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Science, Technology and Medicine in Colonial India

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INTRODUCTION: SCIENCE, COLONIALISM AND MODERNITY

The questions that can be asked about science in modern India are essentially those pertaining to the history and sociology of science elsewhere. What is the social character of scientific knowledge? Who produces science and why? How does science exercise authority within a society and across cultural divides? As historians and sociologists have begun to investigate science, less in terms of its self-declared aims and putatively objective interrogation of nature and more in terms of its internal ordering, social construction and cultural authority, it has become clear that science is 'a highly social activity', one that cannot be 'sealed off from the values of the society in which it is practised'.[1] It is increasingly recognised, too, if not yet universally accepted, that science, far from being monolithic, manifests itself across time and cultures in myriad forms, reflecting as much as informing a given society's cultural, economic and political modalities. Science thus 'reveals itself as much more contingent and culturally specific' than it was once assumed to be.[2] Individuals and groups produce scientific knowledge not in isolation but 'against the background of their culture's inherited knowledge [and] their collectively situated purposes' as well as through 'the information they receive from natural reality'.[3]

The social character and cultural plurality of science has a particular bearing on the history of science, technology and medicine in India, which had a well-established scientific and technological tradition of its own long before being subjected to an extended period of European colonial rule. Although the history of science, technology and medicine continues to be presented in general histories as a record of Western discovery and dissemination, it has become more widely acknowledged than a generation or two ago that not all such histories can be conflated into a single story of European achievement or saga of European enterprise overseas. Particular attention has been directed to understanding the place of science in the colonial world of the eighteenth, nineteenth and early twentieth centuries, in situations in which the history of

[1] Nancy Leys Stepan, *'The Hour of Eugenics': Race, Gender, and Nation in Latin America* (Ithaca, 1991), p. 9; Michael Mulkay, 'Sociology of Science in the West', *Current Sociology*, 23 (1980), pp. 1–184.

[2] Stepan, *'Eugenics'*, p. 10.

[3] Steven Shapin, 'History of Science and Its Sociological Reconstructions', *History of Science*, 20 (1982), p. 196.

science often appears inseparable from the history of imperialism itself.[4] Yet, at the same time, in order to understand the social authority and cultural context of science, it is necessary to look beyond the imperial system, beyond its ideologies and instrumentalities, and to look at the 'recipient' society and the manner in which Western science was received and situated in relation to indigenous epistemologies and practices. A history of science in India must also be a history of India, not merely a history of the projection of Western science onto India. One of the principal rationales for a work such as this, which seeks to give an interpretative overview of science, technology and medicine in India from the late eighteenth to the mid-twentieth centuries, must be that there is a new recognition of the centrality of science to an effective understanding of the history of India during the period marked by the rise, ascendancy and retreat of British colonialism in South Asia.

It will be argued here, by way of introduction, that there were three main elements that broadly typified science, technology and medicine in India over this 200-year period. Firstly, there were the traditions of India's own science, technology and medicine, themselves subject to wide internal variations and different historical influences and cultural practices, and the legacies these provided for the subsequent era of British rule. Secondly, there was the nature of Western (or 'colonial') science, technology and medicine as practised in India, their social and intellectual impact, their organisational forms and dual relationship to the colonial regime in India and to metropolitan science in Europe. And thirdly, there was the authority of science, technology and medicine as central attributes of India's modernity, drawing upon indigenous as well as Western sources and finding contested expression in both imperial ideology and nationalist agendas. We will briefly consider each of these in turn.

INDIA'S SCIENTIFIC TRADITIONS

It would be erroneous to think of India as having a single scientific tradition. Over the millennia, India became heir to a wide variety of different oral and textual traditions, drawing upon exogenous contacts as well as indigenous roots. This plurality makes it difficult not only to characterise Indian science as a whole but also to determine the precise nature of its interaction with the forms of science and technology emanating from the West by the late eighteenth and early nineteenth centuries. Even within what is often thought of as the 'Hindu' tradition, there were several strands of scientific ideas and

[4] Paolo Palladino and Michael Worboys, 'Science and Imperialism', *Isis*, 84 (1993), p. 102.

practices, including a tradition of empirical, observational science (particularly developed in astronomy and medicine) that functioned alongside, and often in tandem with, various cosmological and astrological beliefs. Whereas astronomy in Vedic India was often closely connected with religious practice (because an accurate knowledge of equinoxes and solstices was needed for the proper timing of sacrifices and other rites), in the post-Vedic and early medieval period the study of astronomy, trigonometry and algebra saw a partial move away from the earlier stimulus of religion and ritual. Thus, one of the most important texts of the later period, the *Surya Siddhanta*, composed around AD 400, devoted a series of chapters to the motion and position of the planets, the nature and timing of eclipses, the rising and setting of the sun and moon, and astronomical instruments such as the armillary sphere; but it also dealt with cosmogony and 'certain malignant aspects of the sun and moon'.[5]

Although the richness and diversity of India's ancient scientific traditions has long been recognised, over the past two centuries it has been the convention to see this as a history of precocious early achievement followed by subsequent decline and degeneration. The European Orientalist scholarship of the late eighteenth and early nineteenth centuries represented India as having had an ancient civilisation equalling, in some respects excelling or anticipating, those of classical Greece and Rome. 'The Asiaticks had climbed the heights of science before the Greeks had learned their alphabet', one enthusiast declared.[6] In astronomy, mathematics and medicine in particular, Hindu science was considered to have been remarkably advanced well before the dawn of the Christian era and to have been the source of discoveries and techniques that were only later taken up and incorporated into Western civilisation, such as 'Arabic' numerals and the use of zero.[7] However, according to this Orientalist interpretation, Indian civilisation was unable to sustain its early achievements and lapsed into decline. There followed an uncritical reliance upon earlier texts: tradition replaced observation as surely as religion supplanted science. This was in part attributed to an increasing rigidity in Hindu society of caste practices and religious belief, but also to the rise of Muslim power in South Asia after AD 1100. Although introducing some scientific and technical skills of its own, Islam was largely seen to have been destructive of the remnants of the old Indian civilisation. The breakup of the Mughal Empire after 1707, the division of India into warring factions and regional

[5] For a useful introduction, see Zaheer Baber, *The Science of Empire: Scientific Knowledge, Civilization, and Colonial Rule in India* (New York, 1996), ch. 2.

[6] David Kopf, *British Orientalism and the Bengal Renaissance: The Dynamics of Indian Modernization, 1773–1835* (Berkeley, CA, 1969), p. 102.

[7] Mountstuart Elphinstone, *History of India* (9th edition, London, 1905), pp. 138–60.

states, and the resulting age of 'anarchy' were adduced as further evidence for the stagnation and decay of Indian science, technology and medicine. The history of Indian science thus served as a mere prologue to the eventual unfolding of Western science in South Asia as science was rescued from centuries of decline and obscurity by the advent of British rule and the introduction of the more developed scientific and technical knowledge of the West. This Orientalist triptych – contrasting the achievements of ancient Hindu civilisation with the destruction and stagnation of the Muslim Middle Ages and the enlightened rule and scientific progress of the colonial modern age – has had a remarkably tenacious hold over thinking about the science of the subcontinent. It was a schema deployed not only by British scholars, officials and polemicists but also by many Indians, for whom it formed the basis for their own understanding of the past and the place of science in Indian tradition and modernity. It is still not uncommon for Indian writers to remark, with evident regret, that the 'creative spirit' of Indian science sunk to its 'lowest ebb' between the twelfth and the mid-nineteenth centuries.[8]

Of late, though, some historians of science have sought to break the Orientalist mould. One of the ways in which they have done so has been by looking afresh at the science, technology and medicine of medieval and early modern India, thus revealing the neglected importance of the Muslim contribution to India's scientific traditions or illuminating the emergence, through science, of a dynamic and syncretic Indo-Muslim culture. Medicine has been particularly prominent in this historiographical trend. The mutual enrichment brought about by a 'creative synthesis' between Hindu Ayurveda and Unanitibb, with its Graeco-Arabic origins, and the apparent absence of rivalry or enmity between its practitioners, the *vaids* and *hakims*, have served to exemplify the continuing vitality and fruitful intermingling of scientific traditions in India well into the eighteenth century, though one might equally argue that Unani physiology and pharmacology were interacting as much with the Indian environment and the region's rich materia medica as with the Ayurvedic system as such.[9] There has also been a new effort to demonstrate that India, far from existing in cultural and technological isolation and being averse to all innovation, had over the centuries borrowed extensively from, and contributed generously to, the scientific and technical knowledge of neighbouring regions, from the Middle East and Central Asia to China and Southeast Asia, and in

[8] B. V. Subbarayappa, 'Western Science in India up to the End of the Nineteenth Century', in D. M. Bose, S. N. Sen and B. V. Subbarayappa (eds.), *A Concise History of Science in India* (New Delhi, 1971), p. 484.

[9] R. L. Verma, 'The Growth of Greco-Arabian Medicine in Medieval India', *IJHS*, 5 (1970), pp. 347–63; Baber, *Science*, pp. 78–9.

fields as diverse as agriculture, architecture, astronomy, chemistry, medicine, metallurgy, textile production, shipbuilding and armaments.[10] This celebration of cultural eclecticism and trans-regional exchange aligns the history of Indian science more closely with the models of creativity, diffusion and interaction advanced for China, the Muslim Middle East and other non-European culture areas in recent decades, particularly through Joseph Needham's magisterial account of *Science and Civilisation in China* and through other revisionist histories, such as Lynn White's, that have authoritatively established Europe's long-standing debt to Asian technology.[11]

It follows from this revisionist argument that Europe did not impact upon a stagnant and unchanging India. From the late fifteenth century onwards, scientific, medical and technological exchanges continued through the agency and impetus of trade and warfare and through the migration of scholars, merchants, physicians and craftsmen. Contacts flourished in two main directions – with the wider world of Islam (linking India with Iran, Central Asia and the Middle East) but also, increasingly, with the expanding commercial and technological power of Europe. Astronomy, medicine, textiles and arms-making benefited from the fashioning of an Indo-Muslim polity and culture under the Mughals, but India also profited in such areas as shipbuilding and horticulture from contacts after 1498 with the Portuguese and later with the Dutch, French and English.[12] If there remained a gulf between the craft technology of the uneducated artisan and the science of the literati, if there were few individuals before 1750 to whom one could convincingly apply the term 'scientist', then India was in these respects little different from early modern societies in Europe, China or elsewhere. The intellectual activity of religious and cultural elites and the skills of artisans jointly fashioned for India a distinctive place in the annals of science and technology, even if they existed largely in isolation from one another – except when, as for instance at the court of Akbar, the needs of warfare and the prompting of intellectual curiosity brought them temporarily together.[13]

Although from the early sixteenth century the Mughal court was a vital source of patronage for science and technology, dynastic decline in the eighteenth century did not entirely plunge India into obscurity, even if the number

[10] S. N. Sen, 'Influence of Indian Science on Other Culture Areas', *IJHS*, 5 (1970), pp. 332–46.

[11] Joseph Needham, *The Shorter Science and Civilisation in China* (ed. Colin A. Ronan), (4 vols., Cambridge, 1978–94); Lynn White, *Medieval Technology and Social Change* (Oxford, 1962).

[12] A. Jan Qaisar, *The Indian Response to European Technology and Culture (AD 1498–1707)* (Delhi, 1982); Irfan Habib, 'The Technology and Economy of Mughal India', *IESHR*, 27 (1980), pp. 1–34.

[13] Irfan Habib, 'Akbar and Technology', in Irfan Habib (ed.), *Akbar and His India* (Delhi, 1997), pp. 129–48.

of manuscripts produced in Sanskrit, Persian and Arabic on scientific and technical subjects showed signs of slowing down.[14] A positive interest in science (and, increasingly, in reconciling the sciences of East and West) flourished under royal patronage in the regional courts of India, from the astronomical observatories built by Raja Jai Singh between 1722 and 1739 at Jaipur, Delhi, Mathura, Ujjain and Benares, to the eclectic medical interests and library of Indian and Western medical texts assembled by Serfoji, the last Maratha ruler of Tanjore.[15] New centres of learning sprang up, some, like Hyderabad under its Nizams or Lucknow under the Nawabs of Awadh, specialising in Islamic science and Unani medicine, while other older, mainly Hindu, seats of learning such as Benares and Nadia in Bengal continued to flourish. Despite the withering away of Mughal power, Delhi remained a significant locus for science, art and literature, and, until the cataclysmic events of 1857, enjoyed a twilight 'renaissance'.[16] There were, however, some areas in which India appeared unresponsive to new technologies. Despite the introduction of the printing press by the Jesuits in Goa in the mid-sixteenth century, it had little influence on India before the late eighteenth century, though its spectacular take-off in the nineteenth century belies any suggestion that this was a consequence of some intrinsic 'mechanical backwardness'.[17] Rather than providing proof of any sustained resistance to technological change, the slowness to adopt printing might rather be taken to indicate the selective manner in which Western science, technology and medicine were appropriated and the persistence of prestigious cultural values, embedded, in this instance, in the manuscript tradition and the skills of artisans and scribes.[18] Matters affecting proficiency in warfare were, by contrast, of more urgent concern and attracted a far more active response. This was the case not only with the Mughals, but also subsequently with the armies of Tipu Sultan of Mysore (until his defeat at Seringapatnam in 1799) and those of Ranjit Singh in Punjab, whose foun-

[14] A. Rahman (ed.), *Science and Technology in Medieval India: A Bibliography of Source Materials in Sanskrit, Arabic and Persian* (New Delhi, 1982), pp. xi–xvi.

[15] Baber, *Science*, pp. 85–90; Deepak Kumar, 'Unequal Contenders, Uneven Grounds: Medical Encounters in British India, 1820–1920', in Andrew Cunningham and Bridie Andrews (eds.), *Western Medicine as Contested Knowledge* (Manchester, 1997), pp. 168–82; N. Gangadharam, 'The State of Ayurveda in the Eighteenth and Nineteenth Centuries', in G. Kuppuram and K. Kumudamani (eds.), *History of Science and Technology in India*, I (Delhi, 1990), pp. 13–29.

[16] Gail Minault, 'Sayyid Ahmad Dehlavi and the "Delhi Renaissance"', in R. E. Frykenberg (ed.), *Delhi Through the Ages* (Delhi, 1986), pp. 174–85.

[17] L. S. S. O'Malley, 'Mechanism and Transport', in L. S. S. O'Malley (ed.), *Modern India and the West* (London, 1941), p. 221.

[18] For printing and its uses, see C. A. Bayly, *Empire and Information: Intelligence Gathering and Social Communication in India, 1780–1870* (Cambridge, 1996), pp. 235–43.

dries at Lahore and Amritsar manufactured heavy guns and mortars in the 1820s and early 1830s.[19]

Just as it is necessary to rethink the chronology of Indian science and break down the old periodicity of the Orientalist model, so is it imperative to reassess the significance for science, technology and medicine of India's vast land area and internal diversity. Although it is customary and convenient to speak of 'Indian' science or 'Hindu' medicine, such broad aggregations obscure the wide variations between one part of the subcontinent and another. As the examples in the previous paragraph suggest, the decentred nature of India's political and cultural system enabled, most obviously (though not uniquely) in the eighteenth century, several centres of science, technology and medicine to flourish at the same time and for each to develop its own distinctive characteristics. Diversity brought strengths as well as weaknesses. The decline of one centre did not preclude the survival and adaptation of another; India as a whole could profit from the varied intellectual and material products of its different regions and from their interaction and exchange. There were regional schools of Ayurvedic and Unani medicine, just as there were regional variations in the weaving and dyeing of cloth. The physical diversity of the Indian environment, South Asia's almost continental proportions, and the multiplicity of its cultural and political constituencies not only contributed to internal variety and local specialisation but also, from an opposing perspective, challenged attempts (as by British rulers and nationalist scientists) to use the ideological agency and material instrumentality of science, technology and medicine to try to conquer and integrate India's vast interior spaces.

Recurrent, too, in the history of science in India was a tension between the countryside and centres of courtly or regional power, or between cities old and new. Although colonial science might crudely serve to underline the cultural, commercial and political importance of the rise of the three coastal metropolises – Calcutta, Bombay, Madras – this would be to overlook the contribution made to their evolution by the artisans and intellectuals who flocked to them from older centres of manufacturing and scholarship. It would also be to ignore the resilience of other, more ancient centres of learning such as Benares and Delhi. It is not without significance that a number of universities with leading science departments by the 1940s – Lahore, Lucknow, Allahabad, and Dacca, to identify but four points along the Indo-Gangetic axis – were located in cities already prominent on the cultural and political map of India two centuries earlier.

[19] Arnold Pacey, *Technology in World Civilization: A Thousand-Year History* (Oxford, 1990), p. 144.

As with cities, so with social groups. Some of India's old intellectual elites resurfaced as agents and interpreters of the new scientific order, as in the case of the Brahmins, Vaidyas and Kayasthas who composed the *bhadralok* (middle-class intelligentsia) in colonial Bengal. It is suggestive, too, of the strength of these intellectual and social continuities that the only Nobel prize to be awarded to an Indian scientist before Independence went to a Tamil Brahmin, C. V. Raman, in 1930. But it should not be overlooked that other social groups (including Parsis, Indian Christians and lower-caste Hindus) also found a place among the practitioners of scientific modernity. The extent to which members of the old intelligentsia brought to their 'modern' avocations skills, insights and inspiration derived from 'traditional' backgrounds (rather than simply trading in their intellectual inheritance to acquire new Western knowledge) is an intriguing issue but one that historians have, as yet, scarcely begun to investigate.[20] Equally, although the advance of British power in South Asia in the late eighteenth and early nineteenth centuries resulted in the overthrow or eclipse of a number of Indian states, culminating in the annexation of Awadh in 1856 and the extinction of Mughal Delhi two years later, it is striking how important India's surviving princes and landed aristocracy were to the patronage of science (in its indigenous as well as Western forms) in the nineteenth and early twentieth centuries and in fields as diverse as astronomy, medicine and technical education. That India's first major hydro-electric scheme was constructed in the princely state of Mysore in 1898 and that ten years later Bangalore became the site for the Indian Institute of Science, should alert us to the significance of even the circumscribed power of the princes in providing an alternative (often more adventurous) source of scientific support and technological initiative to that offered by the British. But if in this respect India's continuing disunity appeared to favour the enterprise of science, in many other respects science in late-colonial India was plagued by the difficulty of trying to create and sustain organisations and institutions that would integrate India into a single scientific entity.

The reappraisal of the character of Indian science, technology and medicine before British rule, therefore, not only is of importance in itself, in establishing the vitality and diversity of an 'indigenous' tradition, but also has wide-ranging implications for understanding what happened after the establishment of the colonial regime. It becomes more difficult to treat India as a kind of scientific and technological *tabula rasa*, whose achievements lay in the

[20] Cf. Kapil Raj, 'Knowledge, Power and Modern Science: The Brahmins Strike Back', in Deepak Kumar (ed.), *Science and Empire: Essays in Indian Context (1700–1947)* (Delhi, 1991), pp. 115–25.

remote past and so were unable to affect or inform the course of Western science in South Asia. A recognition of the relative openness and adaptability of India's pre-colonial scientific and technological tradition supports the view that an interactive model might be more appropriate for the colonial period rather than one that depicts either outright confrontation between two intransigent forces or an automatic unassailable Western ascendancy. But, at the same time, pre-colonial science and its legacies should not be asked to explain too much. It is necessary to attach no less importance to the profound rupture caused to Indian society, materially and intellectually, by colonial intervention and the unprecedented impact made by the science, technology and medicine of the West.

COLONIAL SCIENCE

The history of science, technology and medicine in British India has often in the past been represented as essentially the story of the introduction and dissemination of Western ideas, practices and techniques. Such accounts make scant reference either to indigenous scientific, technological and medical traditions (except negatively, as a source of unreasoning and atavistic opposition to the legitimate progress of science, or as a lineage happily long extinct by the late eighteenth century), or to tensions and divergences between science as practised in the colony and that propagated in the capitals of Europe. Of late, however, as the history of science, technology and medicine in India has expanded and as the nature of Western science itself has been subjected to more critical appraisal, the relationship between India and Western science has come to be seen as more complex and less one-directional than previously assumed. The idea of a simple diffusion of a monolithic and progressive Western science into passively recipient extra-European lands has been challenged from several standpoints, not least by a more interactive and regionally focused understanding of how science developed in India from the late eighteenth century onwards.

But it is as well to begin with an ageing orthodoxy. The most influential statement of the diffusionist model of Western science was made by George Basalla in 1967,[21] and though it now appears dated and simplistic in many respects it is still worth summarising as the basis for much of the ongoing discussion of colonial science. How, Basalla asked, did 'modern science' come to be diffused from its original home in Western Europe and 'find its place in the

[21] George Basalla, 'The Spread of Western Science', *Science*, no. 156 (1967), pp. 611–22.

rest of the world'? He argued that the process could best be understood through a three-stage model. In Phase One, Europeans established contact with new lands as part of the process of Western reconnaissance, trade, conquest, and colonisation. The 'non-scientific' society served Europe as a source of scientific data, garnered by Europeans through maps and surveys, and mineral, plant and animal specimens. In keeping with Europe's interest at this stage in 'the systematic exploitation of nature', the dominant sciences of Phase One were botany and zoology, followed by astronomy, geology and geography. Although commercial motives provided some impetus for this scientific reconnaissance, Basalla attached more significance to the scientific culture from which Europeans came and to which they relayed back the results of their investigations. Phase-One science might be scattered around the globe, but only nations with 'a modern scientific culture', such as Britain, Holland and France, could 'fully appreciate, evaluate, and utilise' the knowledge thus acquired, though, in the course of assimilating new information from the wider world, Western science itself underwent modification.

In the second phase, that of 'colonial science', locally born or resident scientists (whom Basalla assumes to be Europeans) started to participate in scientific activities; local scientific institutions began to appear. While interest in natural history continued, almost all the scientific fields currently pursued in Europe were replicated overseas, but the local scientific community remained dependent upon European expertise and institutions and hence was reliant on 'an external scientific culture'. Basalla stressed that by calling colonial science 'dependent' he did not mean that it was necessarily inferior science (though critics have taken that to be his implicit meaning), and he claimed that the term could be applied not just to formal colonies like India, but also to science in uncolonised territories like China and Japan, or to the United States until several decades after its independence. The dependent status of colonial science ensured that many of its practitioners continued to receive their training in Europe and directed colonial scientists into areas of enquiry laid down by Europe. It remained difficult for colonial scientists to enter Europe's leading scientific societies and to gain access to those prestigious and influential 'invisible colleges' where the latest scientific ideas were debated and new agendas drawn up. The local scientific community had not yet reached the critical size necessary for 'reciprocal intellectual stimulation and self-sustaining growth'.

In time, as substantially larger numbers of scientists came to be trained and to work locally, extra-European societies in Phase Three strove to establish an 'independent scientific tradition' and a 'national science' of their own. Political independence might help to inspire greater scientific autonomy, but more

important, Basalla averred, was the creation of national scientific institutions and honours. A political, educational and technological infrastructure emerged that allowed modern scientific research to thrive, conducted by local scientists operating within national boundaries and in accordance with national needs and priorities. Basalla suggested that the United States and Russia reached this stage between the two world wars, overtaking their former mentors in Western Europe. He placed Japan, Australia and Canada on a slightly lower stage of development, with other Asian, African and Latin American countries lagging well behind.

In the absence of a more satisfactory model, Basalla's typology has continued to be widely cited and discussed, though seldom with less than qualified approval. But Basalla was one of the first scholars to try to conceptualise 'colonial science', making it the transitional stage between the first implanting of 'modern science' overseas and its eventual maturation into 'national science' and an 'independent scientific tradition'. He did not, however, attempt to extend his analysis into medicine and technology (which in the case of nineteenth-century India might be seen as having far greater practical significance than science *per se*); nor, more puzzlingly, did he try to differentiate between varieties of colonialism. He ignored the enormous differences in background and experience of such countries as Brazil, Japan, India and Australia, and to anyone even superficially acquainted with their histories it would appear improbable that they all followed the same scientific trajectory through an identical time-scale. Leaving aside territories never formally colonised, there were clearly vast differences between the role of science in settler colonies, like those of North America and Australasia, where indigenous peoples and their cultures were largely swept aside, and 'colonies of exploitation' like India that were subject to colonial rule but where whites were few and indigenous cultures remained strong. By 'colonial science' Basalla clearly intended the science of itinerant and resident Europeans, though the term might equally apply (and has increasingly been applied) to that practised, in a colonial situation, by whites and indigenes alike. (It might also be noted, in passing and as an indication of the multi-stranded complexity of the scientific culture under discussion here, that even among European practitioners of science in a single colony there might be considerable diversity of origin and outlook. Although India's principal scientific and technological relations were inevitably with Britain as the colonial power, scientists from other countries – Danish botanists, German foresters, American malariologists – also contributed to the articulation of Western scientific ideas and practices in India.) Moreover, as Michael Adas points out, Basalla took a view, 'rarely challenged

by his generation of scholars', that science was 'value neutral, objective, empirically demonstrated, somehow transcending time and thus universally valid'. Basalla's diffusionist vision was 'informed by a developmental teleology premised on the assumption that the spread of Western science to the rest of the globe [was] both beneficial and inevitable'.[22] This in turn led Basalla to assume that colonial regimes were willing agencies through which science could readily be diffused, whereas in many cases they might actually distort the development of science or, for ideological and material reasons, inhibit the spread of valued technologies. It might further be doubted whether, even after political independence, many erstwhile colonies had the resources to build their own 'national science' or to escape continuing dependence upon a small coterie of scientific superpowers.[23]

There are, of course, elements of the Basalla model that undoubtedly ring true. For instance, the emphasis given in Phase One to sciences such as botany and zoology is substantially borne out by Indian experience in the late eighteenth and early nineteenth centuries (though this disciplinary bias in fact persisted well into the twentieth century despite Indian attempts to redirect scientific enquiry to the 'purer' realms of mathematics, physics and chemistry). Basalla notes in his concluding remarks the need to examine science in different 'national, cultural, and social settings', but sadly he does not heed his own advice. Instead, by assuming that 'modern science' could have its origins only in the West and had therefore to be disseminated from there to hitherto 'non-scientific' countries, Basalla largely ignores the fact that countries like India and China had a long scientific and technological tradition of their own. Indigenous traditions did not simply evaporate with the first warming rays of an occidental sun: they were initially the subject of close, often appreciative, European scrutiny, and, though in India they were increasingly marginalised during the course of the nineteenth century, they continued to play a vital practical and ideological role. In Basalla's Eurocentric model, dynamism belongs to an (improbably) homogeneous West, leaving the rest of the world to participate only passively in the process of diffusion, unable to make any original contribution of its own or even to negotiate with an ascendant Western science.

[22] Michael Adas, 'Testing Basalla's Paradigm: Colonialism and the Diffusion of Science in British India', paper presented at the XIXth International Congress of the History of Science, Zaragoza, August 1993, p. 36.

[23] Nancy Stepan, *Beginning of Brazilian Science: Oswaldo Cruz, Medical Research and Policy, 1890–1920* (New York, 1976), pp. 14–40; Ian Inkster, 'Scientific Enterprise and the Colonial "Model": Observations on the Australian Experience in Historical Context', *Social Studies of Science*, 15 (1985), pp. 677–704; V. V. Krishna, 'The Colonial "Model" and the Emergence of National Science in India, 1876–1920', in Patrick Petitjean, Catherine Jami and Anne Marie Moulin (eds.), *Science and Empires: Historical Studies about Scientific Development and European Expansion* (Dordrecht, 1992), pp. 57–72.

Scientific knowledge and the ideology of science, it has been argued *contra* Basalla, can be 'actively redefined in the milieu of a recipient culture'. The receiving society, far from being supine, 'subverts, contaminates, and reorganises the ideology of science as introduced by Europe',[24] though one might add the caveat that the extent to which 'ideological subversion' could actually succeed in India before 1947 was constrained both by the political and financial control exercised by the colonial regime and by the influence and authority of the international scientific community.

In further refutation of an argument based on Western diffusionism and indigenous passivity, it is hard to see how, even at a superficial level, Western science could have functioned in many parts of the world without being able to draw upon 'local' knowledge and 'native' agency of various kinds, without local savants, scribes, interpreters and artists, fishermen and forest-folk, to guide and inform it. Increasingly, in conscious reaction against such ethnocentricity, many of the scientific 'discoveries' formerly claimed for the West have been traced back to earlier sources of indigenous knowledge. In the South Asia context, scholars have sought to establish the importance of Indian participation and information even in such seemingly exclusively European fields of colonial science as botany, geology and the trigonometrical surveys.[25]

But, if we are to reject a diffusionist model of 'colonial science', what can we put in its place? It could be argued that any attempt to reduce the complex experience of India to a simple typology is bound to fail, but there are at least two possible alternatives that deserve consideration. One is to argue that distinctions between centre and periphery, between 'metropolitan' and 'colonial' science, fundamentally misrepresent the way in which science evolved internationally from the seventeenth century onwards. Science, it might be reasoned, was not the property of a single society (located in Western Europe) but could be genuinely cosmopolitan, absorbing and assimilating information and ideas from a wide variety of sources and locations. 'Metropolitan science' did not even have a single, fixed locus of power: the 'metropolis' might move over time from one place to another; it might simply represent a certain way of doing or organising science, whether in Europe or overseas.[26] If we were to discard a

[24] Dhruv Raina and S. Irfan Habib, 'The Unfolding of an Engagement: *The Dawn* on Science, Technical Education and Industrialization, India, 1896–1912', *SH*, 9 (1993), pp. 87–8.

[25] E.g., Richard Grove, 'Indigenous Knowledge and the Significance of South-West India for the Portuguese and Dutch Constructions of Tropical Nature', in Richard H. Grove, Vinita Damodaran and Satpal Sangwan (eds.), *Nature and the Orient: The Environmental History of South and Southeast Asia* (Delhi, 1998), pp. 187–209.

[26] Roy MacLeod, 'On Visiting the "Moving Metropolis": Reflections on the Architecture of Imperial Science', *Historical Records of Australian Science*, 5 (1982), pp. 1–16.

Eurocentric approach, and jettison a constricted time-frame that privileges the eighteenth and nineteenth centuries, we might see that, through a long series of interactions, China, India, the Islamic world, even Meso-America, contributed as much, relatively speaking, to the development of science, technology and medicine before 1500 as Europe (and latterly North America) did over the following five hundred years. It could further be argued that, even within the colonial era, scientists in the colonies were equal participants, not inferior agents, in the development of science. Hence, a valid distinction cannot meaningfully be made between a 'low science' of fact-gathering in the colonies and a 'high science' of theory and synthesis in the metropole. Scientists in India, it can be argued, made major contributions to the natural sciences of the eighteenth and nineteenth centuries and won international recognition for their labours; 'colonial scientists' should not therefore 'be categorised as being separate from or inferior to the mainstream metropolitan scientific community'.[27]

However, although this line of interpretation helps to rescue many aspects of colonial science from apparent obscurity and metropolitan condescension, it does not necessarily take us much beyond the one-dimensionality of the diffusionist model. In particular it fails, much as Basalla does, to recognise the 'political character of science'. Although in some respects (in terms of the size of its scientific community, the number and quality of its societies and journals, its access to one of the West's premier scientific and industrial nations) India in the period under consideration enjoyed a relatively privileged position, it was still, none the less, a colonial, not an autonomous, domain. Whether under the East India Company or, following its demise in 1858, the Crown, there was a clear hierarchy of scientific authority that placed Britain and its scientists at the top and fixed India (and even British scientists working in India) in a position of dependence and subordination. Even in the closing decades of British rule, at a time when some historians have seen India as breaking free of imperial constraints in science, technology and medicine, as in many other spheres of activity, it is striking how entrenched British authority remained and how influential, despite the striving of 'national science', the models, agencies and agendas of metropolitan science remained. Science could not easily be divorced from the political ideologies and institutional structures that colonialism had put in place. If, as has aptly been said, Basalla's model 'trivialises the compulsions of colonialism',[28] it remains important to

[27] Satpal Sangwan, 'From Gentlemen Amateurs to Professionals: Reassessing the Natural Science Tradition in Colonial India, 1780–1840', in Grove et al. (eds.), *Nature*, p. 227.

[28] R. K. Kochhar, 'Science as a Tool in British India', *Economic and Political Weekly*, 17 August 1991, p. 1933.

keep those 'compulsions' in mind in seeking to devise other interpretative schema. Moreover, it is important to recognise that science, technology and medicine were more than a colonial force. They were, and surely remain, aspects of a global hegemony; it is prodigiously difficult for states, even those as large and powerful as India, even under Jawaharlal Nehru in the 1950s and 1960s, to attain their own scientific salvation. Internally, too, science became a vital factor in the articulation of class ideologies and structures, especially through the creation of novel systems of industrial organisation and production, through the creation of new professional and working-class identities and through the hegemonic authority of both established and aspiring elites. The term 'colonial science' (and its analogues in medicine and technology) may be flawed, but it is worth retaining and using it (more flexibly than Basalla did) to describe the various technologies of power operating within and through science in a colonial setting.

SCIENCE AS MODERNITY

Another way of approaching science and its significance in the context of colonial India is in terms of modernity. Science was intimately bound up with both colonial and Indian concepts of what constituted the modern world; it gave shape and authority to the understanding of modernity. By the early nineteenth century, following a period in which they showed themselves relatively receptive to Indian ideas and practices, the British saw science, technology and medicine as exemplary attributes of their 'civilising mission', clear evidence of their own superiority over, and imperial responsibility for, a land they identified as superstitious and backward. Science thus conceived served to heighten a growing sense of difference between Britain and India. In the wake of Britain's industrial revolution, technology (especially that of the steam age, heralded by steamships and railways) critically informed this perspective;[29] but so, too, did a growing sense of distinction between Western and indigenous medicine and a belief in the unique capacity of the West to master through engineering, medicine and natural science an environment that still held Indians in its thrall. Confidence in the transforming, modernising power of science climaxed with the viceroyalty of Lord Curzon (1899–1905), when the doctrines of high imperialism were echoed in the rhetoric and institutions of India's 'imperial science'. However, faith in Britain's capacity to modernise and civilise India was always fraught with multiple contradictions, among them a recurrent belief that

[29] Michael Adas, *Machines as the Measure of Men: Science, Technology and Ideologies of Western Dominance* (Ithaca, NY, 1989), chs. 3–4.

Indians were unready (or unfit) to receive the benefits of scientific modernity, a determination to deny India the competitive advantages that full access to modern science and technology might entail, and a romantically tinged anti-industrialism, in which India was destined to remain a land of princes, peasants and artisans, spared the ugliness and turmoil of modern industrial society.

Indians, unsurprisingly, also differed widely in their responses to Western science and its evangelising message of modernity. But some, especially among the Western educated, endorsed the call for India's transformation and identified wholeheartedly with the modernising project. As Gyan Prakash has put it, 'scientific reasoning became the organising metaphor in the discourse of the Western-educated elite. Impressed and stimulated by scientific and industrial progress in the West, the elite began to scrutinise indigenous religions and society in the light of scientific reason, not just rationality.' The 'cultural authority of science' and the 'authorisation of the elite as agents of modernity and progress' together attained 'an enduring dominance in India during the second half of the nineteenth century'.[30] As other scholars have shown, the reach of 'colonial modernity' extended well beyond institutional and economic reform to inform attitudes and practices relating to education and health, domesticity and gender roles, religious beliefs and social reform.[31]

But, for a colonial people, modernity could not be unproblematic. Modernity, and more restrictedly modernisation, has often been seen to represent the dissemination and acceptance of an essentially Western set of institutions and values, along much the same lines as Basalla's typology for the 'spread of Western science'. More than thirty years ago Lucien Pye defined modernisation as being 'based on advanced technology and the spirit of science, on a rational view of life, a secular approach to social relations, a feeling for justice in public affairs, and above all else, on the acceptance in the political realm of the belief that the prime unit of the polity should be the nation-state'.[32] Indians under colonial rule might endorse many items of this agenda but still feel that modernity remained for them an unattainable object of desire. Acceptance of modernity as partisanly presented by colonial officials, missionaries, educationalists and scientists would always confine

[30] Gyan Prakash, 'Science between the Lines', in Shahid Amin and Dipesh Chakrabarty (eds.), *Subaltern Studies IX* (Delhi, 1996), p. 60.

[31] Dipesh Chakrabarty, 'The Difference-Deferral of a Colonial Modernity: Public Debates on Domesticity in British India', in David Arnold and David Hardiman (eds.), *Subaltern Studies VIII* (Delhi, 1994), pp. 50–88.

[32] Lucien W. Pye, *Aspects of Political Development* (Boston, MA, 1965), p. 8; cf. S. N. Eisenstadt, 'Introduction: Historical Traditions, Modernization and Development', in S. N. Eisenstadt (ed.), *Patterns of Modernity II: Beyond the West* (London, 1987), pp. 1–11.

Indians to a state of tutelage and subordination, always leave them one step behind, second-best and imperfect copies of a Western ideal. How, Partha Chatterjee has asked, could Indians accept and assimilate the modernity of the colonising West while at the same time seeking to contest colonial authority and its assertions of Indian inferiority? He concludes that nationalism 'produced a discourse . . . which, even as it challenged the colonial claim to political domination, . . . also accepted the very intellectual premises of "modernity" on which colonial domination was based'.[33] Recent scholarship has sought to wrestle with this conundrum in various ways. One response is to argue, as Prakash does, that the authority of science had to be renegotiated and 'translated' to fit the needs and idioms of Indian society; it could not be accepted simply as it was articulated by the West. Another possibility is to suggest that modernity is not a single entity, patented by the West and retailed across the globe, but is capable of multiple forms and any number of cultural and political variants, which, while inevitably drawing on the science, technology and medicine of the West, also incorporate indigenous traditions and local systems of knowledge, thus enabling a country like India to forge a modern identity appropriate to its own cultural legacies and specific needs.[34]

As will be seen in this book, during the nineteenth and early twentieth centuries, Indian scientists and intellectuals tried to construct their own brand of Indian modernity, particularly through the selective incorporation (or re-invention) of Hindu ideas and traditions, though the mix of elements, the degree of 'hybridity' involved in this process, varied widely from one individual to another, even within the emergent scientific community. However, although this gave science in India a new sense of authority and belonging, it also generated its own dilemmas and sites of resistance. Even at the close of the colonial era it remained unclear how far scientific modernity could command a consensus within India itself and how far a science informed by Indian values could gain acceptance from an international scientific community dominated by the West. Whereas some nationalist politicians like Jawaharlal Nehru declared themselves to be worshippers at 'the shrine of science' and saw science as both the agency and emblem of Indian modernity,[35] others (led by the influential figure of M. K. Gandhi) spurned modernity, with its alien

[33] Partha Chatterjee, *Nationalist Thought and the Colonial World: A Derivative Discourse?* (London, 1986), p. 30.

[34] Prakash, 'Lines', pp. 61–2, 80; Partha Chatterjee, 'Our Modernity', in *The Present History of West Bengal: Essays in Political Criticism* (Delhi, 1997), pp. 193–210.

[35] Address to the National Academy of Sciences, Allahabad, 5 March 1938, in *Selected Works of Jawaharlal Nehru* VIII (New Delhi, 1976), p. 806; Jawaharlal Nehru, *An Autobiography* (London, 1936), pp. 433–7.

sciences and inappropriate technologies. To some extent these conflicting attitudes remain unreconciled in India today; as such they lie beyond the scope of this book.[36] But under Nehru, as independent India's first Prime Minister, a kind of pragmatic compromise was reached by which the nation-state assigned a no more than secondary role to the forces of tradition in science, technology and medicine, while identifying itself, and the needs of the people, with a more internationally recognisable brand of scientific and technological modernity.

[36] See Sunil Khilnani, *The Idea of India* (London, 1998).