures on astronomy and brought out a book on the 1874 transit of Venus. This book explains the phenomenon by a dialogue between a Pandit and a *Siddhanti* (an astronomer). Originally written in Tamil, it was translated into English and other local languages including Urdu.

It was only natural that while serving the scientific interests of the British. The Indians should think of responding to science on their own. This takes us to the third stage of growth of science in India.

The Indian-response stage

Conquests in India made Britain self-conscious. India had been a fabled country; its subjugation was seen as a proof of the superiority of the British way of life. The British, therefore, set out to impress their values upon the Indians. There were practical considerations too. India was already a thickly populated country, where permanent white settlements were out of question. And after the disastrous Portuguese experience, Britain had no intention of producing a nation of half-castes. It was, therefore essential to involve Indians in the task of ruling over India. Thus inherent in the British rule was the preparation of Indians to eventually overthrow that rule. The preparation, slow as it was, started quite early. In 1774, the Company established a Supreme Court of Justice at Calcutta. It was a revolutionary concept. For the first time in the history of India, there was now a framework of law which did not depend upon the personality of the ruler. Indian lawyers would provide valuable leadership in the years to come.

The offshoot of the introduction of judiciary was even more momentous. It became essential for the Company to familiarize itself with the Hindu (as well as Muslim) law. A digest of Hindu law was got prepared from the Pandits, but no one could be found to translate it from Sanskrit into English. It was, therefore, first translated into Persian and then into English. It was thus clear that Sanskrit was not no an entirely dead language; it had a utility value also. The convergence of the practical need of the Company and the scholarship of Sir William Jones brought about the all-European Asiatic Society in 1784, which initiated researches into Indology (Indians were not admitted till 1829).

Moreover, European men of science were fascinated by the mastery of the Pandits in preparing astronomical almanacs even without knowing the why of it. As early a 1687, a Frenchman Simon de La Loubere (1642-1729) who had gone[13] to Siam (Thailand) as an envoy of the King of France brought back a set of Hindu Mathematical Tables which passed from hand to hand as a sort of historic curiosity until they were explained by Cassini, one of the most eminent astronomers of age[14]. John Warren (1769-1830), a former Madras Astronomer and a blue blooded French nobleman , descended from Norman the Conqueror, took up in 1811 a monumental project on south Indian system of timekeeping. The work won approval from the Pandits who named it *Kāla Sankalita*, and showed their appreciation by offering to pay the expense of the wedding of Warren's daughter. Though Warren had started the work on a call of personal friendship Madras Government decided to fund it for this practical value. It was felt that the work will make Indian calendars intelligible to the Europeans, facilitate a comparison of the European and Indian chronologies and thus be of service to gentlemen employed in the Revenue and Judicial departments.[15]

European interest in India's antiquity had far-reaching influence on the Hindus. The discovery of their past glory, as certified by the Europeans themselves, restored the sense of self-esteem of the Hindus and gave them the courage to look the Empire right into the eye. (It also made Hindus revivalist and increased their distance from the Muslims)[16]. During the first 100 years of their lordship over India, the British introduced the Indians to the English language and literature; to western thought; to India's glorious past; and to modern science and education. It was now for the Indians to prove, to themselves more than to anybody else, that they as the inheritors of a great civilization were capable of becoming full-fledged members of the world's science club.

The very first case of Indian response to modern science came not from intellectually active Calcutta but from still Mughal Delhi. Unlike Calcutta, Delhi had shown no interest in English education. The government therefore decided[17] in 1843 to introduce education through the medium of the vernacular language. Ramchandara (1821-80) born in a respectable but impoverished Hindu Kaeth [Kayasth] family 'maintained himself by wining scholarships and prizes,'[14,18]. In 1844 he was appointed a teacher of European Science in the Oriental Department of [Delhi] College through the medium of the vernacular. In 1850 he published in Calcutta his mathematical work *Problems of Maxima and Minima,* which though criticized in *Calcutta Review,* was well received in Europe, thanks to the efforts of India born famous English mathematician Augustus de Morgan. Morgan saw in it 'merit of a peculiar kind, the encouragement of which was likely to promote native effort towards the restoration of the native mind in India. Accordingly the Court of the Directors sponsored in 1859 a reprint of this work in England for circulation in Europe and in India. 'Also the Honourable Members of the Court of Directors were pleased to sanction a *khillut* (dress of honour) of five pieces to be presented to him and also a reward of Rs. 2000. Ramchandra's response was typical : 'I am much thankful to the English Government that they are so bent upon encouraging science and knowledge among the native of this country, as to take notice of a poor native of Delhi like myself. Ramachandra's second book *A New Method of the Differential Calculus* appeared in 1861 [ref. 4]. In 1858 'after the Mutiny has subsided' Ramchandra was appointed teacher of mathematics in the Government Engineering College Roorkee, and about the end of the same year, headmaster of the newly established school at Delhi. In 1863 he was appointed tutor to the Maharaja of Patiala, where he also served as the Director of the newly established Department of Public Instruction. He died on 11 August 1880.

In spite of his own achievements, he can hardly have been a role model for his countrymen. The contemporaneous impact of Ramchandra, in the premutiny Delhi came not because of his Urdu writings or mathematics, but because of his conversion of Christianity, in March 1852, for which he had to 'leave his mother, wife, children and brothers and meet with great opposition from his castemen, his name was held up for a warning as to what results might happen if the English language were allowed to be taught to the young.' Ramchandra barely escaped the wrath of the 'mutineers', thanks to the timely help given by his pupils. Dr Chaman Lal, a fellow Christian, was however not so lucky. He lost his life (4 : 251-4).

It became clear to the Indian opinion makers quite early in the game that the English education being imparted to them was inadequate. Thus the *Hindu Patriot* wrote on 6 April 1854....The end aim of their [native's] education is to make them either accountants or letter writers....The resources of the country will never be developed unless the children of the soil learn to develop them'. The role of science as a social reformer was also noted. Rajendralal Mitra (1829-91), who later became the first Indian President of the Asiatic Society, wrote[19] in 1854 that 'practical training will be an effectual means for the removal of those barriers to progress which have been created by the ancient system of confining the cultivation of industrial art to particular classes, and those the least educated in the community.' Mitra had just established an Industrial Art Society where the Indians could learn practical skills[20]. Here was thus an attempt to create an Indian infrastructure of science parallel to that of British India. Such attempts were few, half-hearted, and ineffectual.

The Bengalis believed that since they knew Shakespeare as well as, if not better than, the British themselves, their edifice of science should be an extension of and supported by, the British effort. 'Science application' was to be left to the Government; it was 'science speculation' that needed cultivation. The leadership came from Dr Mahendralal Sircar (1833-1904), a poor orphan, who owed his station in life to western education. As a 1929 biographical sketch of his puts it (4 : 41) ' The object of Dr Sircar was not to establish a technical seminary and thus make his countrymen a nation of artisans and mechanics, but to diffuse among them the ascertained principles of Western Science in the hope that after mastering what had already been discovered by the Europeans, the Hindus might, in course of time, add their own discoveries to those of their fellow brethren of the West'.

Sircar was a man of strong convictions and tenacity. An MD from Calcutta Medical College, he had the courage to face professional ostracism for his advocacy and practice of homeopathy. (He charged Rs 100 a day for out station visits). In 1869 Sircar came up with the idea 'of a national institution for the cultivation of science by the natives of India', and enlisted the support of Sir Richard Temple, the lieutenant-governor of Bengal during 1874-77 and a 'man of wide sympathies, deep culture and high education. Sircar was 'well aware that official support was the only key to unloose the purse-strings of his wealthy countrymen'. The enlightened middle class will support the project on merit. 'But the merchant princes and landed aristocrats, hungry for title and fame, would slavishly follow the footprints of the official head of the province' (4:32) Finally, 'after six years of restless propaganda,' Indian Association for the Cultivation of Science (IACS) was inaugurated in January 1876. The rather peculiar name for a research laboratory needs comment. In 1876 itself a political organization of the educated middle class named 'Indian Association' was set up by Surendranath Banerjee. The IACS was the scientific extension of the political movement. Members of the rival Indian League unsuccessfully sought the establishment of a polytechnic instead (4:49)

To Sircar's great disappointment, IACS failed to materialize as a research laboratory; it remained a forum for popular and college-level lectures. In 1893 IACS was recognized by Calcutta University as a teaching centre. Two eminent scientists of the day Sir Jagdish Chandra Bose (1858-1937) and Sir Prafulla Chandra Ray (1861-1944) lectured at IACS though they carried out their research work at their own college, the Presidency College. (On retirement Bose set up his own research institute), Another visiting lecturer was Pramatha Nath Bose, a senior government geologist. P.N. Bose is a good example of the transition from the peripheral stage to the response stage. On his retirement from the Geological Survey of India. P.N. Bose was offered appointment by the Maharaja of the mineral-rich state of Mayurbhanj: It is said that Bose educated Jamsetji Nusserwanji Tata on the iron deposits of the area[21]. This resulted in the establishment of the Tata steel mill at Jamshedpur, in 1911.

Another striking example of increasing Indian acquaintance with science is provided by Kavasji Dadabhai Naegamvala (1857-1938), a physics teacher at Government College of Science (now Engineering College) Poona. A protege of the influential British solar physicist, Sir Joseph Norman Lockyer, he was in 1888 provided with an astrophysical observatory by the Bombay government. Significantly, half of the money for the observatory came from Indian donations. Naegamvala regularly sent data to Lockyer, and records show that in 1899 Lockyer even complained to the Director of Public Instructions (E. Giles) against unsatisfactory work at Poona. Naegamvala however did make his own observations and in fact showed that Lockyer was wrong regarding his hypothesis about nebular lines in Orion. The observatory was closed down in 1912 on Naegamvala's retirement and instruments sent to Kodaikanal.[7]

Indian initiative for technical education came from Jamsetji Nusserwanji Tata (1839-1904) who himself was a product of English education and made a successful transition from trading to manufacture, becoming in 1911 the first Indian owner of a car. The Tatas set up a technical university at Bangalore, calling it Indian Institute of Science[21], because the word university at that time had the connotation of being no more than examining body. The Bangalore Institute, which admitted its first students in 1911, represented the investment of 'Parsi money' for a general cause, and that too outside the Parsi mass-base of Bombay. The choice of Bangalore was made possible by the munificence of the Maharaja of Mysore whose Inspector-General of Education, Dr Hormusji Bhabha (Dr Homi Bhabha's grandfather) was related to the Tatas by marriage. (Bhabha's daughter Meherbai married Jamsetji's eldest son Dorab Tata, in 1898.) Here, the control was British, though the students were Indian. (Interestingly, this technical university established by the Tatas in the heyday of the British imperialism was named Indian, whereas the research institute set up on the verge of India's independence, on the suggestion of their nephew by marriage, was named after themselves.)

While the 19th century IACS had failed to take off as a research laboratory, it came in handy for Chandrasekhara Venkata Raman (1888-1970), a teenager Indian government official, to do part-time research in physics that led to a Nobel prize. At about the same time Calcutta University was transformed into a postgraduate studies and research centre by Sir Asutosh Mookerjee[22] (1864-1924) who was the University's honorary Vice-Chancellor during 1906-14 and 1921-23. Mookerjee was appointed a High Court Judge in 1904. He had earlier written research papers in mathematics under his pre-anglicized name, and given lectures at IACS. He turned to law only when he failed to get an appointment at IACS (which had no money) or at the Presidency College (which would not offer him the same status and pay as to the Europeans). As Vice-Chancellor, Justice Mookerjee persuaded , not surprisingly, wealthy lawyers to make endowments to the university for setting up (1914) University College of Science and Technology where the professorships will be held by Indians themselves. Raman resigned his government job to become a professor at the University; in the process his salary went down from Rs 1100 to Rs 600 per month.

The pinnacle of Indian response to modern science was the path-breaking work of Raman, Megh Nad Saha (1893-1956), and Satyendra Nath Bose (1894-1974). It is noteworthy that none of the European professors stationed in India made any significant contribution to scientific research. Available statistics provides insight[23] into the crucial decade of the 1920s. In the period 1920-29, a total of 19 Indians obtained doctorate in physics. (The way physics is defined in the original database, it includes astronomy and even chemistry.) Of these 19, 10 obtained their degree from India Universities, seven from UK, and two from Germany. (In Japan, 22 obtained their doctorate within the country, three abroad). In the twenties a total of 659 research papers were published, out of which only 26% were published in Indian journals. (In contrast, out of 519 Japanese papers, 77% were published within the country). Indian scientists collected a total of 308 citations. Most came from US, followed by Germany and UK. Interestingly in the pre-Nobel prize decade, Raman's citations (53) are slightly less than Saha's (56). Within the country, Raman got more citations, 25 as against Saha's six.

Although Indians have kept hoping for an encore, it is important to keep in mind that these spectacular achievements were made possible by a fortuitous combination of factors. Those were the days when frontline research was just a short step ahead of MSc level studies. Raman published his first research paper when still a student. Saha and Bose translated Einstein's German research paper on relativity for use as course material. (This was the first translation of Einstein into English). Experimental sciences were at a stage where they required elementary infrastructural support. Industrial back up needed for researches of J.C. Bose, P.C. Ray and C.V. Raman was easily available in the country at the level of government science or college laboratories. It was science application under the aegis of the British Indian government that made science speculation by Indians possible. Finally, the take-off stage of modern physics coincided with the peaking of Indian nationalism. Science was seen by Indians as an extension of their freedom struggle. Making scientific discoveries requires a certain amount of defiance. The suppressed anger against the colonical rulers provided that defiance. Paradoxically, while Indian achievements in science were perceived as a symbol of nationalism, at the same time the honours bestowed by the colonial rulers were converted and even flaunted. (P.C. Ray is probably the only exception.)

The most extraordinary example of Indian response to modern science is the college-dropout, creative mathematical genius Srinivasa Ramanujan (1887-1920) whose introduction to modern mathematics at the age of 15 began and ended with Carr's Synopsis of Pure Mathematics' which a friend borrowed for him from the library of the Government College at Kumbhakonam[4]. Fortunately, there were around men of science who had the sense to put him in touch with the mathematicians at Cambridge. One wonders as to what a Ramanujan will have done if he had been born a 100 years earlier. The fact remains that Ramanujan became a source of inspiration for all aspiring Indian scientists.

A corollary of the science's being treated as an extension of the nationalist movement was that it was seen as a pure intellectual exercise, rather than as a means towards production of wealth. Thus J.C. Bose refused to patent his discoveries, and when patents were obtained in his name refused to encash them [4:91]. Later when Sir Shanti Swarup Bhatnagar (1894-1955) received a large sum of money for industrial consultancy, he gave it away to his University, maintaining, in the words of his son, that 'scientific work loses its altruistic and truly cultural character if the worker becomes money-minded and begins to get financial benefits for himself[24]. (Bhatnagar was later asked to head India's efforts at industrial research, which, not surprisingly, did not become money-minded).

An exception to science-as-a cultural activity syndrome was P.C. Ray who advocated coupling of scientific research and industrial production, and himself set up a number of production units. (Sir M. Visvesvaraya is another example).

It is interesting to note that science meant different things to different people, depending upon their social and cultural background. To Raman, born in a caste associated with learning, science was a means of establishing a gurukul on his own terms. To Saha, born in a caste considered socially backward, science was an instrument of social change. To Homi Jahangir Bhabha (1909-66), like Nehru an aristocrat by upbringing, science meant building national institutions under the auspices of independent India's government.

Since the main purpose of history is to influence contemporary events, it may not be out of place to make some comments on the post-independence Indian response to science. One may right away enunciate a principle : The purpose of science is to produce wealth. Purpose of this wealth is to support science. A society whose economy does not depend on science cannot make a sustained contibution to science. Over the years the infrastructure required by science has moved from the level of college laboratory to sophisticated industry. A certain level of industrialization is therefore necessary to set up science laboratories, without which scientific research is not possible.

Then there is also the question of the right frame of mind. A science-dependent society is characterized by boldness, team spirit, and recognition of and reward for merit. These qualities are essential for scientific innovation. In contrast, a society whose production of wealth depends on natural elements still thinks in terms of God above and zamindar on the earth. In such a society, people are timid, afraid of new ideas and new things, obsessed with rituals rather than results, and most comfortable in a demerited patron-protege relationship. In a society that is materially semi-industrial but intellectually pre-industrial but intellectually pre-industrial, there will not be very many chances of making scientific discoveries. Even if a discovery is staring him in the face, it will be missed by a scientist, who being a typical product of the system, is not prepared for the unprecedented. Once a while an exceptional scientist may make a major discovery. The beneficiaries of this discovery will be the nations who are already geared for it. By definition, a major discovery will take the subject fast forward, making the next breakthrough more difficult and less likely to arise in semi-industrial society.

Indian perception of science has been based not on what the British did in Britain but on what the British did to India. Therefore science was not seen as a new means of production of wealth but as an agency that had destroyed traditional Indian manufacture and annihilated India's artisan classes. That is why only the speculation part of science was appreciated, while the application part was ignored. Another reason for this attitude is the fact that traditional manufacturing classes were not represented at all in the English-speaking new middle classe. Winning freedom through nonviolent means has certain disadvantages. There is continuity even where discontinuity is needed. Unfortunately, even after independence, the role of science as producer of wealth was not recognized. Free India has failed to harness science. Accordingly it has failed to enrich science either.

Critique

We have argued that the introduction and growth of modern science in India was with a view to serving the colonial interests. Thus the British-sponsored science, by the very reason of its existence, was field science. Geography, geology and geodesy, botany and zoology, archaeology, medicine and even astronomy -all these stemmed from the physical and cultural novelty of India. This science was colonial in the sense that its agenda was decided on grounds of political and commercial gain. But the studies made in India could not have been carried out anywhere else. The European scientists at work in India felt and acted like pioneers in an exotic land, and were not always on the best of terms with their counterparts back home.

The role assigned to the Indians in this State science was clear cut. They were to provide cheap labour which they did most conscientiously. The Superintendent of the Geological Survey had a very low opinion of the natives. He doubted whether the natives could ever prove competent for independent field work, which required 'the very quality which more than any other makes the western man differ from the eastern'[25]. However there was a general encouragement to the native from the enlightened British bosses. Lambton, and then Everest, took good care of their staff. Everest got a native Syed Mir Mohsin Hussain (who did not know English) appointed as the Head of Mathematical Instrument Department and insisted on his being given the same designation as his British predecessor, if not the same salary. The Madras Astronomer continued his chief assistant Ragoonatha Charry in service (even after he had become senile) so that he could get full pension benefits.

The westernization of the Indian middle class was as much a matter of satisfaction to the British as was the physical subjugation of India. It is expected that an Empire will show some respect for the Republic of Science. When the Indians decided to do science on their own initiative, they received encouragement, if not money, from the British. Thus J.C. Bose was retired on full salary, and Raman was Knighted a full year before he got 'Nobelled'. (Contrast it with the case of noted film maker Satyajit Ray (1921-92), who was awarded Bharat Ratna by the Indian Government when he was on his deathbed and after he had received all conceivable international honours).

We have distinguished here between European scientists engaged in Government science; their native scientific assistants; and the Indian scientists who were full-fledged members of the Club of Science. Our model differs from the one given by Basalla[26], which romanticizes science, trivializes the compulsions of colonialism and ignores the racial factor.

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