

(VS)

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**Science and technology in India –  
from the ancient to the recent past**

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Any account of the classical sciences of India must begin with mathematics, for, as the ancient Sanskrit text *Vedāṅga Jyotisa* (ca. 400 BCE) said,

Like the crest on the peacock's head,  
Like the gem in the cobra's hood –  
So stands mathematics  
At the head of all the sciences.

The Sanskrit word used for mathematics in this verse is *gaṇita*, which literally means 'reckoning'. What is most interesting about the classical Indian view of mathematics is that number was treated as the primary concept – and not geometry, as the Greeks did. Plato said 'God always geometrizes'; and an inscription at the entrance to his famous Academy in 4th century Athens said 'Let nobody who is not a *geometer* enter here'. The distinguished Swiss mathematician-physicist Hermann Weyl wrote in 1929 (in the preface to his pioneering book *The Theory of Groups and Quantum Mechanics*) that 'occidental mathematics has in past centuries broken away from the Greek view and followed a course which seems to have originated in India', where 'the concept of number appears as logically prior to the concepts of geometry'. (He considered that with the advent of group theory in the 20th century occidental mathematics might be returning to the Greek view.) In general the single most striking characteristic of Indian mathematics may be said to be that it reflects the long love affair of Indian culture with numbers. At a time when most societies had difficulty handling numbers beyond a thousand, the Buddhist text *Lalita-vistāra* (before 4th c. CE) not only had no problem with huge numbers, but almost revelled in giving them names (the highest number quoted being  $10^{145}$ , called *dhvaja-nis'ā-maṇi*).

The fact that the numeral system so common today – the closest we have to a universal language – comes from India is now well known. The story has been told so many times that it is unnecessary to go into it here again. The idea of zero and its integration into the place-value system, which enabled one to write numbers no matter how large using only ten symbols, was something which originated in India; at first encounter it appeared marvellous to West Asians, and 'satanic' to Christian clerics in the Europe of the Middle Ages. But it was quickly adopted in 9th century Baghdad, and slowly transmitted to Christian Europe about the 13th century through Jewish scholars working in Islamic Spain, taking a long and tortuous path which was illuminated by such distinguished scholars as the Iranian mathematician al-Khwarizmi (783 ~ 850 CE, who worked in the House of Wisdom at Baghdad, and from whose name the word *algorithm* is derived), and the Italian Fibonacci (of Pisa, 1170-1250 CE, famous for the Fibonacci sequence still so familiar today). What is perhaps not so widely known is that the acceptance of the system in Europe followed centuries of bitter dispute between the *abacists* and the *algorists* (as they were called). The abacists computed with beads mounted on strings or wires; the algorists computed with numbers and symbols on a sand-board (namely figures written on a thin layer of sand or dust spread on a board, smoothed out once the calculations were completed so it was ready for the next). The eventual victory of the algorists replaced physical manipulation of beads by operations with symbols, and led in due course to the nearly universal acceptance of the numerals in use today

only constitution of any state which so prescribes. ← Article 343 of Constitution of India prescribes these form of numerals shall be used by organs of the state.  
across the globe. It is thus not an accident that these 'international' numerals of today are so close in shape to the ones that have been used in Sanskrit for a long time.

BTM But apart from numbers, the idea of *equations*, in particular of algebraic equations, also seems to have come from India, with some very important contributions from West Asia. The *Bakhshali manuscript*, the earliest surviving written material on Indian mathematics now known (dating to 8th c. CE according to the Japanese scholar Hayashi, and discovered in 1881 near Peshawar in today's Pakistan), already has the essence of what we think of as an algebraic equation: namely the use of symbols for unknown quantities and for arithmetical operations (addition, subtraction, multiplication and division), and a statement of equality between appropriate expressions involving those symbols for both operations and unknowns. The correspondence between modern notation and the ancient one used in such texts as the *Bakhshali* manuscript is indicated in Box 1. These ideas, juxtaposed with those from the Greeks and presented with important additions of their own by West Asians, surely played a crucial role in the brilliant explosion of 'mathematicised' science that occurred in Europe, beginning with Galileo and Newton in the 16th and 17th centuries.

*Āryabhata*, whose work the *Āryabhaṭīya* can be precisely dated to 499 C.E., is the key historical figure in India who heralded these developments; his work must surely rank among the great mathematical classics of the world. Although the subject of the book is astronomy it has a chapter on mathematics as well. Like most Sanskrit works it is written in verse, to make the text easier to memorize. (There was no paper in India at that time or for many centuries later; knowledge was usually transmitted orally from the teacher, *guru*, to his disciple, *śiṣya*, who often made notes for himself by inscribing the verses on materials like palm leaf, which could survive for centuries.) It is interesting to analyze *Āryabhata's* approach to the subject and contrast it with the Greek methods that are far more familiar in the West. The most important difference that I see is that *Āryabhata's* view, even on physical problems, is basically *algorithmic*. Indeed one is tempted to coin a word and say that he was doing *algorithmic astronomy*. If we may caricature the picture somewhat, one could say that while the Greek paradigm (as exemplified by Euclid) was to proceed from axiom to proof to theorem, the Indian paradigm seems to have been to proceed from observation to algorithm to verification/improvement/conclusion. The concept of logical deduction from stated axioms does not appear to have been central to the Indian approach. This is most curious, because logic was another major science in the Indian knowledge system, valued highly even in metaphysical speculation; and several vigorous schools of logic have flourished in India for millennia. The reason for the Indian view, I believe, has been general skepticism about the possibility of discovering *reliable* axioms (if indeed they existed at all): the approach was basically pragmatic and empirical. (So when Gregory Chaitin, the well-known mathematician at IBM, said recently that mathematics is 'an experimental field where mathematicians stumble upon facts in the same way that zoologists might come across a new species of primate', he was echoing the classical Indian view.) *Āryabhata's* work – unlike that of many who followed him later on – had some sound physical reasoning as well. For example he noted how motion was relative, suggested that the earth was round and rotated on its axis, and had the correct physical explanation for eclipses. He was undoubtedly influenced by Greek physical-mathematical models, such as for example Ptolemy's epicycles. On the other hand the model was only an inspiration for the algorithm: till everything was finally reduced to methods of calculation with numbers the work was incomplete. The influence of *Āryabhata* on Indian mathematics almost rivals that of Euclid in the West: *Kōdaṇḍa-rāma* wrote a commentary on the *Āryabhaṭīya* as late as ~ 1850 CE!

There were many astronomer-mathematicians who followed Aryabhata. Particularly well-known among them was *Brahmagupta* (b. 598 CE) who had in many ways cleverer and more precise algorithms than Aryabhata, but differed from him in interpretation. Indeed Brahmagupta was very critical of what we would think of as the 'rational' view that Aryabhata and his disciples adopted on the causes underlying eclipses, which went counter to the traditional Indian mythological accounts. It is difficult to imagine that Brahmagupta truly believed his own objections, and there is a legend that towards the end of his life he regretted having poured scorn on Aryabhata and his followers. But there has remained to this day in India the two conflicting scientific philosophies of Aryabhata and Brahmagupta – one rational, the other conservative (both very clever); it is possible that these philosophies have seen cycles of acceptance and rejection, reflecting the social and political circumstances that Indian civilization found itself in.

Among the many who followed Aryabhata and Brahmagupta we can mention here only a few. The algebra that we have referred to above was taken a great deal further by Bhaskara II (b.1114), who is well known for several of his works, including a charming book called the *Līlāvati* (a title which refers, it is thought, to his wife or daughter). Among the most striking features of this work is that many of the problems that it sets for its readers are couched in poetry of both grace and playfulness. (An example: As the young lady tumbled with her lover in bed,/ The necklace she wore – of the fairest pearls – snapped./ A third of those pearls scattered on the floor; a fifth were seen strewn on the bed./ A sixth were lodged in her lovely hair, And a tenth picked up by her lover./ But six still remained on the string. Tell me,/ How many pearls were there originally on that necklace?) (With problems like this, it is no surprise that the famous Indian dancer and choreographer Chandralekha has set the *Līlāvati* exercises to dance!) Bhaskara (and even earlier Brahmagupta) also solved what later became known as Pell's equation (after John Pell, 1611-1685), and proposed *and* solved another that Fermat proposed in 1657 and Euler solved in 1732.

The other direct intellectual descendants of Aryabhata were from the Kerala school which blossomed in the early centuries of the second millennium C.E., and led to an extraordinary burst of creative mathematics and astronomy. This school challenged the prevailing geocentric view, and its mathematics led to the discovery of a variety of infinite series, including that which came to be named after Maclaurin in the early 18th century. Some of these series gave rapidly convergent expressions for pi; Mādhava (1340-1425 CE) offered the 'approximate' (!) value 3.1415 9265 36, an accuracy that was unmatched for centuries to come.

Indian contributions to mathematics were however not limited to numbers and algebra. Trigonometric functions were already defined by the 6th century, and algorithms for what we would today call sine of the half-angle were quickly generated. Similarly the germs of the ideas of calculus were already present; for example Munjala proposed (932 CE) a formula for interpolation that in present notation would be written as

$$\Delta \sin \theta = \Delta \theta \cdot \cos \theta .$$

It was also realized that the maximum of a function occurred where a 'derivative' (such as the limit of the ratio  $\Delta \sin \theta / \Delta \theta$  above) vanishes.

On the whole, Indian astronomical calculations were so accurate that John Playfair, reviewing them in 1790, contemplated (but dismissed) the possibility that 'some ages ago there had arisen a Newton among the Brahmins . . . and a De La Grange . . .'; he preferred the (totally

erroneous) explanation that accurate astronomical observations had been made in India as early as 3100 BCE.

India also contributed to geometry. The earliest available account of the Indian approach to the subject is in the *S'ulva-Sūtra*, of which the most extensive account was given by *Baudhayana* probably in the 7th or 8th century BCE\*. The title of the work may be loosely translated as *The Manual of the Cord*, and was intended to help lay out the fire altars that were such characteristic features of Brahminical sacral practices of those times. (The lay-outs were made with the help of a string or cord, much as Indian masons do to this day; hence the title of the work.) The altars took a variety of shapes, one of the most famous being that of the Vedic eagle. What is interesting in these *Sūtras* is once again their approach – pragmatic and constructive rather than deductive. Thus the work starts with a statement of the units it uses for measurement of length. It then proceeds to state various geometrical results, including (in proposition 12) the 'theorem' that is now known after Pythagoras. (It is virtually certain that the *S'ulva-Sūtra* predates him, but Pythagoras was incidentally a very interesting character himself; his belief in transmigration, his adherence to vegetarianism and his respect for numbers have led to speculative stories that he must have visited India sometime during his life.) The result on the square of the hypotenuse – rather the square of the diagonal of a rectangle as the *S'ulva-Sūtra* has it – is stated in very general terms, as a truth; no proof is offered, and to one schooled in Western thinking the question would arise whether it was seen as an empirical result or a logical deduction. The other interesting feature in the *S'ulva-Sūtra* is the way it handles the construction of an altar that is twice as large (in area) as the standard. The linear dimensions of such an enlarged altar would of course then go up by a factor of  $\sqrt{2}$ . The intellectual agonisation that was characteristic of Greek thinking on such surds is totally absent in the *S'ulva-Sūtra*; on the other hand a surprisingly accurate approximation is offered (1.4142 135), and the book then proceeds to describe the method by which the altar can be enlarged. Thus, even the approach to geometry seems to have had an algorithmic flavour.

The other major science that was highly developed in early India – and perhaps the first to do so along rational lines – was medicine. The *Caraka Samhita* (1 c. CE or earlier) has remarkable statements about diagnosis, the primacy of cause and effect, the importance of frank discussion etc. It advocated a system of medicine that depended on *yukti* (~ skill, human intervention) rather than *daiva* (~ the divine or super-human). This ancient medical system, still widely popular in India as *Āyurvēda*, depended heavily on the use of herbs; a large number of them (around 600 drugs, including those of mineral and animal origin) were noted and their use to treat specific diseases was recommended. It is likely that the luxuriance of tropical vegetative growth (*The wildest dreams of Kew/Are the facts of Khatmandou*, sang Rudyard Kipling) led to the wide availability of 'natural' chemicals whose use to combat specific diseases was clearly extensively studied. That this represents a vast store-house of knowledge, not yet completely tapped, is clear from the advanced scientific work that is still being done on such traditional Indian herbal remedies as neem and turmeric, and the vigorous and large-scale exploration of Indian bioresources multi-national drug companies are currently carrying on.

Indian advances in surgery were even more impressive. The treatise of *Sus'ruta* (redacted 4th c. CE, in existence in some form much earlier) had lasting influence, and as late as the 18th century accounts of Indian surgical practices appeared in learned journals of the West. Vaccination, rhinoplasty and eye surgery were practices well known in India long before they were introduced in the West. Even to this day some of these ancient medical practices are in daily use in Indian villages.

This brief account of Indian science would be incomplete without mention of linguistics, which has occupied a very high position as a branch of learning in India. The structure of language and of the sounds that constitute its spoken form have been a pre-occupation in India for some three thousand years, if not longer. The letters of the Indian alphabets – in all Indian languages – are arranged in a systematic way from vowels to consonants to sibilants and so on, classified according to the location of the source of the sound in the human vocal organs. To an Indian who is brought up on this system, the arrangement of letters in semitic alphabets appears completely disordered. The great *Pāṇini* (ca. 3c. BCE) wrote a treatise on Sanskrit grammar that must be considered one of the most remarkable achievements of the human intellect, for, by an extraordinary act of constructive synthesis, it provides the rules (and in particular the exceptions!) that have completely defined linguistic usage of Sanskrit for all time to come. Furthermore the treatise is so highly compressed that it can all be recited in a matter of some five hours or so. (Such compression was incidentally another Indian preoccupation: as an old Sanskrit verse has it, 'If half a syllable can be saved/They feast as at the birth of a son!') The magnitude of *Pāṇini's* achievement is being appreciated all over once again after two millennia as we now wrestle with the problems of constructing artificial languages for computers, and as the science of communication among human beings and animals acquires compelling scientific interest.

There were other sciences as well that attracted much attention in India. Chemistry was one such, often going with a study of minerals and gems.

Among the technologies metallurgy in many ways holds pride of place. Excavations in the Indus Valley yielded the celebrated figure of a dancing girl cast in bronze some four thousand years ago (– and she strikes a pose that is not unfamiliar today). India was a pioneer in the extraction of zinc – the process used in the Zuvar mines of Rajasthan since the 4th c. BCE was patented in 19th century Britain. The iron and steel industry in India has existed from something like 1300 BCE – and in many parts of the country. Legend has it that one of the gifts that Alexander took from India during his raid was a ball of steel weighing about 15 kg. Smiths in the Gupta Age (4-5 c. CE) created the much-studied iron pillar that stands near the Qutub Minar in Delhi; over 7 m tall and 6 tonnes in weight, it shows no sign of rust whatever. (It was manufactured by forge-welding a number of cylindrical stubs of the metal.) South Indian craftsmen began, from around 1000 CE, to cast superb bronze sculptures that must be among the finest artistic creations of mankind in all time. The famous Damascus swords of West Asia were forged out of an Indian steel called wootz (derived from the Indian word *wook* through a historical misprint that was never corrected). In the late 18th century Tipu Sultan made rockets with iron casings when he was fighting the East India Company in Mysore: his rockets surprised British armies because they had a performance that far exceeded anything that was available then in Europe, chiefly because of the excellence of the steel he used for the casings. Till late in the 18th century India exported iron and steel to England (for it was the only source of high quality iron, apart from Sweden, then known to the British). The iron and steel industry in Europe was at that time expanding rapidly, and the technological advances made during the industrial revolution led to such significant improvements that Indian industry, which had been in such a strong international position till the late 18th century, had completely collapsed by 1850.

Another ancient Indian technology was brick making. Excellent bricks have been in use in India for at least 4000 years; a visit to an Indus Valley site (~ 2,000 BCE) is to this day a most impressive experience, because the bricks used for construction – in buildings, in dockyards, in ditches – seem so well made and so highly standardized. The fire altars described in the *S'ulva-Sūtra* mentioned above were all made out of brick whose dimensions were precisely

specified. The eagle-shaped altar *s'yēna-cita*, used for Vedic sacrifices, included some ten different types of bricks, of various shapes and dimensions.

Perhaps the major industry that has been associated with India for thousands of years is textiles, discussed in Susan Wadley's essay in this volume. Other technologies that India was famous for included boats and ships. Although a lot of Indian shipping moved fairly close to the coast, Indian craftsmen had excellent skills in building ships. In fact the best ships that the East India Company operated in the late 18th and early 19th centuries were usually made in and around Bombay. The first Indian to be elected to the Royal Society of London was the Parsi engineer Ardaseer Cursetji, whose docks in Bombay built ships better than the British could at the time. (Cursetji even managed to stay abreast with the industrial revolution in Britain, and was experimenting with the use of steam engines for his ships at about the same time as Europe was doing it.)

Lorocasticean -  
origin in Persia - worth mentioning?

Also cf. 'Tata' overpage

Tata → Parsi — ancestors from Persia & Zoroastrians — mention?

## PART II

As British power spread across India in the 19th century, in part through the use of superior technology, Indian intellectual leaders began to realize that they needed to understand the revolution that had occurred in European knowledge systems. Eventually the Indian response took the form of three major new institutions. There was first of all the Indian Association for the Cultivation of Science, which was established in Calcutta in 1876 by the medical practitioner Mahendra Lal Sircar; it was here that C V Raman later did the brilliant work for which he won the Nobel Prize in physics 1929. The second was the establishment of the Indian Institute of Science in Bangalore by Jamsetji N Tata, a very successful and far-sighted Parsi businessman and industrialist from Bombay, who saw, long before others, that the pursuit of science as an intellectual discipline in the Western sense was essential for the well-being of the country and its industry. The idea of the Institute was resisted by British commercial interests in India, but the perseverance of Jamsetji eventually led to the acceptance of his proposal and the Institute began work in 1909/11. To these two institutions must be added the Indian Science Congress, which held in 1914 the first of a series of annual get-togethers of all Indian scientists. These enterprises were followed quickly by a variety of other initiatives, and Indian scientists began to make a mark at the Presidency Colleges of Madras and Calcutta, and in universities elsewhere. The distinguished work of scientists like Meghnad Saha (well known for the law of ionization, which can be considered the first theoretical effort in astrophysics), C V Raman (whose discoveries in spectroscopy led to the Nobel Prize), Satyendra Nath Bose (whose unusual statistics, associated jointly with the name of Einstein, led to a particle description of radiation), and many others, caught world-wide attention. But these developments had some harbingers even earlier, such as the singular mathematical genius Ramanujan (1887-1920). From one point of view Ramanujan represented a response to Western mathematics that was in the traditional Indian idiom. His education did not go beyond the pre-university level, and in mathematics was entirely limited to familiarity with some undistinguished British manuals which were basically compilations of mathematical formulas. In particular Ramanujan was still very non-Euclidian, in the sense that he did not proceed with proofs of the kind that form the bed-rock of the spirit of Western mathematics. He 'saw' formulas in their entirety, and often claimed that they came to him, or were bestowed on him by his family goddess, in dreams. Littleton, one of his Cambridge collaborators, remarked that 'If a significant piece of reasoning occurred somewhere, and the mixture of evidence and intuition gave him certainty, he [Ramanujan] looked no further.' But the realization that whether he was able to prove them or not his results were very often correct and were of astonishing originality made an enormous impact on the well-known Cambridge mathematician G H Hardy and his colleagues. Ramanujan's brief career seemed to demonstrate to Indians that their innate scientific abilities could make a mark even in the otherwise unfamiliar territories of Western mathematics. Before Ramanujan, J.C. Bose had, by his experiments on wireless transmission (done before Marconi), made the same demonstration in physics.

By the 1930s there were several Indians who had an international reputation in science, but it was becoming rapidly clear that the opportunities available to them within the country were far too few. The bitter controversies that erupted among Indian scientific leaders of the time (e.g. Saha vs. Raman) were in part due to the problems of having to share very scarce resources. The first great Indian scientist who fled the country in search of opportunities elsewhere was probably the renowned astrophysicist Chandrasekhar (Nobel Prize 1983), who eventually settled down in Chicago via (English) Cambridge. The trickle that he started in the 1930s eventually grew into the westward flood of scientific talent that we have continued to experience, especially since the 1970s.

Haemorrhaging? young of blood

With the end of British rule, the new Indian republic, led by Jawaharlal Nehru (and his successors), took massive initiatives for the growth of science in the country, leading to the establishment of new institutions (or vigorous growth of older ones), including the Council of Scientific and Industrial Research, the Department of Atomic Energy, the Defence Research and Development Organization, the Indian Institutes of Technology, the Indian Space Research Organization and many others. Nehru thought of these institutions, and the dams and factories that were built in the first decades of the new Republic, as 'modern temples': he was convinced that it was impossible to solve India's problems without the use of modern science and technology, and constantly spoke of promoting a 'scientific temper' among the people. But to this day, as the continuing exodus of Indian scientists abroad shows, the limiting resource in India is opportunity, not talent.

One major feature of Indian science and technology in republican India has been the growth of the strategic sector. Considering India's history, and the widespread perception among her leaders that backwardness in science and technology invited the aggressive intrusion of Europe into their land, it is hardly surprising that the country began by making relatively large investments in defense, atomic energy, space and other related areas. (In actual fact these programmes have grown quite slowly, with funding that has been steady but by no means high; for example, the annual budget of the successful space programme is just now approaching a sum of US\$ 400 M.) Agriculture was another sector that received massive support, for India discovered in the 1950s that it was still unable to feed itself; the food shortages of the mid-60s, which forced the government to seek international aid in food imports, brought forcibly to the leadership the realization that the country's autonomy was at stake. In retrospect, the major initiative taken in agriculture in the 1960s turned the tide very rapidly – in a matter of 5-10 years. But the country had to wait till around 1990 to give the same kind of attention to the role of science and technology in the commercial and economic sectors: the payments crisis of 1990 once again forced a change in policy (this time toward a free market economy) that otherwise would have been difficult to undertake.

The present scene in science and technology in India continues, as always, to be uneven: the best (which I believe is actually better than what most people think) unfortunately coexists with the worst: there is perhaps not enough creative destruction. I cannot help feeling that al-Biruni's comment a thousand years ago, about how science in India was a mixture of pearls and dung, is valid even today. India forms part of what the American scholar Altbach has called the gigantic periphery; in spite of size, India's presence in the world of science and technology is still small. The knowledge system of the world is now so highly concentrated that its progress is determined by work done in a small number of countries; the investments required to break into this 'world knowledge system' is huge, and even India and China will find it difficult to afford to do this for quite some time to come. In rough numbers, India accounts for about one-half per cent of the total expenditure in the world on research and development, and about 2% of the resulting publications. These figures confirm India's peripherality as well as its higher productivity (dollars per publication a fourth of world average). The major problem in further development of India today lies in learning to manage the extraordinary talent that the country possesses. India is home to one of the largest scientific communities in the world; that community works in a democratic society which has traditionally respected diversity and so operates under constraints unknown to other 'nationalist', state-centered societies. The current challenge is to find innovative but widely acceptable methods that will promote growth balancing all these factors.

The sudden and somewhat unexpected growth of the software industry in India, and the prominent role that non-resident Indians are playing in US scientific and technological enterprises (in particular in the Silicon Valley), have drawn attention to Indian talent in terms that the US

public can more easily relate to. (An interesting thought is that the Indian prowess in software is really the most recent manifestation of the long Indian love-affair with numbers that I spoke about earlier.)

At the end of this brief survey we can ask that old question about East and West: do the twain ever meet? The classical Indian approach to science does seem to have been different from that of the West: it was empirical, algoristic, and constructivist, showing a reluctance to depend on the path from axioms to deduction or proof to theorem or principle. In retrospect, one can say that India has traditionally distrusted two-valued logic – a distrust that may seem not unjustified as recent scientific developments (e.g. Goedel's theorem) provide new insights into mathematics, nature and man, but a distrust that historically led to a vast underestimate of the potential of such logic in understanding and mastering the physical world. It has been said that if Euclid represents a western paradigm, *Pāṇini* represents the Indian. But the twain *have* met, and there have been major civilizational encounters at least thrice in history. The first occurred around and for some centuries after Alexander's raid on north-west India (ca. 300 BCE); the second at the time of Islamic expansion (ca. 1000 CE); and the third with European colonialism. It is remarkable that, while India proved receptive to certain Greek ideas (e.g. Ptolemy's epicycles), Euclid made so little impact (he was not translated into Sanskrit till the 18th c. CE!). The second encounter occurred towards the end of a classical age that had been very creative for India – in science, technology, literature, philosophy etc. – at a time when Europe was 'medieval'. India gave a great deal during this encounter but received little and indeed helped trigger the spectacular growth of a European science that had been stuck in a Hellenist straight-jacket for a millennium. It has been the other way during the third encounter: the best science in today's India is largely done in the western style.

The unstated philosophical approach of science today in India is that an explosion of knowledge has occurred – willy nilly, perhaps as a result of a historical accident – by a pursuit of methods (chiefly experimental and intrusionist) traditionally unknown to us, and that we have to find out what it is all about. But do Indians accept the Western exceptionalist argument that there was something culturally unique in that tradition that inspired western growth and domination of the world in the last 250 years? I suspect not, if only because that growth was to a considerable extent triggered by eastern sources of inspiration. Indeed, as the Indian scientist today adopts the tools and techniques of post-Baconian western science, he still finds it difficult (I believe) to accept Bacon's injunctions about 'enslaving' nature and her creations. He therefore faces a philosophical dilemma that he has not yet come to terms with.

(5268 words)

### Further reading

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**BOX 1****Classical Indian Notation in Algebra**

Modern	Classical Indian
$A + B$	A B <i>yu</i> or A <i>yu</i> B
$A - B$	A B +
Fractional B:	$\begin{array}{ c } \hline A \\ \hline B + \\ \hline \end{array}$
$A \times B$	A B <i>gu</i>
$A \times B \times C \dots$	A B C ... <i>gu</i>
$A/B$	A B <i>bhā</i> or B <i>bhā</i> A  or $\begin{array}{ c } \hline A \\ \hline B \text{ bhā} \\ \hline \end{array}$ or $\begin{array}{ c } \hline A \\ \hline B \text{ chē} \\ \hline \end{array}$
Square root, $\sqrt{A}$	A <i>mū</i>
x (unknown)	<i>yāvat</i> - <i>tāvat</i> , <i>yā</i> or <i>varṇa</i> (colours : <i>kālaka</i> , <i>nīlaka</i> etc.) or •
$A + B = C$	A B <i>yutam</i> C
$A + B + \dots + C = D$	A B C ... <i>ēvam</i> D or $\begin{array}{ c } \hline A \\ \hline B \\ \hline \cdot \\ \hline \cdot \\ \hline C \\ \hline \end{array}$ <i>ēvam</i> D
$A \times B = C$	A B <i>gunitam jatam</i> (or <i>phalam</i> ) C