DHARAMPAL CLASSICS SERIES

INDIAN SCIENCE AND TECHNOLOGY IN THE EIGHTEENTH CENTURY

DHARAMPAL (1922-2006) authored several books that sought to present different aspects of the Indian society and polity from an Indian perspective. These rigorously documented books disrupted the scholarly consensus about the backwardness and dis-functionality of pre-British India and presented the picture of a society that in fact was highly sophisticated and advanced in its political ideas and arrangements and in its sciences, technologies and education systems. These works are of abiding interest and importance.

In the *Dharampal Classics Series,* we present his major works in their original authentic version and in an aesthetically rich format. The Series is being brought out by the Centre for Policy Studies, a research institute with which Sri Dharampal was associated for several years, and Rashtrotthana Parishat, an organisation that had the good fortune to host Dharampalji at Bengaluru on several occasions and to introduce him and his work to the Kannada readers.

Indian Science and Technology in the Eighteenth Century (1971) is the first of Dharampalji's books based on the materials collected in the course of his extensive study in the British archives. It compiles several articles by early British officers, scholars and observers about the Indian sciences of astronomy and mathematics and the Indian technological practices in metallurgy, agriculture, architecture and medicine, etc. The book created a new appreciation of the sophistication and efficacy of Indian sciences and technologies before the coming of the British.

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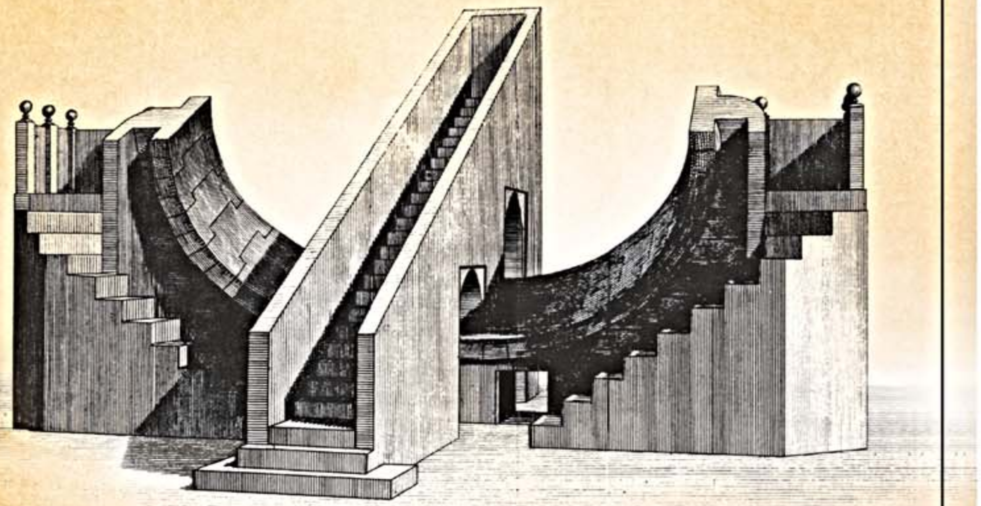

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Some Contemporary European Accounts

DHARAMPAL

Publication No.: 144

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in the Eighteenth Century

Some Contemporary European Accounts

by Dharampal

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About Dharampal Classics Series

DHARAMPAL (1922-2006) authored several books that sought to present different aspects of the Indian society and polity from an Indian perspective. These rigorously documented books disrupted the scholarly consensus about the backwardness and dis-functionality of pre-British India and presented the picture of a society that in fact was highly sophisticated and advanced in its political ideas and arrangements and in its sciences, technologies and education systems. These works are of abiding interest and importance.

In the *Dharampal Classics Series*, we are reprinting the original editions of the most significant of his works. We have tried to keep the text of the first published editions unaltered except for changing some punctuation mark where it seemed essential or introducing a footnote here or there to explain some reference, word or phrase. Where possible, we have compared the archival documents reproduced in these books with the originals and carried out the necessary corrections when necessary.

In the mid-1960s, Dharampal began an extensive exploration into the British Indian archives, especially the India Office Records collection. This research led to three of his major works. The present volume, *Indian Science and Technology in the Eighteenth Century* (1971), is the first of these. It compiles several articles by early British officers, scholars and observers about the Indian sciences of astronomy and mathematics and the Indian technological practices in metallurgy, agriculture, architecture and medicine, etc. The book created a new appreciation of the sophistication and efficacy of Indian sciences and technologies before the coming of the British.

Around the same time, Dharampal published *Civil Disobdience and Indian Tradition* (1971), which presented documents of an intense civil disobedience struggle, that raged in Benaras and several cities of Bihar for nearly two years between 1810 and 1811, against the imposition of a new house tax by the alien British administration. The people found the tax to be an innovation and therefore obnoxious. The book anchored the Civil Disobedience of Mahatma Gandhi in an older and, till recently, vibrant Indian tradition.

The Beautiful Tree: Indigenous Indian Education in the Eighteenth Century (1983) was the third book of Dharampal presenting the British archival records on various aspects of Indian polity. In this volume, Dharampal compiled documents of a survey of indigenous education ordered by Thomas Munro, Governor of Madras, in 1822. The details of the indigenous schools and institutions of higher learning—sent by the Collectors of 21 districts of the extensive Madras Presidency—offer a fascinating picture of the extent, inclusiveness and sophistication of the then prevailing system of education in India. The book also includes extracts giving similarly fascinating details of indigenous education in Bengal and Punjab.

In this *Series*, we are also publishing two of his other books. *Panchayat Raj as the Basis of Indian Polity* (1962), was the first book authored by Dharampal. It presented extracts from the Constituent Assembly Debates on finding a place for Panchayat Raj in the constitutional polity of Independent India. This passionate debate ultimately led to the mention of Panchayat Raj in the non-enforceable Directive Principles of the Constitution. The book gave an early indication of the deep interest Dharampal was to develop in the understanding of classical Indian society and polity and the process of its subversion by the British.

Bhāratīya Chitta Mānas and Kāla (1993), the fifth book in this *Series,* is in a way the final book of Dharampal, though later he did author another couple of books based on his archival studies. In this small, but seminal book, he reflects on the peculiarities of the Indian consciousness, the Indian sense of time and the civilisational essence of being an Indian. The book thus lays down the philosophical perspective from which the whole of his corpus needs to be read.

Centre for Policy Studies has been fortunate to have the honour of Sri Dharampal's association from its inception in 1990. Around that time, Sri Dharampal spent several years in Chennai and, we along with several other colleagues, had the opportunity to closely work with him on many subjects. *Bhāratīya Chitta Mānas and Kāla* was written during this time. It was translated into English and published under the auspices of the Centre in 1993.

The historical event of the demolition of Babari structure at Ayodhya happened when Sri Dharampal was residing in Chennai. The Centre, at his initiative and with his blessings, invited several eminent persons of diverse persuasions to speak on the meaning of that momentous event. The lectures and the subsequent discussion on them were published by the Centre under the title *Ayodhya and the Future India*. Sri Dharampal's lecture, "Undamming the Flow", in this compilation remains relevant even today, especially now when the Ayodhya saga is coming to its culmination.

During his stay at Chennai, Sri Dharampal also began looking into the archival records of a survey of the Chengalpattu region that the British had carried out in the 1770s. The Survey disclosed an affluent, equitable and functional polity in which the locality raised its own resources and performed all the functions that we today expect from a provincial or national State. The Centre has continued to compile and analyse the voluminous data of that Survey and carry forward Dharampal's work in many other directions.

The Centre has initiated this *Series* to edit and publish authentic editions of Dharampal's major works as part of the celebrations of his centenary year that begins on February 19, 2021. The five volumes that we present now mark the beginning of the *Series*. We hope to compile and publish several other volumes of his works in the course of the centenary year.

We dedicate this *Series* to Sri Dharampal who taught us to look at India and the world in a new light.

J. K. Bajaj & M. D. Srinivas
February 19, 2021 CENTRE FOR POLICY STUDIES

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Preface

THE PRESENT VOLUME is part of an attempt to understand the functioning of Indian state and society some eight to ten generations back, i.e., around the period 1750, when India began to fall under European domination—firstly in the Tamil and Telugu areas, and afterwards in Bengal and elsewhere. This attempt consisted in a perusal, during 1966-70, of some of the vast Indian archival material in the English language lodged in the archives of Britain. This volume presents some of the major eighteenth and early nineteenth century documents found during this search on the subject of science and technology.

The authors of these documents came to India in various capacities: as military, medical and civilian servants of the European governments; as travellers, sometimes coming on their own, but more often sent by wealthy patrons or the newly established learned societies (like the Royal Societies of Paris and London; the Society of Arts in London, etc.) and some, like the Jesuits, came on behalf of the various Christian religious orders. According to the European scholarly canons of the time, all these were experts in their respective fields and were considered to be competent to report on what they observed or studied. Most of those included here, spent a substantial part of their active lives in different parts of India.

Practically all European scientific and technological accounts relating to the sciences and technologies of non-European countries (including the ones reproduced here) are an outcome of the seventeenth and eighteenth century European quest for useful knowledge in these fields. The nature of the quest itself got wider and more complex with the passing of practically each decade. Few things, except finished consumer goods or gold and diamonds, etc., were noticed in the non-European world by the earlier European travellers, servants of European states, and the scientists and technologists, etc. Partly this was due to the short duration which most of them spent in any particular area. But the preponderant cause was the lack of requisite comprehension amongst the learned of Europe of the prevailing non-European practices and technologies. Such lack of understanding was still more evident amongst the learned of Britain who seem to have lagged behind some of the other parts of Europe in many scientific and technological fields by about fifty years till about 1800.

Two examples of such lack of comprehension pertain to the practice of inoculation against smallpox, and the use of the drill-plough. Till 1720, when the wife of the then British Ambassador in Turkey, having got her children successfully inoculated,[1] began to advocate its introduction into Britain, the practice of inoculation was unknown to the British medical and scientific world. Proving relatively successful, though for a considerable period vehemently opposed[2] by large sections of the medical profession and the theologians of Oxford etc., an awareness grew about its value and various medical men engaged themselves in enquiries concerning it in different lands. The two accounts of inoculation reproduced here are a result of this post-1720 quest.

Similarly about the drill-plough. The drill-plough is said to have been first used in Europe by one Joseph Locatelli of Carinthia (Austria) in 1662.[3] Its first introduction in England dates to 1730. But it took perhaps another 50 years before it was used on any scale. It was used in India (according to the authors of Chapters XII and XIII) from time immemorial. Observations of its use, by the British, however could only begin in the last decades of the eighteenth century after its awareness had dawned on the more observant amongst them.

Initially, the quest is limited and the queries which are put to those staying or wandering in the non-European world, by the various European learned societies and individual patrons, are fairly simple. In course of time, as knowledge gets added to knowledge and newer formulations develop in Europe, the quest becomes wider and

[1] Lady Mary Wortley Montagu: *Memoirs*, London, 1817.
[2] See mid-eighteenth century *Tracts on Inoculation* in British Museum (BM).
[3] *Encyclopaedia Britannica*: 11th edition (1910-11): Article on *Sowing*, Vol.25, p.524.

more sophisticated and the queries begin to be concerned with the more complex. The interest in the Indian manufacture of Ice; in the making of the Madras Mortar; in the processes of Indian Iron and Steel manufacture; or the Observatory at Varanasi (Benares) (treated as one of the five 'celebrated observatories' of the world by the *Encyclopaedia Britannica* in its editions till 1823) were the outcome of the wider quest and the new sophistication. The quest for newer chemicals and dyes, materials for the water-proofing of the bottom of ships (information and considerable quantities of which were sent as late as the 1790s by a Bombay correspondent to the President of the British Royal Society: Chapter XVII) and such like arose out of rapidly multiplying but specific European needs.

It is in the context of this widening horizon as well as the urgent need (partly resulting from constant warfare in which the Europeans were engaged during the greater part of the eighteenth century) for materials and processes that accounts of the kind presented here were written and submitted by individual Europeans to their respective patrons. It is thus in the European writings of the period (i.e., from about 1720 to 1820) that one discovers the European observed details about non-European science and technology as well as about the societies, institutions, customs and laws of various parts of the non-European world. Before this period the European ability to comprehend this new world was limited; and after about 1820, the knowledge and institutions of the non-European world began to have much less usefulness to the problems of Europe. Further, by the 1820s, most parts of the non-European world are no longer themselves. Their institutions, sciences and technologies are not what they were 50 or a 100 years earlier and have met the same fate as their political systems and sovereignty. By the 1820s or so most of the non-European world had become, at least in European theory and most history texts, if not altogether in actuality, backward and barbarian.

But the imagery of backwardness and barbarism which still serves as a descriptive label for most of the non-European world was no sudden product of the 1820s or any other decade. It grew over a fairly long period but at a much accelerated pace after about 1780. Many of the post-1780 accounts reflect the growth of this attitude amply.

The wide-spread prevalence (no less amongst the learned and scholarly) of European ethnocentric bias is dramatically demonstrated by the post-1780 writings on Indian astronomy and the Observatory at Benares. It comes through even in the very learned review (Chapter II) which Prof. John Playfair, professor of mathematics in the University of Edinburgh, an academician of distinction, did of the then accumulated European knowledge on Indian astronomy. After detailed examination he arrives at the conclusion that the Indian astronomical observations pertaining to the period 3102 years before Christ appeared to be correct by every conceivable test. Such correctness of observation was possible either through complex astronomical calculations by the Indians or by direct observation in the year 3102 B.C. He chooses the latter explanation. The reason for the rejection of the explanation that these could have been arrived at by the Indians through astronomical calculation would have implied that "there had arisen a Newton among the Brahmins, to discover that universal principle which connects, not only the most distant regions of space, but the most remote periods of duration; and a De la Grange, to trace, through the immensity of both, its most subtle and complicated operations."[4] It became intellectually easier for him to concede this astronomy's antiquity rather than its sophistication and the scientific capacities of its underlying theories.

But even the conceding of its mere antiquity was of very short duration. With the strengthening of the fundamentalist and evangelical Christian tendencies, this concession began to look like blasphemy. Keeping in view the European historical premises, originating in the Old Testament, it was just not conceivable for anything except the stated items to have survived "the Deluge" which was computed to have taken place in the year 2348 B.C. By 1814, though things Indian were still being half-heartedly defended by a journal

[4] See Chapter II, p.101.

like the *Edinburgh Review*, even the mere antiquity of Indian astronomy had received a final European dismissal.

While reviewing[5] Cuvier's "The Theory of the Earth", (in which Cuvier had ridiculed and dismissed the ancient date of the Indian tables), the *Edinburgh Review*, took cognizance of the changed attitudes and relationships between Europe and the non-European world and observed: "But though the tide of opinion seems, for some time past, to have set strongly against the high antiquity of the sciences of the East, it does not appear that the main arguments of the Historian of astronomy [i.e., Bailly] have ever been refuted." It tried to resolve the contradiction between the Mosaic and Christian belief, and the earlier date of the Indian tables, by advancing the proposition, that "the early date of that Astronomy, and the usual date of the Deluge, may be perfectly reconciled, on the supposition that the former is a fragment of antediluvian science, which had escaped the general destruction." Such a solution of the controversy was however no longer practicable, nor necessary from the viewpoint of European scholarship, in what had by then become an exclusively European century.

Even when the ancientness of the Indian astronomy was being conceded, as was done by Prof. Playfair, it was difficult to admit that the eighteenth century Indian astronomers and scholars on the subject had any real competence. According to Playfair, the eighteenth century Indian astronomer had "little knowledge of the principles on which his rules are founded, and no anxiety to be better informed."[6] Yet it was only through intercourse with Indian astronomers and by means of instruction and data received from them that the European knowledge of Indian astronomy could be acquired. It was thus acquired by M. le Gentil during his visit to India about 1769. According to the *Encyclopaedia Britannica*: "During the time of his stay in Hindostan, the Bramins had been much more familiar with him on account of his astronomical knowledge, than they usually were with Europeans; and he thus had an opportunity of obtaining considerable

[5] *Edinburgh Review*, Vol.22 (Jan. 1814), pp.474-75. [This review is also by J. Playfair.]
[6] See Chapter II, p.59.

insight into their methods of calculation. In consequence of this instruction he published tables and rules, according to the Indian method, in the academy of sciences for 1772."[7]

It may be more reasonable to suppose that the general incommunicativeness of eighteenth century Indian scholars, and specialists in the various fields, was more due, one, to the usual secretiveness of such persons, and two, to the very sophistication and complexity of their theories which in their view (perhaps mistakenly) were not understandable by most Europeans, rather than their own ignorance of the basic premises of the system and methods used by them. It is possible that the various sciences and technologies were on a decline in India around 1750 and perhaps had been on a similar course for several centuries previously. But there seems little doubt that the processes, methods, theories and formulations described in the contemporary accounts included in this volume were very much a living reality in the areas of India to which they pertain. Whether these were also used or taught or discussed in most other parts is a matter for detailed investigation, not only into the English language records, but more so in the surviving indigenous Indian records of the period, and also the Indian archival material in other foreign languages. The question how the mid-eighteenth century Indian sciences and technologies compared with the sciences and technologies in earlier periods requires similar investigation.

The later eighteenth century European ethnocentric preoccupations had other dimensions also. Some of these are expressed in Chapters III and V, whereby everything existing elsewhere is visualised to have had its origin in India. A different dimension was expressed in propositions like that "the Hindu religion had its origin in the British Isles,"[8] which was held to be the Sweta Dwipa of the Hindu Classics. Though perhaps not so intended, all of these conflicting speculations and formulations ultimately led to the subversion of the non-European reality. Many directly confirmed the grow-

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[7] *Encyclopaedia Britannica*: 6th edition (1823): Article on *Hindoos*, Vol.10, p.477.
[8] *Edinburgh Review*, Vol.16 (1810), p.387; also see "An Essay on the Sacred Isles in the West" by Francis Wilford in the *Asiatic Researches*, Vol.8 (1808), pp.246-247.

ing European view of the barbarism and ignorance of the non-Europeans; the others served the same purpose by becoming easy targets for European ridicule and contempt.

II

Four of the accounts included in this volume deal with astronomy and two with mathematics. The observatory at Benares described by Sir Robert Barker, after a visit to it in 1772, still exists more or less intact and is at present known as the Man Mandir. It stands only a few hundred yards away from the Dasasvamedha Ghat. Its appearance today seems even more neglected[9] than that described two centuries ago, except that a few plates have been fixed indicating the names of the various instruments (yantras) in Hindi and English. Two other plaques indicate the period of the building and the date of the erection of the Observatory. While the building is stated to have been built in the late sixteenth century, the relevant plaque states the erection of the Observatory in the early eighteenth.

Such playing with the dates of the founding of the Observatory has a curious tale to tell. Barker's account was published in the *Transactions* of the British Royal Society in 1777 and it put the erection of the Observatory some two centuries previously. In 1792, in conformity with the request of a Fellow of the Royal Society, another report on the observatory was received from one J. L. Williams of Benares. This was published in the *Transactions* in 1793.[10]

One of the two main points which this later account, as if in passing, tried to make was that the Observatory only came into being some 50-60 years earlier and was not built in the sixteenth

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[9] It is tragic that one of the five celebrated observatories of the world (and in India the most celebrated) though still intact, remains in such neglect. Its counterparts in Britain, France, etc. are greatly cherished and serve as the repositories and centres of their respective astronomical knowledge. India owes that much to itself and its people that places like the "Man Mandir" are duly cherished and looked after.

[10] *Philosophical Transactions*, Vol.83 (1793), Article by John Lloyd Williams, pp.45-49.

century as stated by the Bengal commander-in-chief in his article published in 1777. To support this contention, it produced what it claimed to be the opinion of the Indian magistrate of Benares (who, incidentally, with his colleagues, was in the process of being displaced by the newly enacted Cornwallis' Judicial Regulations, by British judges and magistrates) who is alleged to have said that though the building was built by "Rajah Maunsing, for the repose of holy men and pilgrims", the "observatory was built, by the Rajah Jeysing." Further, it was begun in 1794 *sumbut* (A.D. 1737) and finished in two years and that the Rajah died in 1800 *sumbut* (A.D. 1743). To this was added the even 'weightier' opinion of the Brahmins of Benares "one of whom is professor of astronomy in the new founded college." According to him, "They all agreed that this observatory never was used, nor did they think it capable of being used, for any nice observations; and believe it was built more for ostentation, than the promotion of useful knowledge." Besides these two points, the article gave the measurements of the various instruments but stated that "from the want of sufficient knowledge of the science of astronomy, I have not been able to describe the different instruments, and their uses, satisfactorily; however, you may rely on the measurements being taken with the greatest exactness."

The subject of the Benares Observatory was again taken up in 1798 by William Hunter, an assistant to the British Resident at the Marhatta capital at Poona, in an article "Some Account of the Astronomical Labours of Jayasinha, Raja of Ambhere, or Jayanagar". The interest in Raja Jayasinha arose as Jayasinha "rising superior to the prejudices of education, of national pride and religion" strove to enrich his country "with scientific truth derived from a foreign source", in this particular instance, Europe. The writer was quite candid and outspoken about his purpose. He said: "I have always thought, that after having convinced the eastern nations of our superiority in policy and in arms, nothing can contribute more to the extension of our national glory, than the diffusion among them of a taste for European science. And as the means of promoting so desirable an end, those among the natives who have penetration to see, and ingenuousness to own, its superior accuracy and evidence, ought to be cherished."[11]

This article made an attempt to provide documentary evidence of the Benares Observatory having been the creation of this early eighteenth century Raja Jayasinha by quoting from what is called the *Zeej Mahommedshahy*.[12] According to this document, having "assembled the astronomers and geometricians of the faith of Islam and the Brahmins and Pundits, and the astronomers of Europe" etc., Jayasinha "bound the girdle of resolution about the loins of his soul, and constructed here (at Dehly) several of the instruments of an observatory." And "in order to confirm the truth of these observations" i.e., at Dehly, "he constructed instruments of the same kind in Suvai Jeypoor, and Matra, and Benares and Oujein." With the foregoing statement from the *Zeej Mahommedshahy,* the documentary proof ended. For the rest he added, "the observatory at *Benares* having been described by Sir Robert Barker and Mr. Williams, I have only a few remarks to offer, in addition to the account delivered by those gentlemen"[13] and the writer made some more observations on its measurements, etc.

Various other Britishers seem to have gone and made reports on the Benares Observatory in the early decades of the nineteenth century but the subject soon disappeared from public discussion. It was re-opened in 1920 by the author of "*A Guide to the Old Observatories*",[14] originally published by the Archaeological Survey of India. It stated that the Man Mandir, i.e., the actual building of the Benares Observatory, "was built about the beginning of the seventeenth century. …The astronomical instruments were added by Jai Singh about A.D. 1737." It added: "…the date is not certain, and nearly every writer gives a different one."

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[11] *Asiatic Researches*, Vol.5 (1799), Article by W. Hunter, pp.177-211.

[12] If it still exists, much more needs to be known about this mid-eighteenth century document: how it came to be written, by whom, under whose patronage and in what year.

[13] Hunter, *op. cit.*

[14] G. R. Kaye (honorary correspondent of Archaeological Department of India), Calcutta, Government Printing Press, 1920.

It further observed, "Prinsep wrote: 'The building was converted into an observatory by Jysing in A.D. 1680' and refers to a supposed description of it by Tavernier." Dismissing all these other dates[15] this author concluded that "Williams' date for the observatory at Benares, 1737, may be accepted" as he "on all points that can be verified, is extremely reliable", and quoted Hunter as speaking "of the accuracy of Mr Williams' measurements."[16]

The eighteenth century dating of the Benares Observatory thus rests on the two articles published in 1793 and 1798 respectively; the first, at the instance of a Fellow of the Royal Society, and the second, in a longer piece wishing to convince the Eastern nations of the superiority of European eighteenth century science with a view to "contribute more to the extension of our national glory." What Tavernier said in his published, '*Travels*' was: "Near to this great Pagod upon the summer-west, stands a kind of a college which the Raja Jesseing, the most potent of all the idolaters in the Mogul's empire, built for the education of the youth of the better sort."[17] Tavernier visited Benares in 1655-56. It may be added that quite a few 'Jayasinha' (spelt variously) have been Rajas of 'Ambhere' through the centuries. It is possible that this fact has also contributed to different writers claiming widely separate dates for the construction of the Benares Observatory.

A rather curious point arises here out of this chronology about the dating of the Benares Observatory: Barker along with Pearse, and A. Campbell visited the Observatory in 1772. If the Observatory was actually built in 1737, it was only 35 years old at this date. Both Barker and Pearse specifically state that it had been there for some two centuries. They must have arrived at this statement after meeting and conversing with persons who, if the Observatory had been constructed only 35 years previously, must have been eye witnesses to its construction. As there was no controversy in 1772 about the date of the construction of the Observatory, it is inconceivable that Barker's informants misled him on this point. The

[15] Kaye adds a footnote: "Tavernier died in 1689, three years after Jai Singh's birth."
[16] Kaye, *op. cit.*
[17] J. P. Tavernier: *Travels in India*, Calcutta, 1905, p.425.

conversion of two centuries into 35 years is the most fabulous aspect of this later controversy.

Next is the long and learned review (Chapter II), "Remarks on the Astronomy of the Brahmins", by John Playfair, read by him in 1789. In this article, the author begins by referring to certain astronomical tables received from the East Indies by European scholars at an early stage in their contact with the East. Some of these tables were received from Siam and their "epoch" corresponded to 21 March 638 A.D. But the thing to note was that the "meridian" of these tables was not Siam but Benares!

Other tables received from South India had one thing in common. Their "epoch" coincides with the era of "Kaliyuga", that is, with the beginning of the year 3102 B.C. Professor Playfair begins by enquiring whether the "epoch" was real or fictitious; that is, whether the planetary positions at that time were actually observed or were merely calculated back from the 'epochs' of more modern tables to coincide with a mythical Kaliyuga.

Professor Playfair observes that it is not for astronomy, even in its most perfect state, to go back 46 centuries and to ascertain the situation of the heavenly bodies at so remote a period, except with the help of lately developed Integral Calculus and the Theory of Gravitation. He finds that the positions of the planets as given in these tables is very close to the position as calculated back with the help of modern Integral Calculus and the Theory of Gravitation. All other systems of calculation, whether Chaldean or Egyptian or Greek which the Hindus might have used for their purpose gave very different results. So for him, the inescapable conclusion is that these positions were observed by the Brahmins, and it is rather a wonder that the Brahmins could do so rather precisely at so distant a past. Professor Playfair also observed that the construction of these tables implied a good knowledge of geometry and arithmetic, and the possession of a Calculus equal to Trigonometry.

The paper (Chapter IV) by Colonel T. D. Pearse, sent by him to the Royal Society, London, and surviving in their archives, refers to the Indian knowledge of the four Satellites of Jupiter and the seven

Satellites of Saturn. Pearse further felt that the Indians must have possessed some kind of telescopic instruments to have acquired such detailed knowledge. The author of Pearse's memoirs, while including a slightly modified version of this piece in the memoirs, states:[18] "We cannot pass this interesting communication without offering some reflection upon the subjects it embraces. The circumstances of the four girls dancing round the figure of Jupiter, as they ought to be according to the Brahmin's statement to Colonel Pearse, is a strong argument in favour of the superior knowledge of the heavenly bodies which the ancient Arabians and Hindus possessed. The four dancing girls evidently represent the four satellites of Jupiter. These *circumjovial* satellites (as they are styled by modern astronomers from the quickness of their motions in their orbits) were not known in Europe before the year 1609, and the third and fourth only are visible, and this but rarely and in the clearest atmosphere to the naked eye. But it is truly interesting and curious that the figure of Saturn should be represented with seven arms. At the time Colonel Pearse wrote his letter to the Royal Society, the sixth satellite of Saturn had not been discovered: it was first discovered by Herschel on the 28 August 1789; and the seventh satellite, which the seventh arm of the figure, without dispute, must be intended to represent, was not discovered by Herschel until he had completed his grand telescope of 40 feet focal-length, when it was first observed by him on the 17 September 1789. All the satellites of Saturn are so small, and the planet is so remote from the earth, that the best telescopes are necessary for observing them. May not the seventh arm *having hold of the ring* denote a circumstance connected with the orbits of these planets, which is, that the planes of their orbits so nearly accord with that of the ring, that the difference is not perceptible? Undoubtedly, the ancient astronomers must have possessed the best instruments: probably differing from modern ones, but fully as powerful."

The writer added further: "We are not aware that the Royal

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[18] *Bengal: Past and Present*, Vol.6 (1910), pp.279-280.

Society in any of its printed papers have noticed Colonel Pearse's communication, but our imagination, warmly interested as it has been in all that relates to the subject of the present memoir, has pictured the probability that Colonel Pearse's paper may have met the eye of Herschel, and may have been an additional spur to the indefatigable and wonderful labours of that great man."

Reuben Burrow's unpublished paper (Chapter III) was addressed to the British Governor General Warren Hastings soon after Burrow had come to India to take up his new job at Calcutta. It is highly speculative and in a way is more in line with the contemporary intellectual tradition of the European enlightenment of the eighteenth century.[19] Though in itself it does not provide much factual data, and perhaps comes to even several erroneous conclusions as we would see them today, its very speculativeness seems to have provided inspiration and stimulus to a number of subsequent enquiries about Indian sciences, particularly mathematics. The article "A Proof that the Hindus had the Binomial Theorem" by Burrow himself, and the later dissertation by H. T. Colebrooke on "Hindu Algebra" (given as introduction to his translation of "*Algebra with Arithmetic and Mensuration*" of Brahmegupta and Bhascara) decidedly follow such speculativeness. Acknowledging Burrow's contribution, particularly in bringing Indian Algebra to the notice of Europeans, the article on "Algebra" in the *Encyclopaedia Britannica* (8th edition) stated: "We are indebted, we believe, to Mr. Reuben Burrow for some of the earliest notices which reached Europe on this very curious subject. His eagerness to illustrate the history of the mathematical sciences led him to collect oriental manuscripts, some of which in the Persian language, with partial translations, were bequeathed to his friend Mr. Dalby of the Royal

[19] The tradition has, in fact, continued well into the present time; only as time passed, however, it has become more and more Eurocentric. The late 19th century dictum, "Except the blind forces of nature, nothing moves in this world which is not Greek in its origin," enunciated by Maine (one-time Law Member of the Governor General's Council in India) was merely an intellectual and scholarly expression of the mounting Eurocentric character of this speculativeness.

Military College, who communicated them to such as took an interest in the subject, about the year 1800."[20]

The article (Chapter V) on "the Binomial Theorem" was published in 1790 in Calcutta. Till then, and in British reference books like the *Encyclopaedia Britannica* well into the twentieth century, the discovery of this theorem has been credited to Newton.[21] Some thirty years later Burrow's article was followed by another titled "Essay on the Binomial Theorem; as known to the Arabs".[22] This later article was a sequel to the first by R. Burrow, and it concluded that "…it plainly appears, that whatever may have been the case in *Europe*, yet long before the time of Briggs the *Arabians* were acquainted with" the Binomial Theorem. (Briggs was teaching around 1600, about a century before Newton.)

This later author quoted Dr Hutton concerning the origin of the Binomial Theorem in Europe. The following, from the longer extract of Hutton's account, is worth quoting:

"…Lucas de Burgo extracts the cube root by the same coefficients, about the year 1470. …Briggs was the first who taught the rule for generating the coefficients of the terms, successively one from another, of any powers of a binomial, independent of those of any other power. …This theorem then being thus plainly taught by Briggs about the year 1600, it is surprising how a man of such general reading as Dr. Wallis was, could possibly be ignorant of it, as he… fully ascribes the invention to Newton… But I do not wonder that Briggs remark was unknown to Newton, who owed almost everything to genius and deep meditation, but very little to reading: and I have no doubt that he made the discovery himself, without any light from Briggs."[23]

H. T. Colebrooke's dissertation on "Hindu Algebra", resulting from all the preceding investigations by men like R. Burrow, F. Wilford, S. Davis, Edward Strachey, John Taylor, etc., and from his own considerable knowledge, is a learned survey and comparison of

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[20] *Encyclopaedia Britannica*: 8th Edition (1850), Article on *Algebra*, Vol.2, p.487.
[21] *Encyclopaedia Britannica*: 11th Ed. (1910-11), Article on *Binomial*, Vol.3, p.951.
[22] *Asiatic Researches*, Vol.13 (1820), Article by R. Tytler, M. D., pp.456-67. [23] *Ibid.*

the developments in Europe and India. But the conclusion that "Indian Algebra", etc., may have had an independent development proves difficult for him to digest. Reversing the speculations of Burrow he comes to the conclusion that the "Algebra of the Greeks", imperfect though he admits it to be, "was made known to the Hindus by their Grecian instructors in improved astronomy."[24] But wishing to be gracious and charitable, he infers that "by the ingenuity of the Hindu scholars, the hint was rendered fruitful, and the algebraic method was soon ripened from that slender beginning to the advanced state of a well arranged science…"[25]

III

As contrasted with the eighteenth century European consideration and discussion on Indian sciences, the accounts of Indian technology did not give rise to passionate controversy. Perhaps such passion was neither necessary, as it ordinarily did not challenge any fundamental European dogma or belief, nor possible. The results of the technology were there for all to observe and utilise. And it may incidentally be the lack of such controversy itself that explains the complete current ignorance of most aspects of this technology.

It appears that Indian medical men (with whatever names they may be termed at the end of the eighteenth century) made consider-

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[24] Playfair, the reviewer of *Algebra, with Arithmetic and Mensuration*, in the *Edinburgh Review*, Vol.29 (1817), pp.141-164, however thought differently and stated that it "could not have been derived from Greece." Commenting on Colebrooke's opinion he added: "Mr. Colebrooke, after demonstrating the excellence of this algebra, and comparing its more perfect algorithm and its superior advancement with the Greek algebra, as explained in the work of Diophantus, seems nevertheless willing to admit, that some communication about the time of the last mentioned author, may have come from Greece to India, on the subject of the Algebraic Analysis. Of this we are inclined to doubt; for this simple reason, that the Greeks had nothing to give on that subject which it was worth the while of the Indians to receive. Mr Colebrooke seems inclined to this concession, by the strength of a philological argument, of the force of which we are perhaps not sufficiently sensible. It seems however certain, that the facts in the history of Algebraic Analysis, taken by themselves, give no countenance to the supposition."

[25] See Chapter VI, p.164.

able use of surgical techniques in different parts of India. According to Colonel Kyd in "Chirurgery (in which they are considered by us the least advanced) they often succeed, in removing ulcers and cutaneous irruptions of the worst kind, which have baffled the skill of our surgeons, by the process of inducing inflammation and by means directly opposite to ours, and which they have probably long been in possession of."[26] Dr. H. Scott (Chapter XVII) seems to corroborate the above and further reports the prevalence of plastic surgery in Western India, in his letters to the President of the Royal Society, London. In 1972, he states: "In medicine I shall not be able to praise their science very much. It is one of those arts which is too delicate in its nature to bear war and oppression and the revolutions of governments. The effects of surgical operation are more obvious, more easily acquired and lost by no means so readily. Here I should have much to praise. They practice with great success the operation of depressing the chrystalline lens when it becomes opake and from time immemorial they have cut for the stone at the same place which they now do in Europe. These are curious facts and I believe unknown before to us."[27] Two years later he refers to the "putting on noses on those who have lost them" and sends to London a quantity of "*Caute*", the cement used for "uniting animal parts".[28]

Inoculation against the small pox seems to have been universal, if not throughout, in large parts of Northern and Southern India, till it was banned in Calcutta and other places under the Bengal Presidency (and perhaps elsewhere) from around 1802-3. Its banning, undoubtedly, was done in the name of 'humanity', and justified by the Superintendent General of Vaccine[29] Inoculation in his first report in March 1804.[30]

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[26] India Office Records (IOR): *MSS Eur F/95/I*, Some Remarks on the Soil and Cultivation on the Western Side of the River Hooghly, ff.81r.

[27] See Chapter XVII, p.287.

[28] Chapter XVII, pp.289-290.

[29] A vaccine (the Latin *vacca*, meaning cow) from the cow, for use in the inoculating against smallpox was manufactured by Dr. E. Jenner in 1798. From then on this vaccine replaced the previous 'variolous' matter, taken from human agents. Hence the method using the 'vaccine' came to be called 'Vaccine Inoculation'.

[30] J. Shoolbred, *Report on the Progress of Vaccine Inoculation in Bengal*, Calcutta, 1804, p.92.

The most detailed account of the practice of inoculation against the smallpox in India is by J. Z. Holwell, written by him for the College of Physicians in London.

After giving the details of the indigenous practice, Holwell stated (Chapter VIII, pp.177-178): "When the before recited treatment of the Inoculated is strictly followed, it is next to a miracle to hear, that one in a million fails of receiving the infection, or of one that miscarries under it." It is possible that Holwell's information was not as accurate as of the newly appointed Superintendent General of Vaccine Inoculation in 1804. According to the latter, fatalities amongst the inoculated were around one in two hundred amongst the Indian population and amongst the Europeans in Calcutta, etc. "one in sixty or seventy".[31] The wider risk, however, seems to have been in the spreading of disease by contagion from the inoculated themselves to those who for one reason or another had not been thus inoculated.

It is possible that there were some areas in India where inoculation did not prevail. This, of course, is a matter for enquiry. But wherever it did, it appears to have been universal over a whole tract. After the imposition of British rule in Bengal, Bihar, Orissa, areas of Madras Presidency, etc., this situation seems to alter. According to the Superintendent General of Vaccine Inoculation, a section of the people, either "from indigence" or "from principle", did not any longer (*circa* 1800) receive the inoculation.[32] Those who did not receive it "from principle" seem to have been the Europeans in Calcutta, etc. Partly this may have been due to the greater mortality (i.e. one in sixty or seventy, as indicated above) amongst them. Further it may have also resulted from the persistence of Christian theological objections to any inoculation amongst them.[33]

Not receiving it "from indigence" on the other hand pertained to sections of the Indian population. Like many other categories of specialists, (including school teachers, doctors, establishments of

[31] *Ibid*, pp.27-28. [32] *Ibid*, p.94.
[33] See *Tracts on Inoculation*, referred to earlier. [See also, Rev. E. Massey: *A Sermon Against the Dangerous and Sinful Practice of Inoculation*, London, 1722.]

religious institutions and places, village establishments, etc.) it is probable that the inoculators in India had also been maintained on subventions from public revenues. With the imposition of British rule, the Indian fiscal system began to collapse and various categories of specialists and functionaries were thrown out on the streets and left to wholly fend for themselves. It is this development, and the simultaneous deepening of poverty amongst the people, that most probably resulted in many not being inoculated "from indigence". Such a situation must have naturally made the practice of inoculation seem even more undesirable to the Europeans who, while they themselves did not like to be inoculated, yet could not function without whole contingents of Indian domestic servants.

So what, till the latter part of the eighteenth century, when practised universally in any tract, was a relatively effective method involving no contagious effect, as all were then similarly inoculated, by 1800 had begun to seem a great hazard to the Europeans in Calcutta. But in spite of the bannings, prohibitions, etc. resorted to in Calcutta and other cities and towns, the introduction of vaccine inoculation was very halting. Such halting development must have been caused by insufficient provision of resources or by sheer indifference. Or, as hinted by the officiating Superintendent General of Vaccination for N.W.P. (the present U.P.) in 1870, it may also have been caused by the peoples' reluctance to get vaccinated as, according to this authority, the indigenous inoculation possessed "more protective power than is possessed by vaccination performed in a damp climate."[34] Whatever the causes, the indigenous inoculation seems to have been still practised around 1870. For areas near Calcutta, those who were not so inoculated are estimated at 10 per cent of the population around 1870, and for the Benares area at 36 per cent.[35] The frequent smallpox epidemics which were rampant in various parts of India in the nineteenth and early twentieth century may largely be traced back on the one hand to the state's backwardness and indifference in making the requisite arrangement for univer-

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[34] W. Watson, *N.W. Provinces: Returns of Vaccination for the Season of 1869-70*, Allahabad, 1870, p.19.

[35] *Ibid.*, p.23.

sal vaccination, and on the other hand, to having made the existence of the indigenous practice of inoculation most difficult by not only withdrawing all support to it but also forcing it to be practised secretly and stealthily.

Another important point which emerges from Mr. Holwell's account of the Indian method of inoculation relates to the prevalence of some theory of bacterial infection amongst the mid-eighteenth century Indian inoculators. According to them "the small-pox is more or less epidemical, more mild or malignant, in proportion as the air is charged with these animalculae", i.e. bacteria, and that these "adhere more closely, and in greater numbers, to glutinous, fat, and oily substances." That these "*imperceptible animalculae* floating in the atmosphere …are the cause of all epidemical diseases, but more particularly of the Small Pox;" that "they pass and repass in and out of the bodies of all animals in the act of respiration, without injury to themselves, or the bodies they pass through;" but "such is not the case with those that are taken in with the food," as these are "conveyed into the blood, where, in a certain time, their malignant juices excite a fermentation" and end "in an eruption on the skin."[36]

The observation by Alexander Walker (Chapter XII), that "the practice of watering and irrigation is not peculiar to the husbandry of India, but it has probably been carried there to a greater extent, and more laborious ingenuity displayed in it than in any other country,"[37] is in dramatic contrast to present day text-book accounts of "the comparative absence of artificial irrigation" in eighteenth century India.[38] How Indian agricultural principles, implements and practices (and these may have somewhat varied in different parts of India itself) compared with those elsewhere: in China, Egypt, various countries of Europe, etc., can only be known after a detailed comparative study of the subject. The causes of relative scarcity of resources constantly facing the Indian husbandman also need to be enquired into. It is probable that in most parts of India such scarcity

[36] See Chapter VIII, p.180. [37] See Chapter XII, p.214.
[38] R. C. Majumdar, H. C. Raychaudhuri, K. K. Datta: *An Advanced History of India*, 3rd edition, Delhi, 1967, p.564.

was of late eighteenth century origin and directly resulted from political causes. But it seems clear that besides widespread artificial irrigation, the practices of (i) crop rotation, (ii) manuring, (iii) sowing by means of the drill plough, and (iv) use of a variety of other implements were fairly widespread. The nature and quality of soils seemed to be well understood and in areas like Malabar, certain species of paddy are propagated by cuttings. The use of the drill plough, however, (and perhaps also of some other implements and practices), as noted in Chapter XIII, varied from husbandman to husbandman, the poor not being in a position to use it as it required larger resources not only in implements but also in draught cattle. The latter-day decline in the variety and efficiency of agricultural implements seems to be a result of the general economic impoverishment brought about by the state appropriating all it possibly could in the late eighteenth and the nineteenth century.[39]

The composition of the "Madrass Mortar" (Chapter IX) is very curious, while the process of making paper (Chapter XI) is perhaps not very different from that currently in use in the manufacture of hand-made paper. Chapter X, on the process of making ice, however, is still more fascinating. It was first published in 1775 in London. But it appears that this subject and the manner in which ice was made had been observed even earlier by a number of Britishers in India and had given rise to considerable scientific curiosity in England. The artificial making of ice seems to have been till then unknown in Britain (and perhaps also in other European countries). The observation that "boiling the water is esteemed a necessary preparative to this method of congelation" aroused particular interest. Sir Robert Barker, the author of this article, while referring to this point wondered "how far

[39] The material concerning the proportion of the gross produce of agriculture taken away by the state constitutes a major portion of British Indian archival documents. Theoretically, the land revenue due to government was fixed at 50%. In large parts of India under British rule till 1855 or so the proportion that during most years actually went towards governmental land revenue was appreciably higher. For instance, according to certain enquiries in the Madras Presidency Ryotwary areas during the 1850s about one-third of the irrigated land had over the years altogether gone out of cultivation as the amount of land revenue on such land had begun to approximate the gross produce itself, and at times even exceeded it.

this may be consonant with philosophical reasoning" (i.e., with scientific proof). As a consequence, after carrying out various experiments, a professor of Chemistry at Edinburgh University provided the following explanation:[40]

"…the boiled and common water differ from one another in this respect; that whereas the common water, when exposed in a state of tranquility to air that is a few degrees colder than the freezing point, may easily be cooled to the degree of such air, and still continue perfectly fluid, provided it still remains undisturbed: the boiled water, on the contrary, cannot be preserved fluid in these circumstances; but when cooled down to the freezing point, if we attempt to make it in the least colder, a part of it is immediately changed into ice; after which, by the continued action of the cold air upon it, more ice is formed in it every moment, until the whole of it be gradually congealed before it can become as cold as the air that surrounds it. From this discovery it is easy to understand, why they find it necessary to boil the water in India, in order to obtain ice."

Dr. H. Scott (Chapter XVII) makes mention of many other processes and of dyeing and other agents and substances. "*Dammer* a substance in universal use through the whole eastern world,"[41] for covering the bottom of ships and for other uses where water proofing was required, was one such.

But the substance which seems to have evoked most scientific and technical interest in the Britain of the 1790s was the sample of *wootz* steel sent by Dr. Scott to Sir J. Banks, the President of the British Royal Society. The sample went through examination and analysis by several experts.[42] It was found in general to match the best steel then available in Britain, and according to one user,

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[40] *Philosophical Transactions*, Vol.65 (1775), Article by Joseph Black, M.D., pp.124-28.

[41] See Chapter XVII, p.291.

[42] *Philosophical Transactions*, Vol.85 (1795), Experiments and Observations to investigate the Nature of a Kind of Steel, manufactured at Bombay, and there called Wootz: with Remarks on the Properties and Composition of the different States of Iron, by. George Pearson, M.D., F.R.S., pp.322-346. See also D. Mushet: "Experiments on Wootz or Indian Steel" (1805), reproduced in D. Mushet: *Papers on Iron and Steel, Practical and Experimental*, London, 1840, pp.650-662.

"promises to be of importance to the manufactures" of Britain.[43] He found it "excellently adapted for the purpose of fine cutlery, and particularly for all edge instruments used for surgical purposes." After its being sent as a sample in 1794 and its examination and analysis in late 1794 and early 1795, it began to be much in demand; and some 18 years later the afore-quoted user of steel stated, "I have at this time a liberal supply of *wootz*, and I intend to use it for many purposes. If a better steel is offered to me, I will gladly attend to it; but the steel of India is decidedly the best I have yet met with."[44]

Till well into the nineteenth century, Britain produced very little of the steel it required and imported it mostly from Sweden, Russia, etc. Partly, Britain's lag in steel production was due to the inferior quality of its iron ore, and the fuel, i.e., coal, it used.[45] Possibly such lag also resulted from Britain's backwardness in the comprehension of processes and theories on which the production of good steel depended.

Whatever may have been the understanding in the other European countries regarding the details of the processes employed in the manufacture of Indian steel, the British, at the time *wootz* was examined and analysed by them, concluded "that it is made directly from the ore; and consequently that it has never been in the state of wrought iron."[46] Its qualities were thus ascribed to the quality of the ore from which it came and these qualities were considered to have

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[43] J. Stodart to B. Heyne: Quoted in Heyne's *Tracts Historical and Statistical on India*, London, 1814, p.363. According to Robert Hadfield, Stodart was probably "the same Mr. Stodart who many years later assisted Faraday in preparing and investigating a large number of steel alloys." (*Journal of Iron and Steel Institute*, Vol.85 (1912), p.146). According to Heyne, Stodart was "an eminent instrument-maker", and according to Pearson, whom he assisted in conducting the experiments on Wootz in 1794-5, Stodart was an "ingenious artist".

[44] B. Heyne, *op. cit.*, p.364.

[45] Writing in 1824, J. M. Heath, later a leading manufacturer of iron and steel at Sheffield, stated: "It is well known that England is entirely dependent upon foreign countries for all the iron required for this purpose, and last year the importation of foreign iron into England, for the purpose of making steel alone, exceeded 12,000 tons… Year after year does the Society for the Encouragement of Arts offer a premium for the manufacture of English Iron fit for steel making, and to this time the premium has never been claimed; nor is it likely that it ever will, from the nature of the English ores, and the inferior quality of the English fuel." (*Madras Public Proceedings*, January 1825).

[46] G. Pearson, *op. cit.*, p.345.

little to do with the techniques and processes employed by the Indian manufacturers. In fact it was felt that the various cakes of *wootz* were of uneven texture and the cause of such imperfection and defects was thought to lie in the crudeness of the techniques employed.

It was only some three decades later that this view was revised. An earlier revision in fact, even when confronted with contrary evidence as was made available by other observers of the Indian techniques and processes, was an intellectual impossibility. "That iron could be converted into cast steel by fusing it in a close vessel in contact with carbon" was yet to be discovered, and it was only in 1825 that a British manufacturer "Charles Mackintosh took out a patent for converting iron into steel by exposing it to the action of carburetted hydrogen gas in a close vessel, at a very high temperature, by which means the process of conversion is completed in a few hours, while by the old method, it was the work of from 14 to 20 days."[47]

According to J. M. Heath, founder of the Indian Iron and Steel Company, and later prominently connected with the development of steel making in Sheffield, the Indian process appeared to combine both of the above early nineteenth century British discoveries. He observed: "Now it appears to me that the Indian process combines the principles of both the above described methods. On elevating the temperature of the crucible containing pure iron, and dry wood, and green leaves, an abundant evolution of carburetted hydrogen gas would take place from the vegetable matter, and as its escape would be prevented by the luting at the mouth of the crucible, it would be retained in contact with the iron, which, at a high temperature, appears from Mr. Mackintosh's process to have a much greater affinity for gaseous than for concrete carbon; this would greatly shorten the operation, and probably at a much lower temperature than were the iron in contact with charcoal powder."[48]

And he added: "In no other way can I account for the fact that

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[47] J. M. Heath: "On Indian Iron and Steel", *Journal of Royal Asiatic Society of Great Britain and Ireland*, Vol.5 (1839), pp.396-397, quoted in D. Mushet, *op. cit.*, p.671.
[48] J. M. Heath in D. Mushet, *op. cit.*, p.671.

iron is converted into cast steel by the natives of India, in two hours and a half, with an application of heat, that, in this country, would be considered quite inadequate to produce such an effect; while at Sheffield it requires at least four hours to melt blistered steel in wind-furnaces of the best construction, although the crucibles in which the steel is melted, are at a white heat when the metal is put into them, and in the Indian process, the crucibles are put into the furnace quite cold."[49]

The above quoted British authority however did not imply that the Indian practice was based on a knowledge "of the theory of his operations"[50] by the Indian manufacturer. He felt it to be impossible "that the process was discovered by any scientific induction, for the theory of it can only be explained by the lights of modern chemistry." And feeling that "all speculation upon the origin of the discovery seems useless",[51] he proceeded to deal with the more practical matters.

Several scores of British accounts (some more, some less detailed) pertaining to widely separated areas of India, and perhaps pertaining to about a hundred districts, are available on the Indian manufacture of iron and steel. Though some date to the 1790s, most were written during the period 1820-1855. That included in Chapter XV is probably the most graphic and detailed amongst them while the one in Chapter XVI tries to provide some perspective and comparison of the different processes and corresponding details prevailing in different countries. Though there seems to be some fairly detailed accounts of the process of Indian iron and steel manufacture in other European languages dating back to the late seventeenth century,[52] that in Chapter XIV is probably one of the earliest British accounts of it.

The design, measurements, and construction of the furnaces and accessory implements, described in Chapter XV, require much detailed examination by experts. Similar examination is essential of

[49] *Ibid*. [50] *Ibid*. [51] *Ibid*., p.669.
[52] See, for instance, an English version of D. Havart's *Rise and Decline of Coromandel* (from the original Dutch work published in 1693 from Amsterdam), pp.291-94, 401-3, in *Mackenzie MSS (Private)*, Vol.88, in IOR.

the large amounts of data provided in Chapters XV and XVI. But a cursory study of the data seems to indicate that the proportion of iron recovered from the ore and the amount of charcoal required to produce a given quantity of crude iron in Central India is comparable with the respective ratios pertaining to the manufacture of iron and steel in Sweden, etc. It is possible that these quantities varied considerably in different parts of India. Maybe, with the continuous deterioration which had set in, the consumption of fuel in the production of iron increased considerably. It is perhaps due to this later development, or basing himself on the data from some selected areas, that Mahadeva Govind Ranade remarked (in the 1890s) that indigenous Indian "processes involve a great waste of power and resources, as much as fourteen tons of fuel being required to produce one ton of iron." And thus he concluded that "besides the effects of foreign competition, the collapse of the iron industry has been brought about by the increasing scarcity of fuel."[53]

According to Chapter XV,[54] 140 seers of charcoal produced 70 seers of crude iron at Aggeriya, etc., in the district of Jabalpur. At Jowli, in the same district, 165 seers of charcoal were required to produce 77 seers of crude iron. How much charcoal was required to convert the crude into malleable and wrought iron is not indicated in Chapter XV, but considering that the amount of charcoal required to convert the ore into crude iron is of the same order as the quantities required in European countries, it may be inferred that the requirement of fuel in subsequent processes would not have been very different.

It is not easy to estimate the total number of such furnaces which may have been in operation in various parts of India in the eighteenth century. Certain mid-nineteenth century enumerations, however, place the number of furnaces operating in certain districts, talooks, etc., in hundreds. It is therefore probable that the number of iron and steel furnaces functioning throughout India in the latter part of the eighteenth century was in the region of 10,000. According to the data

[53] M. G. Ranade: *Essays on Indian Economics*, 3rd edition, Madras, 1916, p.153.
[54] See Chapter XV, p.238.

given in Chapter XV the production of iron per furnace amounted to somewhat above half a ton per week. Assuming that a furnace on an average worked about 35-40 weeks a year, the production of iron per furnace may be assumed at 20 tons annually.

Besides the furnaces and accessories so graphically described in Chapter XV, certain other devices varying from area to area also appear to have been used in Indian metallurgy. One such was the use of the *Panchakki* (water-mill) in the crushing of ore by the manufacturers of Kumaon and Garhwal. According to J. D. Herbert and J. Manson "in reducing the ore to fragments, the Dhunpoor miners employ the *Panchakki* or water-mill. When water is present no better plan can be devised."[55]

Several questions arise out of the material on technology described and discussed here. One of them arises from the generally shared European opinion, and at times assertion, that the Indian manufacturer of iron and steel, and in other instances of other commodities or practitioners in other professions, could not have had any knowledge "of the theory of his operations". Though such opinions essentially originated from the ethnocentric views and inclinations[56] of the societies to which such observers belonged, and were not in their essence derived from the subject observed and described, these, as mere statements which generally hold true at all times, need not be disputed. But most practitioners of a profession which they have learnt after a long apprenticeship and in which their essential job is to repeat ever more perfectly what they had done before, never require, and seldom possess, such knowledge. The possession of

[55] National Archives of India (NAI): HOME, Misc. Records, Vol.437, *Report of the Mineralogical Survey of the Himalaya Mountains,* 1826, p.627.

[56] Even the British Royal Society does not seem to have remained untouched from such inclinations. Referring to the letter of Dr. Scott on *wootz,* it quoted him as having written that it "admits of a harder temper than any thing known in that part of India." What Dr. Scott had actually stated was that "it appears to admit of a harder temper than any thing we are acquainted with." As is obvious, Dr. Scott's 'we' implied "we in Europe". But as this must have seemed inadmissible in the pages of the *Philosophical Transactions*, the observation got altered to "than anything known in that part of India.' (See G. Pearson, *op. cit.*, p.322; and Chapter XVII, p.289 in this volume).

such knowledge and its development and refinement is, at all times, the function of a separate, though interlinked, group. Such division between the practitioners and the theoreticians is currently more evident than ever before.

It is possible that the link between the practitioners of the various techniques or professions and the professors of the theoretical knowledge relating to them had largely snapped in India by the end of the eighteenth century. It is even probable that though not altogether snapped such a break had begun to take place centuries earlier. This, however, is a view which cannot be determined by mere conjecture. Its substantiation requires detailed studies of Indian techniques and processes as they operated over several centuries till the early nineteenth.

But even if these links had already snapped but the practices had continued, it is very probable that in a changed political climate resulting from the success of the early eighteenth century resurgence, such links as demanded by the situation, would either have been re-established between the practitioners and the surviving professors of the theoretical knowledge, or been newly forged by emergence of appropriate formulations.

Another of them arises from the above discussion on the manufacture of Indian iron and steel. If Indian iron and steel manufacturing processes were so very superior and widespread throughout the country, why did they disappear? So far, our knowledge of such widespread manufacture has itself been very scanty. Therefore, answers to such a question at present can merely be tentative. Mainly the disappearance seems to have resulted from large-scale economic breakdown and hostile state policy. From about 1800 onwards, India was to be treated as a consumer of British manufactures. Yet some of the British in India did visualise the undertaking of large scale production of iron and steel in India. But even they, when they came forth with such plans, were at great pains in stating that such production would in no way injure the production in Britain or the consumption of British iron in India. Even this type of proposition was, however, difficult for the British Government to contemplate. For example, replying to an early application for setting up such works in the Bengal area, the London authorities in 1814 stated, "But as we entertain strong doubts as to the policy of encouraging the prosecution of such works to any extent, we direct that no further expense may be incurred."[57]

IV

Many other aspects of science and technology are not at all referred to in the accounts which are reproduced in the following pages. Textiles, armaments, horticultural techniques, or the breeding of animals are among those omitted aspects. Designing and construction of boats and other sea-faring vessels are also not referred to. A mention in this respect may, however, be made of an observation made by Solvyns in the "Les Hindous". Introducing the 40 or so sketches of boats and river vessels in use in Northern India in the 1790s, he observed, "the English, attentive to everything which relates to naval architecture, have borrowed from the Hindoos many improvements which they have adapted with success to their own shipping."[58] Commenting on Indian rowing an early eighteenth century observer remarked, "Their Water-men row after a different manner from ours. They move the Oar with their Feet, and their Hands serve instead of the *Hypomochlion*, or Roller on which it turns."[59]

It is not as if nothing at all is known of the various accounts reproduced in this volume. Chapters I, II, V and VI dealing with astronomy and mathematics are perhaps known to many concerned scholars. The accounts dealing with the manufacture of paper, the composition of the 'Madrass Mortar' and Iron Works at Ramanakapettah are possibly known to a still wider circle. Even the practice of inoculation against the smallpox is known to have existed in

[57] IOR: *Public Despatch to Bengal*, July 29, 1814, Para 9.
[58] Francois Baltazard Solvyns: *Les Hindous*, Vol. 1, Paris, 1808, p.28.
[59] *Philosophical Transactions*, Vol.28 (1709), "A Letter from Father Papin, Bengale, December 18, 1709", p.226.

ancient times in India, for, according to one modern writer, "Preventive inoculation against the small pox, which was practised in China from the eleventh century, apparently came from India."[60] Something also seems to be known about the manufacture of iron and steel in Salem through the writings about it by Campbell, the Assistant Surveyor General, Madras. Ranade himself seems to have been fairly well informed about the export of *wootz* to England and other countries.

But all this knowledge among the scholars and prominent writers on Indian economics has not so far created any general awareness of the teaching and practice of these sciences and technologies, or the questioning of the prevailing hypothesis of "the eighteenth century" being "one of the darkest periods" in Indian history,[61] etc. The reasons for the lack of appropriate awareness or prevailing indifference are manifold. Primarily the responsibility for such a situation lies with the system of education prevailing in India, which by nurturing indifference, even contempt, for everything indigenous effectively blocks such enquiries.

The intellectual basis of the contempt and indifference which began to grow around the close of the eighteenth century, is perhaps best illustrated by the article on "Algebra" in the *Encyclopaedia Britannica*, in its 8th edition (1850). Discussing Indian Algebra, it referred to the review by Prof. John Playfair, of Colebrooke's work on Indian Algebra, and observed:[62]

"This last article, published in 1817, may be supposed to contain the matured opinions of one of the most ardent, able, and we must say most candid, enquirers into the history of Hindoo mathematical science. There is here certainly an abatement of his first confidence in the opinion of Bailly on the Indian astronomy, and a corresponding caution in his own opinion as to the antiquity of the mathematical sciences. The very remote origin of the Indian Astronomy had been strongly questioned by many in this country, and also on the

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[60] Kurt Pollak: *The Healers: The Doctor, Then and Now*, London, 1963, pp.37-38.
[61] R. C. Majumdar *et al*, *op. cit.*, p.561.
[62] *Encyclopaedia Britannica*: 8th edition (1853), Article on *Algebra*, Vol.2, p.488.

Continent; particularly by Laplace, also by Delambre in his *Histoire de l'Astronomie Ancienne*, tome i. p.400, &c., and again in *Histoire de l'Astronomie du Moyen Age*, *Discourse Preliminaire*, p.18, &c., where he speaks slightingly of their algebra." The article added: "and in this country, Prof. Leslie, in his very learned work on *The Philosophy of Arithmetic*, pp.225 and 226, calls the Lilavati 'a very poor performance, containing merely a few scanty precepts couched in obscure memorial verses'."

Playfair's observations, alluded to on this occasion, while differing from the views of Leslie etc., expressed some scholarly scepticism of the Indians' capacity in mathematical sciences. He had said: "Among many subjects of wonder which the study of these ancient fragments cannot fail to suggest, it is not one of the least that algebra has existed in India, and has been cultivated for more than 1200 years, without any signal improvement, or the addition of any material discovery. The works of the ancient teachers of science have been commented on, elucidated, and explained with skill and learning; but no new methods have been invented, nor any new principle introduced. The method of resolving indeterminate problems, that constitute the highest merit of their analytical science, were known to Brahmegupta hardly less accurately than to Bhascara; and they appear to have been understood even by Arya-Bhatta, more ancient by several centuries than either. A long series of scholiasts display in their annotations great acuteness, intelligence, and judgement; but they never pass far beyond the line drawn by their predecessors, which probably seemed even to those learned and intelligent men as the barrier within which it was to be confined. In India, indeed, everything seems equally insurmountable, and truth and error are equally assured of permanence in the stations they have once occupied. The politics, the laws, the religion, the science, and the manners, seem all nearly the same as at the remotest period to which history extends. Is it because the power which brought about a certain degree of civilisation, and advanced science to a certain height, has either ceased to act, or has met with such a resistance as it is barely able to overcome? Or is it because the discoveries which the Hindoos are in possession of are an inheritance from some more inventive and more ancient people, of whom no memorial remains but some of their attainments in science?"

The choice of this passage during the 1850s by the *Encyclopaedia Britannica* was in keeping with the sentiments of the period. But the 24 page unsigned article in the *Edinburgh Review* (Nov. 1817)[63], from which this sceptical passage is taken, had also said many other things. Earlier in the article, Playfair observed: "A commentary on the *Vija Ganita*, bearing the date of 1602, contains a full exposition of the sense, with complete demonstrations of the rules, much in the manner of Ganesa; and there is a scholiast of a still later date, who appears to have flourished about the year 1621. If, therefore, it be true, that the Hindus of the present time understand nothing of their scientific books the decline of knowledge among them must have been very rapid, as it is plain that, at the distance of less than two centuries from the present time, the light of science was shining in India with considerable lustre."[64] Proceeding further while deploring the lack of 'analysis' even in the *Vija Ganita*, he noted that Brahmagupta had given "a solution that appears quite general" concerning "Indeterminate Problems". And he observed, "The solution then of a very difficult problem given by an Indian Algebraist, more than 1200 years ago, is such as can vie with those of two of the mathematicians the most distinguished for genius and invention which Europe could boast of ever having seen, at the end of the eighteenth century." Dismissing that the finding of such a solution by Brahmegupta may have been due to chance, he added, "There are inquiries where chance and accident have great influence and where a man of very inferior genius and knowledge may make great discoveries. But the subject we are treating of here, is not of that number; it is one where no one *finds*, who does not know how to *search*; and where there is no reward but for intense thought, and patient inquiry."[65]

[63] Vol.29 (1817), pp.141-164.
[64] *Ibid.*, pp.143-144.
[65] *Ibid.*, p.154.

Given the doubts of academicians like Playfair, and of Laplace, Delambre, etc., and the supporting role of the fast multiplying tribe of 'oriental scholars' amongst the servants of the British authorities in India (including those amongst the missionaries) Macaulay's verdict on Indian sciences and learning was inevitable. Only Macaulay expresses such doubts and contempt with greater drama and bombast. But what he said, in his minute of 2 February 1835, was shared fully not only by the then British Governor General of India, Bentinck ("I give my entire concurrence to the sentiments expressed in this minute") but practically by every other learned or powerful European. Referring to the orientalists Macaulay observed:

"I have never found one amongst them who could deny that a single shelf of a good European library was worth the whole native literature of India and Arabia. The intrinsic superiority of the western literature is indeed fully admitted by those members of the committee [of Public Instruction] who support the oriental plan of education."

And then he added:

"It will hardly be disputed, I suppose, that the department of literature in which the Eastern writers stand highest is poetry. And I certainly never met with any orientalist who ventured to maintain that the Arabic and Sanskrit poetry could be compared to that of the great European nations. But when we pass from works of imagination to works in which facts are recorded and general principles investigated, the superiority of the Europeans becomes absolutely immeasurable. It is, I believe, no exaggeration to say that all the historical information which has been collected from all the books written in the Sanskrit language is less valuable than what may be found in the most paltry abridgements used at preparatory schools in England. In every branch of physical or moral philosophy the relative position of the two nations is nearly the same."

Concluding, Macaulay refused to associate himself with any support or assistance to Indian learning and declaimed: "If, on the other hand, it be the opinion of the Government that the present system ought to remain unchanged, I beg that I may be permitted to retire from the chair of the Committee. I feel that I could not be of the smallest use there. I feel also that I should be lending my countenance to what I firmly believe to be a mere delusion. I believe that the present system tends not to accelerate the progress of truth but to delay the natural death of expiring errors. I conceive that we have at present no right to the respectable name of a Board of Public Instruction. We are a Board for wasting the public money, for printing books which are of less value than the paper on which they are printed was while it was blank, —for giving artificial encouragement to absurd history, absurd metaphysics, absurd physics, absurd theology, —for raising up a breed of scholars who find their scholarship an incumbrance and a blemish, who live on the public while they are receiving their education, and whose education is so utterly useless to them that, when they have received it, they must either starve or live on the public all the rest of their lives. Entertaining these opinions, I am naturally desirous to decline all share in the responsibility of a body which, unless it alters its whole mode of proceedings, I must consider, not merely as useless, but as positively noxious."[66]

Remarks, observations, threats and declamations, like those quoted above, have shaped all the writing and teaching about India, and more or less continue to do so, in the manner and direction indicated by Macaulay and by his more (though less known in India) powerful precursors like William Wilberforce and James Mill.[67] Ignorance and apathy and utter mental confusion, particularly about life and society in the eighteenth century not only in India but in West Europe itself, are the natural products of such writing and teaching.

The doubts and declamations (of Playfair, Laplace, Macaulay, etc.), however, are not the sole causes of this ignorance and apathy. These partly seem to arise from much deeper issues which pertain to the conflicting hypotheses about state and society. The seventeenth,

[66] NAI: *India Public Proceedings*, March 7, 1835, Minutes on Public Instruction.
[67] See, amongst others, speeches of William Wilberforce on India in the British House of Commons, *HANSARD*, June 22 and July 1, 1813; also James Mill's *History of British India*, 3 Volumes, London, 1817, particularly Volume I.

eighteenth and nineteenth century European view of society, and thus of science, technology, politics, etc., was diametrically at variance with the views about them held by non-European societies.

Consequently, the sciences and technologies of the non-European world also had different seekings and developments to those of Europe. Further, in countries like India, their organisation was in tune with their more decentralist politics and there was no seeking to make their tools and work places unnecessarily gigantic and grandiose. Smallness and simplicity of construction, as of the iron and steel furnaces or of the drill-ploughs, was in fact due to social and political maturity as well as arising from understanding of the principles and processes involved. Instead of being crude the processes and tools of eighteenth century India appear to have developed from a great deal of sophistication in theory and an acute sense of the aesthetic.

It is in such a context that a man like Voltaire considered India "famous for its laws and sciences" and deplored the mounting European preoccupation (both individual and national) of those in India with the amassing of "immense fortunes". This quest for riches intensified the struggles, plunder, etc., during his own time, and made him remark that "If the Indians had remained unknown to the Tartars and to us, they would have been the happiest people in the world."[68] Looking back at what has happened, since he wrote these lines, Voltaire seems to have been very perceptive in his judgment. But the whole world, if such contacts had not occurred, would have been very different not only in politics and society but also in science and technology. Speculations about what it may have been, though fascinating, are far beyond the scope of this volume.

A question yet remains. This is about how sciences and technologies which seem to have been very much alive about 8-10 generations have been wholly eclipsed? The causes of such eclipse are very complex. Some of them are also, till there is systematic and detailed research available about Indian science and society, largely speculative. A few of them may, however, be suggested here.

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[68] Voltaire: *The Age of Louis XV*, London, 1774, pp.83-84, 87.

Firstly, the notion that all these sciences and technologies have wholly disappeared is not altogether true. Residues of many of them still exist and function but at a most neglected and impoverished level. For instance, it is said that some aspects of indigenous plastic surgery were being practised till recently in places as far apart as Kangra and Junagadh.[69]

The second point relates to the economic breakdown of India during 1750-1900. Whatever may have been the nature and extent of exploitation of the agricultural and manufacturing population, or the question of what happened to the extorted money and goods (the 50 per cent of the gross agricultural product taken as governmental land revenue is was one such) the point that the breakdown of the economy was overwhelming and total is indisputable. No sciences or technologies can survive intact such catastrophe.

A third point which may be indicated, relates to the contrary nature of the new state fiscal system as compared to the indigenous system (or systems) prevailing at the beginning of the European impact. It seems that the indigenous budgeting of state revenues (whether for larger or smaller political entities) left the overwhelming proportion of revenue, through various in-built devices, at the local levels. The British created fiscal system on the other hand not only doubled or trebled the rates of various assessments and effectively brought all people under its sway, but it took away the overwhelming proportions to the central exchequers and the metropolises and places above them. The studied neglect and contempt, referred to above, added to the economic breakdown and the transformation of the fiscal system, seems to have completed the uprooting and elimination of indigenous sciences and technologies not only from society but from Indian memory itself.

There are many philosophical formulations about the growth and decline of human societies (or the various stages which they are supposed to pass through). The theory of atrophy as usually applied

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[69] See S. C. Almast, "History and Evolution of Indian Method of Rhinoplasty", in G. Sanvenero-Rosselli, ed., *Transactions of the Fourth International Congress on Plastic Surgery*, Amsterdam, 1969.

to India is one of them. It is possible that it also has some relevance in explaining the growth, flowering and decline of Indian society. Though the contemporary data, as separate from opinions and formulations, does not seem to indicate that the eighteenth century sciences and technologies in India were in a state of atrophy, some of them may well have been in such a state. It is also possible that various other current or past formulations on the subject of growth and decline of human societies also have some contribution to make in explaining what happened to Indian science and society over the millennia.

Whatever may be the actual relevance of the theory of atrophy or other theories of European origin in explaining the development of Indian society, it appears much more probable that in most respects the sciences and technologies of India had reached a desirable balance and equilibrium much before the eighteenth century. In the context of the values and aptitudes of Indian culture and social norms (and the consequent political structure and institutions) the sciences and technologies of India, instead of being in a state of atrophy, were in actuality usefully performing the tasks desired by Indian society. It is the application of unrelated standards and judgments (particularly those emanating from eighteenth-nineteenth century Europe) which hide and distort the actual situation and relationship.

V

It appears to the present researcher that, though, organisationally weak in a military-political sense, in most respects the political and social ideas of India and its legal and administrative arrangements as well as sciences and technologies had achieved maturity and balance at some time previous to its present day contacts with the European world. Its social and political structure at this period, though seemingly different from those that obtain in the European world of today, was able to provide basically a similar sort of freedom, well-being and social security as is at present available in much of the European world. It also seems to have had somewhat similar ideas about ruler-ruled relationship, the resolution of disputes, legal punishments, sexual mores, protests against those in authority, etc. But while the whole led to more freedom and equality, these characteristics added to a basically decentralised political and military structure contributed to this society becoming more prone to external attack.

During the centuries, particularly between the twelfth and seventeenth, there is no dearth of such external onslaughts. The onslaughts to an extent are absorbed and accommodated by Indian society, but over a time they contribute not only to further political and military weakness, but also to damaging the various integrating factors which had provided the necessary intellectual and spiritual links between different regions and specialist and ethnic groups. But over all, however, though considerably weaker and perhaps also psychologically at a low ebb, the major arrangements and expressions continued to serve the physical, social and spiritual needs of the Indian people satisfactorily.

At the time of the European onslaught, the indigenous tendencies in India seem to have been in a state of slow resurgence. The resurgence, while it restored a measure of confidence, weakened at the same time the political and military structure. With the beginning of European dominance in India, the resurgence got transformed into depression and unimaginable disorganisation. Foreign aggression and dominance was not wholly unknown in India before the resort to it by Europe in the mid-eighteenth century. But the Europeans of this period belonged to a wholly alien world in relation to India. They were not only armed with the concepts and hierarchical institutions of a long feudal European past but had also been preparing for the occasion for two to three centuries. The subsequent application of their concepts and values completed the destruction of Indian science and society which had been started by the political and military defeat of India at their hands.

What has developed in India in the field of science and technology during the past century, and at a greater pace since 1947, is mainly a transplanting of some of that which has developed during this period in the European world. Such transplanting has happened not only at the level of theories but even more so as regards the organisation of technology and the direction of research. It is largely due to such transplanting and its unthinking acceptance that though many individual Indian scientists and technologists are as creative and inventive as their colleagues in the European world, the impact of this science and technology on the larger society of India is in fact minimal. It is perhaps no exaggeration to add that the field of science and technology in India as far as it concerns its ordinary life is only a little less barren than India's state system and its politics.

Borrowing of ideas and practices in themselves need not be obstructive to India's development or creativity. During the centuries India must have borrowed many ideas and practices from other lands in the same way as Europe received much in the field of science and technology from the Arabs etc., or the Arabs and others did from India. To the extent that such borrowings lead to further innovation and creativity they are to be greatly welcomed. But unfortunately, so far, the past century's unthinking transplanting of European sciences and technologies in India have mainly resulted in retarding and blunting of indigenous innovation and creativity.

The problem for India today, as perhaps for many other lands which are still recovering from the effects of eighteenth and nineteenth century European dominance, is how to achieve and increase such innovation and creativity. Such innovation and creativity can arise only from a widespread indigenous base. Such a base has yet to be identified (and the superstructure accordingly modified and linked with it) in countries like India. For that, knowledge and comprehension of how they functioned before the beginning of this dominance seem to be essential. Even for the purposeful adaptations from European (or for that matter Japanese, Chinese or any other) science and technology and their integration with the more indigenous concepts, knowledge and forms, it is necessary that these countries achieve such knowledge and comprehension at the earliest possible.