Science as a Tool in British India

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The production and growth of modern science in India was encouraged by the British with a view to furthering colonial interests. British-sponsored science, by its very nature was field science and its agenda was decided on grounds of political and commercial gain. In the pursuit of this state-sponsored science, Indians provided cheap labour. It was only much later, with the westernisation of the Indian middle classes, that Indians began to pursue science on their own initiative but this was as an extension of the nationalist movement and science increasingly began to be seen purely as an intellectual exercise rather than as a means of producing wealth.

WHILE discussing the impact of modern science on India, it is important to take note of India's role in the development of modern science. The arrival of the first British ship in India coincided with the invention of the telescope in Europe. There were huge profits to be made from trade with India, provided the ocean navigation could be made safe. To survive on a vast featureless ocean, a mariner had to know his latitude and longitude, and for this he needed telescopes, sextants, clocks, and star charts. Farmers, weavers, and other traditional craftsmen in Britain now took to making scientific instruments. Many apprentices in the clock-making trade later became inventors of industrial machines and helped usher in the industrial revolution [1]. Thus it was a clock-maker who helped barber-turned-industrialist Richard Arkwright build his epoch-making 'water frame'. Also, James Watt started his career as a maker of mathematical instruments, like sextants and compasses.

For an invention to make an impact, it should take place at a time when the society has the capital as well as a market. A turning point in the history of India as well in the history of science and technology is the battle of Plassey. Before 1757, Bengal had a surplus balance of payments; its exports exceeded the imports by a factor of four. In contrast, during 1757-80 Bengal pumped in a substantial sum of 38 million pound sterling into England [2]. Its effect was electric.

The first inventor of a textile machine, John Kay, who patented his fly shuttle in 1733, barely escaped with his life, finally dying pennyless in far-away France. His machine was smashed by other weavers [3] who sensed that it would drive them out of the limited domestic market they all competed for. But by the time John Hargreaves made his spinning jenny (1764) times had changed. His very first machine was also smashed, but very soon he had weavers back at his door, this time asking him to make machines for them. They could now form a guild and jointly enjoy the overseas market. It is thus no wonder that cure for scurvy, the dreaded disease of the mariner (1754) came just before Plassey, while spinning jenny (1764), water frame (1769) and steam engine (1769) soon followed.

The money from trade with the east Indies created a wealthy middle class in Europe whose way of looking at things was different. It was for the first time in the history that human prosperity depended not upon the goodwill of the king or god, but on human skill. Since the source of money was science, the pursuits the leisured class chose were also scientific. The new craftsmen became rich and respectable; and the new wealthy became patrons of science. It is significant that the profits of the makers of scientific instruments did not come from the government, who paid less but imparted prestige and recognition. The profits instead came from the private buyers [4]. It was thus the accumulated wealth of India that funded the industrial and scientific revolutions of Europe. Note that the scientific revolution came after the industrial revolution. The existence of a wealthy middle class, independent of the government, is a prerequisite for the growth of science. The purpose of science is to produce and protect wealth. The purpose of this wealth is to support science.

Western science was not a cut-and-dried product that was taken off the shelf and shipped to India. The British influence in India, modern science in Europe, and the use of science in India all grew together, so that by the beginning of 20th century Indians were ready for a tryst of their own with modern science. We present here a model as a framework for discussing the advent and growth of modern science in colonial India. The model distinguishes between three mutually overlapping stages of development.

The first stage here called 'the colonial-tool stage' encompasses the whole span of European presence in India and 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 characterised by scientific activity by Indians themselves and on their own initiative. We shall now discuss each stage separately, drawing illustrations mostly from the Survey of India [5], which represented science in the most dedicated service of the state.

Colonial-Tool Stage

The gold coins minted by the Portuguese for use in India depict the armillary sphere, the basic instrument of navigation used for determination of the latitude[6]. It was Portugal's way of paying tribute to a science to which it owed its power. The Portuguese arrived in India even before the Mughals did, loved Christianity more than they loved Indian territory, and did not know how to successfully deal with the scurvy deaths on the sea.

The earliest men of science from Europe were the missionaries of the Society of Jesus, who first arrived in 1542 and remained active for more than 200 years[5a]. In 1759 the king of Portugal banished all Jesuits from Portuguese colonies; and in 1773 the Pope banished the Order altogether. It was revived in about 1818, with the first English Jesuits arriving in Calcutta in 1833. The Jesuits were the only European men of science in India who did not have a materialistic axe to grind. No wonder their work did not have any contemporary significance. The Jesuit geographical data were dug up from the archives and put to use in the mid-18th century when knowing India became a paying proposition.

The Portuguese success brought British and the French traders to India. The parent 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. It paid to join the company, and it paid to know astronomy.

With the post-Aurangzeb collapse of the Mughal empire, the European 'vaishya' outfits developed 'kshatriya' ambitions and got down to the task of acquainting themselves with their future empire. 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 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[5a].

Astronomy was the first modern science to be brought to India for use as a geographical and navigational aid[5a]. Its 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 a jagirdar. The company bahadur was fully conscious of its needs: survey of its present and future lands, safety navigation; increased revenue; and proper administration. The first need was geographical knowledge. In 1757 itself when Clive was still at the nawab'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 Rannell was made the 'Surveyor General of Bengal'.

Surveys were continually required for military purposes. Geographical location of important places in the country were 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 surveys can be gauged by 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 6,000 to a surveyor for a map of Mysore accompanied by a memoir[7].

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, Major William Lambton modelled his on the lines of the recently started surveys in France and England. The Trigonometrical Survey of Peninsular India 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 January 1, 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 who was also 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 the '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 and to a mathematical model of the earth, known as Everest geoid.

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[5a].

> 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.

The Coromandel coast is rocky full of shoals, 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 was brought from England, on free passage and equipped with his instruments.

Since his work required a reference meridian, an astronomical observatory[8] 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", the key objective was left unstated: so as to promote the company's profitability.

Science was only a part of the duties of the company's officers. The value of various services can be gauged by the value placed on them. Topping's monthly salary as the 'Company's Astronomer and Geographical Marine Surveyor' was 192 pagodas (1 pagoda = Rs 3½; £1 = Rs 8). He got double this amount (Rs 400 pagodas) as the 'Superintendent of Tank Repairs and Water Courses'. An additional 100 pagodas came from the superintendence of the surveying school[5a].

In the early years, the observatory was no more than a surveying outfit. This role ended with the 1830 reorganisation of the GTS, but navigational needs were still outstanding. Increased sea-trade activities of the British required familiarity with the southern skies. In 1844 after 14 years of labour, Thomas Glanville Taylor (FRS) produced the celebrated Madras catalogue giving positions of about 11000 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[8].

The observatory was now redundant. Even the British astronomers who now had 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[8]: "I earnestly hope that the rulers of India will take a higher and more extended view of the matter, and consider what is due to this country... ." This rhetoric, and the workshops of the public works department, ensured the observatory's survival but not its prosperity.

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 would 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[8]. A solar observatory was set up at Kodaikanal in 1899.

Once the Trigonometrical Survey was begun, the government lost interest in the Madras observatory. In 1801 the 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 up to Rs 800, the survey chief's had jumped to a substantial Rs 2,565. 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[9].

The last word on where pure science stood up *vis-a-vis* the applied belongs to teh 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 a field tour. On his return Everest made a strong protest against the loan, saying[8],

> ... 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...

From geography to geology was but a natural step. In 1818 Henry Voyesey, 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". 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 of the person of 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 hill carriage, and free issue of instruments and stores, to say nothing of an advance of Rs 2,500 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 that working either might injuriously affect important articles of British export". Laidlaw did not pay attention to anything, and was dismissed after two years[5c].

Voyesey'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 realisation 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[10]. (The survey of India, the geological survey, and the medical service, were the only science services in the pre-mutiny 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. As was the case with GTS earlier, the geological survey arranged for lectures at Presidency College, Calcutta[10].

The company's interest in Indian botany did not arise from medicinal and commercial plants as was the case with the Portuguese, but from wood. Shipments out of Calcutta required the building of freight vessels for which teak was bought at a high price from Burma. Could teak be grown near Calcutta itself? To find an answer, a botanical garden was set up at Calcutta[10]. (Years later decline in availability of timber for ship building on the Malabar coast made the government wise to the destruction of forests and led to the appointment of A Gibson as conservator of forests for Bombay presidency)[7].

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 (Benjamin Heyne) was ordered by the governor general to accompany the surveyor, with the following instructions[5a]:

> 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].

In the next 50 years 'systematic, geographical and economic studies' of the Indian flora were carried out. The company did not mind the 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. It refused to promote a project by Joseph Dalton Hooker and Thomas Thomson for its compilation, notwithstanding a memorandum from the British Association for the Advancement of Science, Hooker's monumental seven—volume *Flora of British India* (1875-1897) had to wait for orders from the secretary of state[10].

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[7], because it brightens a particularly dark period in Delhi. As early as AD 1360, Firishta informs us, when Firozeshah Tughlak cut through a hill with 50,000 men to dig a west Yamuna canal, he noticed bones of giants three yards long. After preliminary survey in 1809-10, restoration work was begun in 1815 and completed in 1827. In the meantime, in 1779, the Rohilla Fauzdar of Saharanpur, Zabita Khan, had set up a public garden at Saharanpur and appropriated the revenue of seven villages for its maintenance. Ghulam Kadir, and after him the Mahrattas, continued the arrangement. In 1823 Lord Hastings converted it into a 400-acre botanical garden (to which was later added a nursery of trees for canal banks).

Hugh Falconer, FRS, the superintendent of the Saharanpur Botanical Garden (who was aware of Firshta's report), and Sir Proby Thomas Cautley, superintendent of canals, collected a large number of fossil bones, 300 of them within six hours. 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. Falconer wanted to devote his full time to his great work Fauna Angiqua Sevalensis, but as a 1878 *Memoir*[7] put it he "was not spared to complete it". This work was edited and published after his death.

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 the council for scientific and industrial research was set up for providing scientific support for the war effect.

We have thus 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. We now discuss the role of the Indians as laboratory assistants.

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". In the 1780s, the surveyor general of Madras employed "Munshys to survey some roads between places well ascertained in the map" and procure "some very useful information". The company reimbursed the expenditure of Rs 12,000. 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". "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.

The most spectacular use of the native surveyors was by Col Charles Reynolds (later lieutenant-general), 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. 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[5a].

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 Rennell had supposed but arose 40 miles apart[5a].

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 they might add to the knowledge of the Europeans they might become knowledgeable themselves, or worse, sell the information to the French or Dutch rivals. For the latter 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[5a,b]. 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". Only the company's own covenanted or military officers could carry out surveying and map making[5b].

The role of the 'pandits' (educated Hindus, regardless of the caste) and 'munshis' (educated muhammadans) was over for the time being. In the next 15 years, new geopolitical equations were established, and the British grip on India became unassailable. It was only then that 'babus' were trained and pressed into service. As the 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 (1828)

The British surveyors naturally argued for the use of the natives[5c]:

> 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.

The policy found support at the highest level. In 1829, Lord William Bentinck, governor general of India, wrote in a minute on the organisation of the survey[5c]:

> It is by a more enlarged employment of native agency that the business of a government will be at once more cheaply and efficiently transacted.

It is quite remarkable that the needs of the survey were reflected in the company's attitude towards native education.

In the post-Plassey period, it became essential for the British to know India, not only the land but people also. This information can have come only from the Indians themselves. Accordingly there opened a[11] 'Muhammadan Madrasa' (1781) at Calcutta and a 'Sanskrit College' (1791) at Banaras so that band of young Hindus and Muslims could separately collect the traditional information from their elders and pass it on to the British (English was not taught at these institutions). We may call this 'the Moonshee phase' of education in British India with the old spellings being advisedly used to underline the intended purpose.

In 1792, one of the company directors had succinctly expressed the argument against educating the natives; "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". Once the British were firmly entrenched, they shifted gear to impart English education to the Indians with a view to training them for minor jobs in the new administration. This was the beginning of 'baboo phase'.

The period 1813-35 is the transitional period. It was in 1813 that the company acquired an education policy whereby it was asked to spend not less than one lakh rupees on education. (Actually it spent twice the amount during 1813-30)[11]. The ambivalence as to how this money was to be utilised was deliberate. As befits a cautious and clever ruler, the transition from the Moonshee to the Baboo phase was to be effected in an unobtrusive manner, and with the full and active support of the native leadership.

The oriental colleges were slowly anglicised. Unani and Ayurvedic classes were added (1827) to the Madrasa and the Sanskrit College, which then made way (1835) for a full-fledged (western) medical college. Delhi College was started on oriental pattern in 1823; but English was introduced two years later, and science soon thereafter. In 1817 Hindu College was started at Calcutta. Scientific equipment arrived in 1823 and science teaching was started. Interestingly George Everest, who arrived in India in 1806 when barely 16, himself learnt his science from survey-related books available in British. Earlier the company had hired Hindu and Muslim boys to attend Oriental Colleges. Now the Hindu boys paid from their pockets to receive English education.

Calcutta's Hindu College became a trusted source for supplying scientific Babus to the survey. The 1830 reorganisation 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[5d]. (Hindu College was taken over by the government in 1855 and renamed Presidency College.)

Offer of employment as computers was sent to a number of students; salary was to be Rs 30 per month during a six-month probation, then Rs 40. Radhanath Sickdhar 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 per month. He was then 19 years old. He rose to become the 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. "Colonel Everest was at first dissatisfied but afterwards admitted me in his own table[5d].

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[5d].

The career-graph of other computers is instructive. 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 per month also left. The GTS recruited another Indian, Ram Dayal De as a sub-assistant in 1840, but dismissed him in 1844.

The surveyor-general's office naturally took interest in the 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 per month. The science teaching was apparently not substantial. 20 years later, in 1855, Mahendralal Sircar, much interested in science, left the Presidency College to join the Medical College, saying[12] that "the principal object of education was to teach the pupils how to read and write the English language".

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 they were 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[7,13].

It will be appropriate here to give some details[7,13]. "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 College for award to meritorious native explorers. We do not know the name of this gold medallist, 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 appellation) 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 retirement in 1884 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[8,9] 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. 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. Hyderabad observatory was attached to the Osmania University and had a rather unspectacular existence.

Except for clandestine activities 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 the 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 of railways, telegraph, roads and canals.

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 emphasised 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, Sibchunder Nandy, who kept alive the vital telegraph link between Calcutta and Bombay.

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.

Samanta Chandrasekhar (1835-1904) [15,16] 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 Bhaskara (b AD 1114) and using primitive instruments he completed at the age of 30 his *Siddhanta Darpana*, containing 2,500 Sanskrit 'shlokas' of various metres, including 2,284 of his own composition. He was looked down upon by his Kshatriya clansmen, including his nephew, the king, for taking to a brahmanical profession. The raja of Puri bestowed on him the titles 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 Maha-mahopadhyaya", with the viceroy explaining to the secretary of states for India[16]:

> . . . 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 feeling. . . 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[15].

In sharp contrast stands the case of Chintamani Ragoonatha Charry (1828-80) [8,9], who was the son of an assistant at the Madras observatory. He joined the observatory as a daily-wager when still a teenager and 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 elements of traditional 'panchangs'. He compiled a work in Tamil entitled *Jyotisha Chintamani* (he did not know Sanskrit). He also published an almanac *Drig-garita Panchanga* 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, Indians should think of responding to science on their own. This takes us to the third stage of growth of science in India.

Indian-Response State

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 consideration 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 off-shoot of the introduction of judiciary was even more momentous. It became essential for the company to familiarise itself with the Hindu (as well as Muslim) law[17]. A digest of Hindu law was 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 an entirely dead language; it had a utility value also. This 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. Thus, John Warren, a former Madras astronomer and a blue blooded French nobleman descended from Norman the Conqueror, took up a monumental project on south Indian systems of time-keeping. The work won approval from the 'pandits' who named it *Kaala Sankalita*, and showed their appreciation by offering to pay the expenses of the wedding of Warren's daughter. Though Warren had started the work 'on a call of personal friendship' the Madras government decided to fund it for its practical value. It was felt that the work would 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"[18].

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 long-lost sense of self-esteem of the Hindus and gave them the courage to look the Empire right into the eye. (It also created Hindus revivalist and increased their distance from the Muslims).

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 civilisation were capable of becoming full-fledged members of the world's science club.

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 April 6, 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 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 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 Mahendralal Sircar (1833-1904) a poor orphan who owed his station in life to western education. As a 1929 biographical sketch[12] of his puts it "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 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 would support the project on merit. "But the merchant princes and landed aristocrats, hungry for title and fame, would slavishly follow the foot-prints of the official head of the province"[12].

Finally, "after six years of restless propaganda"[12], the Indian Association for the Cultivation of Science (IACS) was inaugurated in January 1876. The rather peculiar name for a research laboratory needs a comment. In 1876 itself a political organisation of the educated middle class named 'Indian Association' was set up by Surendranath Banerjee. The IACS was the scientific extension of the political movement.

To Sircar's great disappointment, IACS failed to materialise as a research laboratory; it remained a forum for popular and college-level lectures. In 1893 IACS was recognised by the 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 [10]. 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 was Bose who educated Sir Jamsetji Nusserwanji Tata on the iron deposits of the area. This resulted in the establishment of the Tata steel mill at Jamshedpur [10].

The lesson was not lost on the Tatas. They set up a technical university at Bangalore, calling it Indian Institute of Science, because the word university at that time had the connotation of being no more than an examining body. The Bangalore institute, which admitted its first students in 1911, represented the first 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, Hormusji Bhabha, (Homi Bhabha's grandfather), was related to the Tatas by marriage. 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 eve of India's independence was named by the Tatas after themselves).

While the 19th century IACS had failed to take off as a research laboratory, it came in handy for Chandrasekhar Venkata Raman (1889-1970), a teenaged 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 (1864-1924) [21] who was the university's honorary vice-chancellor during 1906-14 and 1921-23. Mookerjee was appointed a high court judge in 1904. Earlier, he had written research papers in mathematics under his pre-anglicised name and had 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 it did to the Europeans). As vice-chancellor, Mookerjee persuaded wealthy Indians, especially lawyers, to make endowments to the university for setting up (1914) the University College of Science and Technology where the professorships would 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 1,100 to Rs 600 per month [22].

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 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. Thus, Saha and Bose translated Einstein's German research papers on relativity for use as course material. (This was the first translation of Einstein into English). Secondly, 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. 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 colonial 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 coveted 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 Srinivasan 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 [23]. Fortunately, there were around men of science who had the sense to put him in touch with the mathematicians at Cambridge.

A corollary of sciences 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 the production of wealth. Thus J C Bose refused to patent his discoveries [20], and when patents were obtained in his name refused to encash them. Later when Sir Shanti

Swarup Bhatnagar (1894-1955) received a large sum of money from industrial consultancy, he gave it away to his university, maintaining [24], 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". The only exception to science-as-a-cultural-activity syndrome was P C Ray who advocated the coupling of scientific research and industrial production, and himself set up a number of production units.

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 terms. To Saha, born in a caste considered socially backward, science was an instrument of social change. To Homi Jahangir Bhabha (1909-66), born outside the caste structure but like Nehru an aristocrat by upbringing, science meant building national institutions under the auspices of independent India's government.

CRITIQUE

We have argued that the production and growth of modern science in India was encouraged by the British with a view to furthering 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. Since the natives generally knew their place, there was a general encouragement to them from their 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 the 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 westernisation of the Indian middle class was as much a matter of satisfaction to the British as was the physical subjugation of India. It was to be expected that an Empire would 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 before he got 'Nobelled'. The success of the British in projecting themselves as the patrons of science as well as of the Indians can be seen from the fact that even today Ramanujan is introduced as the first Indian Fellow of the Royal Society, while in reality his fellowship is more a tribute to the good sense of the society than to him.

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 [25], which romanticises science and trivialises the compulsions of colonialism. The development of science and technology in the west did not take place in a vacuum. It was directly linked to the colonisation of India, which financed the whole exercise and in return received fringe benefits.

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