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Dhruv Raina:

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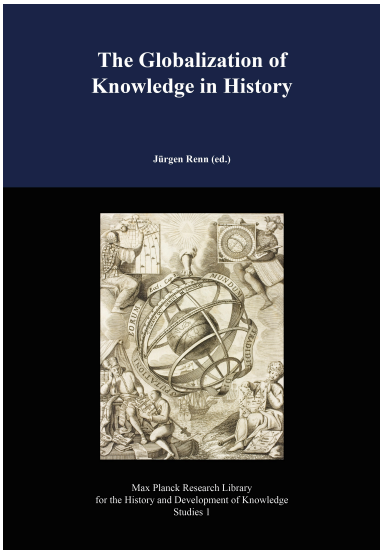

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Chapter 15
The Naturalization of Modern Science in South Asia: A Historical Overview of the Processes of Domestication and Globalization

Dhruv Raina

15.1 Introduction

The ascent of India as a player in the world of modern science has been a subject of much recent discussion. This paper discusses the institutionalization of modern science in South Asia. The globalization of modern science involved a process of the localization or domestication of modern scientific knowledge and its institutions, as well as an associated process of decolonization that marked the middle decades of the twentieth century wherein the nation state became a contested site for negotiations over the kind of science to be inaugurated in an independent republic (Raina and Habib 2004). Informed by recent developments in the historiography of "post-colonial science" it is argued that this process of domestication of the global was simultaneously accompanied by a process wherein the local was shaped by the global that in turn was reconstituted by the local (Raj 2007).

The study of the globalization of science in non-Western contexts has over the past three decades been shaped amongst other factors by the changing regimes of international politics. The revision of the frames of academic discourse about science in the non-West is more or less concurrent with the process of decolonization initiated within former colonial societies. In particular, post-colonial perspectives of science have been complemented by developments in the sociology of scientific knowledge (Harding 1998; Raina 2007). Consequently, several disciplinary frames engage with the drift produced by the entanglement of the scientific project with that of nineteenth-century European imperialism and colonialism (Adas 1990; Kumar 1995). Science as an essential component of the civilizing mission was in the older perspective the vector of a particular kind of globalization, and its value neutrality ensured its own globalization. The new perspectives reveal the socially embodied nature of scientific knowledge reflected in the manner it is reconstituted in the encounter with other ways of knowing and acting on the world. The meeting of different systems of classification, the process of the cultural appropriation of scientific or technological ideas from one cultural context to another, produced idea hybridizations at the peripheries of modern science (Grove 1995; Raina 1996). This process of hybridization at the periphery stimulated new traditions of research

"back home" in the metropolises of Western Europe. The history of modern science in India, it has been suggested, over the last three centuries is on the one hand linked with the arrival of European travelers, missionaries and traders in the seventeenth and eighteenth centuries, and finally the inauguration of colonial rule in the nineteenth century. Under late colonialism it is equally important to recognize that the establishment of scientific institutions and organizations installed before India became independent of colonial rule were linked with the anti-colonial nationalist struggle (Bernal 1942).

This chapter elaborates upon three aspects of the process of the domestication and globalization of science in South Asia. In the first section, the encounter between modern science and the multiple knowledge systems that characterize the South Asian regions is discussed. This encounter is simultaneously both an epistemic one as much as it has been the subject of investigation for the politics of knowledge. The discussion covers the period between the seventeenth and the end of the nineteenth centuries, which marks the century of the encounter between Europe and India and the end of the period marks the reign of the mature phase of colonialism. The second section deals with the coupling of the question of the modernity of science and the modernity of the nation. The trajectories of two distinct projects are entangled. The one having to do with the naturalization or domestication and the expansion of the dominion of modern science and the other with the construction of the modern nation. In other words the modernity of science is entangled with the project of anti-colonial nationalism. And finally, from the 1950s onwards science is harnessed to the projects of development and decolonization in the former colonies. This section traces the evolution of the scientific and technological research system from 1950 until the end of the twentieth century. In the discussion that follows, three terms are apparently employed interchangeably as if they were synonyms for one another, these being 'domestication,' 'naturalization' and 'localization.' However, a clarification is in order. The term naturalization refers to the process of the introduction of plants to places where they flourish but are not indigenous, while the term domestication connotes more or less the same process in addition to which it also connotes "to cause to feel comfortable at home." I have employed these terms to refer to the process of the introduction of modern science into another environment and not to the introduction of plants or animals, but often enough employ them interchangeably. Though it could be argued that the process of domestication involves the additional process of legitimating the knowledge system in another environment. Localization, on the other hand, refers to the process of making local, but where it differs from the other two is that naturalization and domestication could be seen to operate at the semantic level, the process of localization alludes to making new cultural practices local. Consequently, these terms refer to the process of the shuttling that goes on between different knowledge systems as communities of practitioners struggle to make sense of one or the other.

The term knowledge systems has acquired currency in discussions of science and politics over the last three decades, and figures prominently in the literature on the so-called ethno-sciences and the politics and anthropology of science. The idea of South Asian Knowledge Systems is further complicated since the geographic region it encompasses is of continental dimensions and is concomitantly endowed with a multiplicity of cognitive and conceptual schemas that have evolved over time and some of them continue to do so. Furthermore, in the same geographic region more than one "high tradition" could be concurrently practiced with several other "high," "low" or "folk" traditions. It has been variously argued that the Sanskritic, Indo-Persianate, and several "folk" orders entered a phase of rapid institutional neglect and decline between the last decades of the eighteenth century and through the nineteenth century as colonial modernity spread its web across the region (Pollock 2004; Kaviraj 2005). The process of transforming cognitive maps, classificatory and conceptual schemas was accompanied by an institutional decline that in several cases also produced the phenomenon of "disappeared" knowledge systems. In the discussion that follows the term "South Asian Knowledge Systems" will be employed contextually to refer to the computational and astronomical systems, conceptions of the body and medicinal practices as they were practiced in the region, while being embedded in normative orders, linguistic and cognitive frames entailing in terms schemes for abstraction and theorization.

15.2 The Encounter Between Modern Science and South Asian Knowledge Systems

From the mid-eighteenth century onwards, it has been argued, the expansion of the dominion of modern science and European colonial expansion were inextricably linked. We would be committing a gross error of presentism were we to conflate the adventurous forays of European trading companies in South Asia with the full-blown colonial endeavor of the nineteenth century. No matter what the motivations in the two centuries were, European voyagers, missionaries and administrators proceeded with the scientific exploration of the subcontinent and map making since these were closely tied up with the strategic projects of the East India Company and later the colonial state. From the perspective of the history of imperialism the steamboat was easily the most important invention of the nineteenth century. The gunboat and steamship were undoubtedly the most significant technological weapons in the armory of European imperialism (Headrick 1981, 15–19). Furthermore, the cartographic construction of a spatial image of the East India Company's dominion would finally stand in as a representation of the empire itself, conferring upon it a "territorial integrity" (Edney 1997, 2). This construction was deeply inscribed within the imagination of British imperialists and equally among the Indian nationalists by the end of the nineteenth century (Edney 1997, 15). The symbiotic relationship between the spread of modern science and the expansion of colonial power was reflected in the transformation of

India as a British colony into the site of a vast scientific experiment. However, the institutionalization of modern science in India was by no means a mechanistic process but was characterized by a complexity that prevailed upon simplistic ideas concerning the hegemonic imposition of scientific ideas from above.[1]

In the encounter between the so-called traditional systems of knowledge prevalent on the sub-continent and that of the European metropolitan sciences, numerous projects of cultural redefinition in the colonized provinces, in our particular case India, were triggered off. These projects of cultural redefinition were not restricted to domesticating the content of modern science, but generated in a variety of other cultural spheres an interrogation of the foundations of European modernity and a re-examination of what the modern educated Indian elite class began by the end of the nineteenth century to reflect upon as Indian culture (Sarkar 1973). Put differently, Western science had to be reinvented in the idiom of a modernizing India. Broadly defined, the process involved recuperating elements of reason and rationality from within the resources of Indian culture (Sarkar 1973). These processes of localization or domestication or naturalization were epistemically worked through the construction of cognitive homologies that provided the metrics for translating modern science into the language of the existing systems of knowledge and later for revisiting these traditional systems of knowledge through the frame of modern science (Raina 2003). For example, the father of chemistry in modern India, P.C. Ray would forage through the Ayurvedic *materia medica* and, as a trained modern chemist, devise ways of manufacturing Ayurvedic formulations in a company established for the purpose: Bengal Chemicals and Pharmaceuticals.[2] The essence of the project resided in identifying the "active principle" of these Ayurvedic formulations in order to manufacture the "modern equivalents" of traditional formulations—a conception that might have been quite foreign to Ayurvedic pharmacology.

The colonial educational system and its pedagogy and textbooks provide us with interesting insights into the processes of domestication or naturalization. Macaulyan educational policy and colonial diktat triggered the decline of the "traditional" systems of knowledge either by withdrawal of support or the institutional substitution of one by the other. In reality, science teachers struggled with local cultural frameworks and knowledge forms, produced translations of modern science textbooks and created new lexicons, thereby rendering the unfamiliar in the language of familiarity (Venkateswaran 2002). Some of the most interesting encounters between the so-called traditional sciences of India and modern science date back to the end of the eighteenth century and were guided by an optic that subscribed to the idea that modern science could be grafted onto a Sanskritic base (Visvanathan 1985). But by the middle decades of the nineteenth century, with a change of political climate, the epistemic gaze had changed inasmuch as the traditional was viewed as knowledge that had been phased out by the triumphalist

[1] See (Shapin 1983; Prakash 1999; Raina and Habib 2004).
[2] See (Raina 2003, chap. 3).

rise of modern science. Nevertheless, until the beginning of the last quarter of the nineteenth century in some of the sciences and in mathematics interesting pedagogic episodes of naturalization can be encountered—encounters that certainly enrich the literature on science teaching in global multicultural contexts (Sehgal et al. 2000).

In the nineteenth century these experiments and dialogues did not find an echo in the metropolises of science. This possibly arose from the totalizing nature of the discourse of science of the times, wherein it was still difficult to countenance the possibility that science could be done another way. A colleague and I worked on a nineteenth-century Indian mathematician Y. Ramchandra from New Delhi who had developed an alternate way of solving problems of elementary calculus. The British mathematician, Augustus De Morgan, knew of the work and sought to promote Ramchandra's book in English schools. His introduction to the English edition of Ramchandra's book stands out as a testimony to the inherent difficulty of the time to suggest the idea that an Indian mathematician had discovered an alternate pedagogic device to introduce modern calculus to Indians without reference to any topology (Raina and Habib 2004). The project was itself inspired by the Orientalist understanding of the time that Indians lacking in a geometrical understanding had nevertheless to be introduced to modern calculus. De Morgan felt that Ramchandra's book entitled *A Treatise on Problems of Maxima and Minima* (1859) could be employed to instruct English students on how to solve problems of geometry by employing algebraic methods. The book's importance to De Morgan derives from his involvement in the reform of mathematics education in England. However, the project was aborted in India as subsequent educational policy did not encourage projects that sought to structure education around conversations between Sanskritic or Indo-Persian learning traditions.[3] But an equally relevant feature of the late nineteenth century and certainly of the early half of the twentieth century was that the idea of methodological pluralism in the sciences was difficult if not impossible to entertain. This more than anything else may have posed obstacles to the positive reception of Ramchandra's work.

In other words, the response of the South Asian literati to the spread of modern science was more nuanced than one distributed bi-modally between states of acceptance and resistance. Imperial historiography frequently portrayed the early nineteenth-century Indian intelligentsia as decadent and inward looking. On the contrary post-colonial studies have underlined that the growth and communication of knowledge in the Indian public sphere of the 1840s was not impeded by the hidebound structures and rules of a "traditional society." In other words the intelligentsia had begun adapting their practices to the modernist idiom and literary technologies. This process of adaptation was itself a product of decades of reflection on the status of Indian and Western learning (Bayly 1997, 247). During the first decades of colonial rule the state did not have any singular policy on the question of science or the language of instruction. But the priorities of

[3]See also the discussion in about calculus teaching in Brazil discussed in chapter 18.

scientific research were set in relation to the demands of the colonial state and were additionally tethered to the priorities of metropolitan science. At the level of school education, and in particular after 1835, Western science was expected to promote Christian values.[4] Four decades later evangelicals and missionaries discovered that the project had failed miserably, since their Indian students had taken to Western science without taking to Christian religion or values. Within the community of colonial officials, competition among amateurs stimulated scientific research. The discriminatory relationships between colonial officials and their colonized subjects characterized by the sheer asymmetry inherent in the colonial experience prompted a positive evaluation of the Indian scientific traditions by Indians themselves (Bayly 1997, 253). By the middle of the nineteenth century heterogeneous networks of research and teaching emerged in the South Asian region. These networks played a significant role in the localization of modern science and in the enrollment of networks of local knowledge producers into the embrace of global science. One specific channel for the universalization of material and cultural practices is evident in the calibration of scientific instruments and the standardization of scientific practices as these instruments and practices traveled to venues outside Europe (Raj 2007).

Similarly, in the domain of technology a recent study by Geijerstam entitled *Landscapes of Technology Transfer* chronicles the visit of three Swedish engineers, Julius Ramsay, Nils Mitander and Gustaf Wittenström, to India during the years 1860–1864 to establish iron producing plants in the Kumaon region and in Burwai in the Narmada valley. The history of the ironworks established by these Swedish engineers reveals the differences between iron production in India and in Sweden. The establishment of an industrial enterprise of the scale of the Kumaon and Burwai works was preceded by mineral surveys undertaken by British explorers who for their mapping of natural resources depended on local traditions and local knowledge; this local knowledge was gradually assimilated and integrated into the practices of Swedish and English engineers. In like manner, existing knowledge of traditional iron making, Geigerstam documents, proved indispensable for British surveyors. Nevertheless, the relationship between the local informants and the recipients was never free of conflict and involved the clash of differently perceived interests. From the perspective of the colonizers and industrialists, the ties between science and commercial or industrial interests were fairly close and closely guarded. The fascinating feature of this reconstruction is that the absence of archival material is supplemented by field studies that fill the gaps in our knowledge of the two works; the planning was fairly complicated and yet the different natural resources of the two regions meant that the plants were powered very differently (Geijerstam 2004). Furthermore, from the perspective of the history of technology, the Swedish engineers in India benefited from international networks of the iron-making trades and knowledge moved fairly rapidly across continents despite what appears by contemporary standards to be fairly sluggish modes of

[4]See (Gosling 1976; Habib and Raina 1989; Venkateswaran 2002).

communication. The technology that arrived at Kumaon and Burwai was the most modern and the inability to realize a successful innovation could have had little to do with its obsolescence. In fact the socio-technical system that had been elaborated at the iron works was fairly brittle since the boundaries between the British management, the Swedish engineers, the British skilled workmen and the Indian workmen were rendered vulnerable by the conflict ridden nature of the relationship between the different groups of actors. The system was further compromised by the continuous addition of elements by the colonial system that weakened it even more. These among a complex assemblage of economic and technical factors ensured that the two iron works were never able to integrate into a stable network of social and economic interests that might have ensured their sustenance (Geijerstam 2004). This "thick" photographic and literary contextualization of a technological system ably navigates between the complex issues involved in the process of the transfer of technology.

15.3 The Modernity of Science and the Nation

The institutional and organizational context within which modern science was domesticated is equally important. Most histories of science recognize three organizational phases of this process of the institutionalization of modern science (Visvanathan 1985). The first is considered the period of the great surveys commencing in the late eighteenth and early nineteenth centuries when the East India Company initiated enormous projects to map the terrain, resources and the peoples of the South-Asian subcontinent, such as the Geological Survey of India and the Trigonometrical Survey of India. The second phase corresponds to the founding of learned societies, such as the Asiatic Society of Bengal and, in the second half of the nineteenth century, the Indian Association for the Cultivation of Sciences, a voluntarist society founded by the first generation of modern Indian scientists, the National Institute of Sciences—known today as the Indian National Science Academy—and dozens of others founded in the twentieth century. The third and most intense phase was the establishment of a scientific research system within the universities (Raina and Jain 1997).

One of the most important decisions taken after the annexation of India by the British imperial crown in 1857 was the founding of the universities in Mumbai (Bombay), Chennai (Madras) and Kolkata (Calcutta), (Ashby 1966). The universities or "first generation" universities established in India were modeled after London University. These were largely examining bodies rather than teaching universities or teaching and research universities. The modern university was visualized as the colonial government's primary organization for the production of an Indian class to enable the governance and administration of the empire (Kumar 1991). The universities primarily focused on literary and humanistic studies (Viswanathan 1989). Within less than a decade of the founding of the universities there was a growing demand for the introduction of science education within the

charter of the university. The absence of science education in the universities was supplemented by the founding of scientific societies such as the Indian Association for the Cultivation of Science mentioned above.

A "second generation" of universities came to be established in the early decades of the twentieth century. Established through voluntarist donations, they were modeled on Oxbridge and were equally inspired by the globalizing idea of the Humboldtian University. The latter centered the university as the primary site for the production of scientific knowledge. By the time India became independent of colonial rule reasonable centers of scientific research had emerged, not just in the Presidency towns of Bombay, Calcutta, Lahore and Madras, but also in Bangalore, Benares, Delhi, Hyderabad, Pune and Jaipur, to name a few. These universities developed fledgling research facilities outside the imperial research institutes established under colonial rule. This was an outcome of decades of struggle pressing for the introduction of post-graduate teaching and research. In 1904 the University Charter Act was finally passed that more or less announced the commencement of research in the Indian universities. Prior to this development, research was either pursued in imperial institutions mentioned above or by Indians working within voluntarist learned scientific societies (Raina and Jain 1997). It has been remarked that British recognition of Indian independence really came in 1914 when Indian scientists organized the first Indian Science Congress (Dionne and Macleod 1979).

During the period 1850–1880, at the level of higher technical education, the designs of the colonial capitalist state were manifest in the establishment of technical schools and colleges explicitly oriented toward producing a class of technical personnel trained in public works of engineering essential for the sustenance and reproduction of colonial rule. The changing place of Britain in the international economy required that the colonial state be innovative in the founding of formal technical institutions (Inkster 1991).

Clearly then classical percolation models have proved unsatisfactory in comprehending the relationship between modern science and culture in colonial India. The expansion of European sciences was catalyzed by the joint efforts of several actors with divergent motives and included imperial bureaucrats, their scientific entourage, businessmen, missionaries, and on the other side indigenous elites and the literati who finally had to legitimate the uptake of this new knowledge form. Indigenous elites visualized this encounter with science as a means for enriching their repertoire of skills as well as a path to revitalization (Kopf 1969; Panikkar 2007). Studies of Ayurvedic and Unani and Tibb medicine in late nineteenth-century Delhi suggest that traditional knowledge was often reworked and configured in the light of modern scientific developments (Metcalf 1986; Panikkar 1992).

The transformation of Ayurvedic and Unani Tibb medical practice in the late nineteenth and early twentieth centuries was initiated through the efforts by three iconic figures: P.S. Varier, Hakim Ajmal Khan and P.C. Ray. The latter two were closely associated with the nationalist struggle. The trope of decline of the

traditional systems of medicine was employed by the three of them to press for the modernization/revitalization of traditional systems of medicine. Revitalization in their eyes required three transformations: an epistemological reframing of these systems of medicine, a reform of institutional practices of Ayurveda and Unani, and a radical reorganization of the manufacturing and distribution system of drugs and medicaments (Raina and Habib 2005). All three components of the revitalization of the traditional system of medicine were to be informed by the practices of modern science and were adapted within the frame of the existing medical systems. Inasmuch as the colonial system was also one of economic expropriation, the manufacturing and distribution of Ayurvedic and Unani pharmacopeia aligned with the early twentieth-century politics of self-rule. The Indian nationalist movement, unlike the contemporary incarnation of ultra-Hindu nationalism, was one premised on a theory that sought not merely to liberate India of the yoke of colonial rule but to liberate the English of the idea of imperialism (Visvanathan 1997). In order to do so, new identities were often forged—and this is reflected in the creation of institutions such as the Ayurvedic and Unani Medical College (Raina and Habib 2005). This process of reworking skills of traditional knowledge practitioners within the frame of contemporary scientific practices was institutionalized within educational organizations set up for the process and was reflected in the pedagogy of institutions such as the Kala Bhawan, Baroda or the college of Unani Tibb in Delhi (Raina and Habib 2004). This dynamic relationship itself constantly reshaped modern science.

On the other hand, within the traditional historiography modern science is seen as the vector of a modern worldview. As a central element in the social theory of modernization, modern science encroaches upon and invades the domain of the traditional sciences of non-Western societies. The slow expansion of modern sciences is seen to be an outcome of impediments and resistance posed by persisting pre-modern forces within these societies in transition. This explanatory frame finds its most explicit elaboration in the colonial science model of Basalla (1967), much disputed on several counts and from a number of perspectives.[5] The model suggested that what the West took from the East was raw information that was cooked, processed, theorized upon, and subsequently transferred back to the East. Premised on a Rostowian understanding of the transfer of technology, it combined descriptive and prescriptive components of theorizing. The practice of science mirrored the dependency of the colonies on the metropolises of science in the West, in terms of problems considered suitable for research as well as in terms of theoretical influences.

The central question concerning the slow expansion and institutionalization of science under colonial rule, especially during a period of extended, expansive and creative contact between European scientists and Indian savants, remains an important one. This was quite in contrast with the situation in Japan after the Meiji restoration in 1867. One plausible explanation for this tardy growth

[5]See (Macleod 1982; Baber 1996; Raina and Habib 2004).

had to do with the priority accorded to the field sciences over the pure sciences (Sen 1988). But the fact remains that India was a colony and sovereign nations like Japan and China could negotiate their trajectories of institutionalization and scientific modernization more effectively.

The study of the complex social processes involved in the institutionalization of Western/modern science in India has recently been marked by the decline of diffusionist models of the history of science which in turn was triggered by the interrogation of the underlying theory of modernization (Baber 1996) and the recognition that these models trivialized contributions of local knowledge (Storey 1996). Nevertheless, it was important to ask what the impact of colonial rule was on indigenous scientific knowledge and institutions, and what roles did British and Indian scientists play in the creation of scientific knowledge and the institutions of science. The symbiotic relationship is evidenced in the construction of a large-scale scientific research system and the emergence of the colonial capitalist state. The colonial state was innovative in founding formal technical institutions that later served as models "for replication in England in the late nineteenth century and the colonial encounter contributed to the development of technical education in England" (Dionne and Macleod 1979). Furthermore, the "histories of colonialism" are also implicated in the disciplinary history of the "universal sciences"[6] as much as the state played a role "in the development of the scientific analyses of society" (Kalpagam 2000, 38). The imperatives of governmentality accordingly produced statistical knowledge of the country, which included classificatory schemes for the census. While newspapers were instrumental in creating public spheres, new conceptions of the economy and society crystallized in new discourses of history and progress (Kalpagam 2000, 52).

Different meta-historical frames sought to get a handle on the differences evident in the geography of knowledge. The center-periphery framework tried to approach the fundamental asymmetry characterizing the conceptualization of the process of the production of knowledge (Ben-David 1984). Analytical categories such as that of colonial science portrayed the knowledge produced at the periphery as being derivative in nature, and therefore as a lower order of science: from the end of the eighteenth century processes of data gathering and calculation in science were considered to be lower order activities in the Western European scientific imagination (Daston 1994). Consequently, the science pursued in the colonies was of an empirical nature; the task of theoretical synthesis was to be performed in the metropoles of London, Paris, Berlin and so forth. (Pyenson 1985). The science pursued in Calcutta, Auckland, Beijing or Tokyo in the early twentieth century was never quite the real thing. But the advantage of a scientific research career far from the metropolis was the absence of peer pressure, and this created the possibility of idea hybridization at the periphery (Chayut 1994). This is instantiated in the case of S.N. Bose from Calcutta collaborating with

[6]See (Nandy 1980; Visvanathan 1985; Nandy 1988; Baber 1996; Kalpagam 2000, 38; Raina and Habib 2004).

Einstein in the formulation of quantum statistics in the 1920s, and of M.N. Saha, also in Calcutta, developing the incipient program of theoretical astrophysics and astronomy through his work on the ionization formula. Similar idea hybridizations could account for C.V. Raman's contribution to the phenomenon of scattering, Heidekei Yukawa's development of meson theory, and Tomanaga's contribution to the study of quantum electrodynamics. The possibility of science at the periphery surpassing science at the center, DeVorkin suggests, arose in Saha's case from his "relative freedom in isolation" that enabled him to tread entirely new pathways, although it constrained him from exploiting the potential of his theory (DeVorkin 1994, 126).

Other metahistories focusing upon scientific practices ran against the grain of these earlier explanations (Pingree 1992). These metahistories appeared during the 1980s, but during the initial stages of decolonization, scientists in India produced a history of science that sought to break out of the frame of a Eurocentric history of science, seeking cognitive justice (Visvanathan 1999) and a due place in the sun (Bose et al. 1971). Inspired by the Needhamian historical project, some of them attempted to identify the causes behind the tardy expansion of the sciences in India over the last two centuries (Rahman 1984; Sen 1988). Colonial policies obstructed the path of authentic modernization: this was further manifest in explicit colonial reservations concerning the abilities of Indians to pursue science. The expansion of science was arrested by colonial interests, and sometimes explicitly racist policies (Kumar 1991).

However, until the end of the nineteenth century, episodes of the encounter between the traditional sciences and ways of knowing and that of modern science continued to play themselves out on the growing stage of modern science in India. An anthropological engagement with these episodes reveals a great deal about the localization of modern science and re-opens the question of science and modernity. Indian scientists schooled in modern science struggled to inaugurate a scientific and technological research system. The purported objective was to draw India closer to the international community of science. This first generation of Indian scientists embarked on an unenviable project of building bridges between the science they were pursuing and the knowledge forms that were part of the cultural life of the region before colonialism (Raina 2003). This task often produced a variety of responses that appeared curious to the Western eye. For example, Jagadis Chandra Bose, the first of modern India's physicists, is one of the deities in the pantheon of the founders of the modern scientific tradition in India. Amongst Indians, Bose's research has been seen as India's response to Western science, while in the West he continues to be an enigma. But scientists in the West and in India have often marveled at his acumen as an inventor of instruments. His name, alongside that of Marconi, is often associated with a misplaced priority dispute concerning the discovery of radio waves (Dasgupta 1999). From a contemporary perspective, Bose is credited with the production of short wavelength radio waves, and was the inventor of truly ingenuous coherers. It has been suggested by some that

Bose's later work on plant physiology, alongside Ramanujan's equally enigmatic mathematical style, could be seen in epistemic terms as an attempt to construct an alternative Indian science (Nandy 1980).

From a metatheoretical perspective attempts to explore the "cultural context of scientific creativity in science in the non-Western world" was itself a product of disenchantment with modern science. In other words, the inevitability of modern science was no longer considered tenable and it was increasingly felt that there were other trajectories available—trajectories that were labeled "alternate sciences": possible sciences eliminated by the march of a dualist modern science. Traces of these alternate sciences could be found, it was argued, in those precolonial forms of knowledge, including scientific knowledge whose evolutionary trajectories did not intersect with those of modern science. And those whose trajectories did intersect with modern science during the course of localization or domestication were eventually marginalized. This search recognized that the search for an Indian alternative would be "impossibly unmanageable" (Nandy 1980, 15).

The assimilation of modern science naturally commences at the level of pedagogy. This process was normally conceived in terms of the replacement of the traditional pedagogy and curricula by the new ones under the pressure of the imperial dispensation. In reality, science teachers had to contend with local cultural conceptions and knowledge forms, as well as the need to mobilize existing teachers within modern schools. These contingent pressures provided avenues for the localization of "universal science," and as some recent studies have suggested, provided pedagogic exemplars that in turn influenced the education system in England (Baber 1996; Tschurenev 2008).

15.4 Science in Development and Decolonization

The scientific research system was not established afresh in independent India but built upon structures established during the period of colonial rule, tailoring them to a new social and political agenda. Before independence, although there were just a few universities in the country, seen in the context of that time, they were the primary sites for the production of quality scientific research. Over the last fifty years, a number of factors coalesced to move scientific research away from the universities to what may be termed elite research institutes (Raina and Jain 1997). This shift began initially very slowly in the 1950s, even though the founding fathers of science in modern India were aware of the long-term dangers of such a development. The founding fathers were sensitive of the role of the university in the building of a scientific research tradition, but were compelled to carve out their own research institutes outside the university system. The evolution of the Tata Institute of Fundamental Research, Mumbai, the Indian Institute of Science, Bangalore, the Institutes of Technology and then, from the 1970s onwards, the mushrooming of institutes funded by the Department of Science and Technology and the Atomic Energy Commission appeared to have sealed the fate of research

in the universities, though a handful of universities bravely rallied around and managed to keep quality research going. This shift was catalyzed by a number of domestic structural changes in the world of higher education as well as global changes in the regimes and practices of science.

From the beginning of the twentieth century the leadership of the scientific community in India was closely associated with the nationalist struggle, and legitimated science by highlighting its importance in nation building and development. In the post-independence period, science was strongly coupled with the process of decolonization as well as the programs of the developmental state (Zachariah 2005). In a planned economy, the priorities of scientific research were integrated into policies of the 1950s, relating to matters such as import substitution and the building of indigenous capabilities. Promoting economic self-reliance, in turn, was anchored on scientific and technological self-reliance (Abrol 1995). In order to accomplish these ends, it was necessary for the scientific community to enlist the political establishment in the realization of its avowed goals and objectives. This was successfully accomplished under the leadership of Nehru. The generation of Indian scientists who assumed leadership of the scientific community at the time of independence—Homi Bhabha, S.S. Bhatnagar and Meghnad Saha—while acknowledging the contributions of the previous generation rushed on to complete the processes of professionalization and institutionalization that had commenced (Raina and Habib 2008). They were pressurized into leap-frogging, as they feared the nation might lapse once more into the state of dependency or neo-colonialism. This anxiety manifested itself in the form of several imperatives. The industrial research imperative provided a fillip to the Council of Scientific and Industrial Research that blossomed in the 1950s. Between the 1950s and 1960s, over twenty CSIR institutes were set up, a feat that has never been repeated since (Raina and Jain 1997). Similarly, the nuclear research imperative set up the axis for the growth of nuclear science. By the 1970s, while science had undoubtedly expanded, it had done so at the expense of the universities in India. Mission-oriented research transformed in significant ways the ethics of research both in India and abroad. It is important to remember, however, that this was then a global trend and not just true of India.

Once scientific research acquired a home outside the university and established itself in the research institutes driven by goals other than the pursuit of knowledge, it often abandoned what Shiv Visvanathan has called, its "incest taboos" (Visvanathan 1997). In the Indian context, we can see over the last fifty years the socialization of generations of science and engineering students in a technocratic ideology of science. In fact, with some notable exceptions, this is the only ideology of science that seems to captivate entire generations of Indian students and gives science both its power and a legitimacy that was not questioned until the 1980s. Further, the Manhattan project irreversibly transformed another very fundamental norm of scientific leadership. Leadership in the scientific community before the 1950s, according to a number of sociologists, had hitherto been

intellectual or paradigmatic. Important contributions to science were rewarded by a social system that conferred awards, memberships of societies and leadership to scientists who had made contributions to the domain of science. Afterwards, the Manhattan project leadership became institutional and institutions became territories. This transformed the norm for scientific leadership into an ability for garnering and managing scientific teams. Under certain circumstances institutional leadership prevailed upon paradigmatic or intellectual leadership (Gibbons and Wittrock 1985).

These transformations were debated in the scientific community both in India and abroad. The seminal contributions of the first generation of scientists during the pre- and post-independence period had integrated them into the global community of science and collegial ties enabled them to forge collaborative networks of research as well as of policy with their colleagues in Europe (Anderson 1999a,b). Scientists from Britain and France such as J.D. Bernal, Frederic Joliot-Curie, P.M.S. Blackett and J.B.S. Haldane played an important role in cementing these ties which proved beneficial for the organizational expansion of Indian science. The scientists mentioned had a left wing orientation and were keen on bridging the gap between the developing and the developed world, especially in their insistence that science belonged to the global commons (Petitjean 1999). UNESCO on the other hand contributed to the organizational development of science in the former colonies. And as the Cold War progressed it possibly became the only international agency that was able to keep channels of scientific communication open between both sides of the Iron Curtain. Naturally, India benefited from such international collaborations. The collaborative ties of the disciplinary community often prevailed over that of the nation (Raina and Habib 2008). Yet, in the extra scientific sphere, scientists abroad could hold contrary, patronizing and, sometimes, imperialist positions. By the 1970s, India had come to serve as a role model for several of the nations that had undergone decolonization since the 1950s. In other words, if in the pre-independence period the processes of localization involved the reorientation of traditional cognitive orders along the lines of modern science, in the post-independent period the processes of localization were more of an institutional and organizational nature than one of reinventing the cognitive order of science.

The 1950s and 1960s were the high tide of the Nehruvian era of science, of heavy industry, big dams, and the period when nuclear capabilities were developed. However, this was also a time when a larger number of Indian students began to undertake their higher studies in the United States which had by then emerged as the new scientific destination with an excellent university system. India's elite technological institutes, established through collaborations with the United Kingdom, Germany, USSR and the USA, developed their curricula on the lines of the American university system—from the outset they adopted MIT and the California Institute of Technology as their models (Sebaly 1972). In the subsequent decades, while there was a spillover of students from the Indian Institutes of Technology

(IITs) into Indian industry and the research system, there was also a serious brain drain into the American university system. A minuscule number of students returned to India after completing their higher studies and manned the departments of the IITs and other research institutes (Sukhatme 1994).

By the beginning of the 1970s, the image of science the world over had reached a critical turning point, almost as momentous as the one India reached in the 1950s. Close to three decades of the optimism that characterized science as the endless frontier began to fade (Elzinga and Jamison 1986). Skepticism concerning strategies and programs of development in the Third World, and large-scale investments in mega-development projects, accompanied by the realization amongst economists of the failure of trickle down to deliver on that much-hyped conception of development began to come unstuck, even in policy circles (Raina 2003). The world suffered through an oil crisis and the idea that nature was not an infinite resource of recyclable goods began to ring the alarm bells in the world of science. The consequent emergence of the idea that small is beautiful initiated a process of rethinking the agenda for science both in India and abroad. These developments were compounded by the rising tide of anti-modernism, and anti-science and anti-vivisectionist movements. Clearly, a particular kind of scientism had run its course. This disenchantment produced in India a diversity of intellectual responses. At one level, it seeded an interrogation of European modernity and its conjugate modern science as solely paradigmatic of modernity and science (Nandy 1988). This was accomplished from two vantage points among others. The common understanding shared by both was that the dualism of fact and value logically culminated in a vivisectionist science that confronted its limits and its possible culmination in the concentration camps of Auschwitz and the nuclear destruction of Hiroshima. This modernity took its toll in genocidal development that the third world had been witness to as well (Uberoi 2002). In the realm of the sciences, this inspired the search for alternate sciences and the possible episteme that underpins them within the scientific culture of modern India.

In conclusion, it could be said that decolonization involved firstly the reconfiguration of the institutional context of colonial science to serve the politico-economic policies and programs of the new nation state. The task was not conceived as one requiring the demolition of British legacies, but of pragmatically assimilating elements that were suited to the post-colonial developmental goals. Secondly, movements for independence from colonial rule had planned for the establishment of educational and scientific infrastructure after the passing of colonialism. The scientific leadership, earlier involved in the anti-colonial struggle, acquired latitude for negotiation and influence with the post-independence political leadership in fashioning the destinies of the scientific and technological institutions of independent India. The relationship between a statesman such as Nehru and the scientific leadership represented by scientists such as Bhabha has become emblematic of this phase of science in decolonization. The political legitimacy conferred by the state on science and vice versa facilitated the building

of scientific institutions. Strategic areas of scientific research were protected from bureaucratic and political intervention; this created the illusion of the autonomy of science from the social institutions that legitimated it. The dualist character of the economies of the region further reified this chimera of autonomy. Nevertheless, by the end of the twentieth century researchers at premier institutes of scientific research had joined the global scientific community with intellectual ties extending over long distances (Schott 1998). Despite the relative evening out resulting from the development of new communication technologies, certain features of science as practiced under colonialism remained. As happened with the case of Saha and the inauguration of theoretical astrophysics, research programs pioneered in India were not able to sustain the momentum generated at the moment of creation. A study of a research program pursued at the Department of Aerospace Engineering at the Indian Institute of Science, Bangalore, reveals the difficulties of stabilizing research networks at the periphery. The point is further reinforced by scientometric studies suggesting that collaborative ties between institutes in India and the West are much stronger than the collaborative ties between institutes in India itself. Consequently, long-distance ties between scientists have grown much faster than ties between scientists in India or ties between scientists in neighboring countries (Schott 1998).

The expansion of "Western science" and the globalization of science itself do not reveal the replication and reproduction of a paradigmatic version of science that emerged in Northern Europe in the seventeenth and eighteenth centuries. Sociology of scientific knowledge and theories of multiple modernities have divulged the untenability of a canonical version of Western science or modernity migrating unattenuated across impermeable boundaries and is installed in the non-West. The complex process characterizing the encounter between modern science and other knowledge forms results in the emergence of local versions of modern science. In the process, the encounter metamorphoses modern science. These local variations manifest themselves in the diverse organization of pedagogical and evidential cultures. Under the microscope the purely normative account of science, or its globalization, begins to exhibit distinct regional adaptations, rather than homogenization on the Western model.

The globalization of Western science, or to use a more neutral term, modern science is then not a process that commences from an original home of modern science (Needham 1969). In evolutionary terms we have several sciences in a constant relation of localization and globalization. As Needham's river metaphor so aptly suggests, modern science emerged in a specific historical context of Western Europe and on expanding into other cultures it undergoes a dual process of universalization and localization. Does abandoning the idea of the universality of science in an "absolute, or even functional, sense" lead us into the trap of localism? Montgomery argues that the recognition of the context of knowledge is not identical with reducing the one to the other. The history of scientific transmissions has often been preoccupied with the percolation and diffusion of a pre-existing version

of universal science. The multicultural history of science appears to suggest that universality is not given a priori but is constantly refurbished and thus evolves over time. This occurs within the context of the encounter of local scientific knowledge with so-called global science. In either case, the time is ripe enough to rethink the narratology adopted to study this process of domestication and globalization. Only an acute sensitivity to the context of the circulation of knowledge would ensure that the new histories would not lapse back into the older narrative forms.

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