Chapter 2
Science in India: Ancient and Modern

Indian Civilization

A lot of research has been conducted on the origin and development of Indian civilization.[1] Archaeological sites date from before 30,000 to about 10,000 B.C. In South Asia from the beginning of the sixth millennium B.C. and perhaps considerably earlier, wheat and barley were cultivated, and domestic sheep and goats were kept by the earliest settlements. The evidences show, around 5000 B.C., a stable agricultural community existed. People lived in mud brick houses. They knew of the smelting of copper, making fine colourful pottery and trading over great distances. The beginning of a continuous process of development of stability and agriculture resulted in the early stage of the Indus civilization around 3000 B.C.

An early or Pre-Harappan urban phase of the Indus civilization emerged in the period between c. 3000 and 2500 B.C., which shows the establishment of a uniform style of life and subsistence, which indicates an increase in trade and commerce.

India's cultural frontiers were closely defined. It was because of clearly marked physical frontiers. To the south, south-east and south-west, it is ocean which facilitated trade but isolated her culturally. To the north, north-east and north-west are massive mountain ranges that divided her from the rest of Asia. The access was not easy for traders and travellers, but it also screened her from the arctic winds and air currents of central Asia. As a result, the climate is hot and dependent on a monsoon cycle of seasonal rainfall. The northern mountains are not only physical or cultural frontiers but also climatic frontiers. Almost every type of tropical or almost tropical climate can be found within the subcontinent.

The pre-Neolithic cultures of India fall into three groups, which in general follow one another sequentially throughout the subcontinent, namely, Early, Middle and Late Stone Age. These three groups represent a continuous process of development. But there are also marked regional differences within these groups. Some regions

[1] Here *Indian* means *Indian subcontinent*.

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lagged behind others in new techniques and tools. Some had developed new ways of life, while other continued old ways for longer or shorter periods of time.

In the Early Stone Age, the hand-axe industries developed was comparable to those in Europe. The tools from succeeding terraces of the *Soan* river, a tributary of the *Indus* (now in Pakistan), ranged from crude, heavy hand axes and chopping tools made on pebbles in the upper terraces to small finely worked hand axes, cleavers, discoidal cores, flakes and chopping tools in the lower terraces. The industries of hand axes and other tools are also found in the valley of the *Beas* river, another tributary of the *Indus*, on the Indian side of the frontier; in the south near Madras (now Chennai); in Adamgarh Hill in the *Narmada* valley; and at the gravel of the *Wainganga* river, a tributary of *Godavari* river.

The archaeological evidences show that during the Early Stone Age, man does not seem to have lived regularly in caves anywhere in the subcontinent.

The Middle Stone Age tools were made mainly from cryptocrystalline silica of various kinds such as agate and jasper, or chalcedony, which had a smoother and more regular conchoidal fracture than the granular quartzite favoured in Early Stone Age times. The material appears to have been obtained in the form of river pebbles.

The Late Stone Age throughout India is characterized by microlithic industries. The change from Middle to Late Stone Age, that is, from the flake to the microlithic tradition, appears to be a process of continuous development rather than a sudden change. The stone industry shows certain sequential changes and developments; the tools became smaller, more delicate and more varied. Pottery also makes an appearance at this period.

The Late Stone Age collections in both central and peninsular India also form a small proportion of the finished tools. Very often they are made on fragments of quartz even when the rest of the assemblage is made of cryptocrystalline silica. The quality of both the material and workmanship is considerably better. The technical perfection of these industries went beyond the demand for utilitarian purposes. Many of the semi-precious stones such as agates which were used for making microliths in Central India are still employed by jewellers and bead-makers who obtain many of their best stones from the gravels of the *Narmada* and other rivers – the same sources which supplied the Late Stone Age hunters [1].

Numerous rock shelters discovered in Central India are embellished with drawings on the walls and ceilings, using varying shades of purple, red and light-orange brown. Some belong to later times, but many of the drawings are associated with the hunting cultures of Stone Age or immediately post-Stone Age times. They reveal animals of many kinds: deer or antelope, wild pig, rhinoceros, elephant, buffalo, humped cattle and monkeys.

Pre-Harappan or rather Early-Harappan settlements in Sindh, Punjab and north Rajputana show that the Indian subcontinent was inhabited by tribal communities whose technology was based primarily on stone, and whose principal tools were the bow and arrow, the trap, the snare and the digging stick. There were many different local cultures based on fishing, hunting and foraging.

Around the end of the fourth millennium B.C. in the valley of *Indus* and its tributaries, signs of colonization appeared. The foundations of the first Indian civilization were laid at Amri (Sindh), Kot Diji (Sindh), Harappa (Punjab) and Kalibangan (Rajasthan). There is a remarkable cultural uniformity, both throughout the several centuries during which the Harappan civilization flourished and over the vast area it occupied. In larger settlements, cities or towns, there occurs oriented grid of streets, which intersect the blocks of dwellings. There was standardization of brick sizes, both of burnt and mud bricks. Great care was taken for domestic bathrooms and latrines and on the chutes which linked them to brick drains running down the streets. The drains were connected with soakage pits or sumps, and their good maintenance implies highly effective municipal authority. The tools and vessels were made of copper and bronze. There were numerous highly developed arts and crafts. The bead-maker's craft, long barrelled beads of carnelian, seal cutting, art of shell inlay and stone and metal sculpture are technical masterpieces. The technical uniformity over great areas was unparalleled in the ancient world.

The variations of house sizes and localization of groups and barracks indicate class differences even amounting to slavery. It may be the origin of the caste system which plays a dominant role even now. Some features of religion of *Vedic* times or later Hinduism were seen at this period.

Around 2000 B. C., the uniform culture of this great area broke up. The cause of decline is uncertain. Several causes have been forwarded, for example, calamitous alterations of the course of the *Indus*, repeated flooding of the city, invasion from the west, etc.

> The general opinion among scholars now is to ascribe the demise of the Harappan tradition to ecological factors, for instance, a prolonged spell of aridity. At the end of the mature phase, when new elements appeared on the scene (and prior to the demise of the Harappan culture), the resultant culture was still a derivative of the Harappan. But when the *Aryan* entry took place, the late Harappans were culturally overwhelmed and absorbed into the new mainstream. They contributed to its growth, but at the cost of losing their own identity. Probably, a fraction moved southwards, outside the initial *Aryan* zone of influence. [2]

Chronology of prehistoric India [2]

c. 7000 B.C.	Advent of (wheat and barley) farming, animal husbandry and settled life at pre-pottery, Neolithic Mehrgarh in Baluchistan
c. 4700 B.C.	Handmade and coated-basket pottery, appearance of cotton
c. 4000 B.C.	Wheel-made pottery, use of copper
c. 3500–2500 B.C.	Early-Harappan regional cultures
c. 2500–2000 B.C.	Centralized mature Harappan phase with urban centres and seaports. Double cropping in Gujarat
c. 2000–1300(?) B.C.	Late Harappan localized cultures. Double cropping in north-west India
c. 850–400 B.C.	Painted Grey Ware culture of pastoral agriculturists on merger with the local late Harappan culture. Limited use of iron
c. 600 B.C.	Beginning of Indian historical era
c. 700–100 B.C.	Northern Black Polished Ware culture with full-fledged use of iron and urbanization of the Ganga Plain

The proto-Indo-European speakers emerged as a prehistorical entity in the steppes, north of the Black and Caspian Seas with the domestication of the wild horse. By the time they started dispersing, the Indo-Europeans were already familiar with metal and were not only riding horses but also using wheeled vehicles. The similar Indo-Iranian-speaking groups moved southwards from the Eurasian steppes in c. 2000 B.C. and spread over central Asia, Iran and Afghanistan up to River *Indus*. The merger of the non-*Rigvedic* Indic speakers with the post-urban Harappans led to the establishment of the various late Harappan cultural phases, including the important Cemetery H culture in Punjab.

In c. 1700 B.C., another group of Indic speakers settled in south Afghanistan and took to the composition of the *Rigvedic* hymns in the region between the Helmand and the Arghandab. The description of *Saraswati* and *Sharayu* in the Rigveda, and even in *sutra* literature, fits the Afghan rivers *Helmand* and *Hari Rud* better than any river in India. In c. 1400 B.C., the Rigvedic people moved eastwards to the middle *Indus*. Eventually, they absorbed the Cemetery H people to found the Painted Grey Ware culture in c. 850 B.C. in Punjab and on the upper *Ghaggar*.

The Vedic people stayed back to the west of the Yamuna-Ganga doab until c. 850 B.C. The large-scale settlement of the Ganga Plain took place only when the use of iron became widespread and, perhaps, when population increased. During their migration, the Indo-Aryans carried with them not only their poetry and religious beliefs but also place and river names which they selectively reused [2].

Since no historical documents are available, history has to be extracted from religious texts. The available sources are the *Vedic* texts, the *Puranas* and the two epics, the *Ramayana* and the *Mahabharata*. Other sources are *Avesta*, the sacred book of the Zoroastrians, Buddhist and Jain literature.

The *Vedic* texts are Holy Scriptures, composed by a large number of authors over a long period of time, which went through many revisions in the hands of a number of independent schools, resulting in a multidimensional corpus. There are three categories. The essence of corpus is made up of four *Samhitas* (collection of hymns (*sūktas*)) of *Rigveda*, *Samaveda*, *Yajurveda* and *Atharvaveda*. The *Brahmanas* are attached to *Samhitas*, which are prose texts devoted to an interpretation of the rituals. The *Aranyakas* (forest books) which contain mysticism and symbolism are appendices to *Brahmanas*. The *Aranyakas* form a natural transition to the philosophical texts of the *Upanishads*. The *Samhitas* and *Brahmanas* together are known as *sruti* (heard, implying revelation). The *Aranyakas* and the *Upanishads*, along with the philosophy in it, are called *Vedanta* (the end part of *Vedas*). The third category is *Kalpasutras*, which contains detailed instructions for performing rituals.

The hymns were memorized meticulously and transmitted orally to the forthcoming generations for many centuries. A number of devices were used for memorization and for the correct articulation of the sound, which determined its efficacy – a prime requirement in ritual texts. It was confined to a small, select group of *Brahmins*, who on the basis of knowing the *Vedas* claimed superior knowledge, and they alone were allowed to perform major rituals.

In the sixth century B.C., the establishment of kingdoms, oligarchies and chiefdoms and the emergence of towns brought about a historical transition in north

India. The emergence of *gana-sangh*[2] was a form of proto-state. There appeared a control over a defined recognized territory. The urban centre was the location of authority, which could also be the location of craft activities that were produced for both local consumption and commercial exchange. It was the emergence of the state system.

In the fifth century B.C., there was the rise of the *Magadha* Empire, which remained powerful and controlled nodal points in the Ganges river system that gave it access to the river trade. In 327 B.C., Alexander of Macedonia entered the Indian provinces. The subsequent period is the history of various empires, dynasties and invasions.

Ancient Science

When human beings formed a society, it became necessary for them to have knowledge of nature for their survival. The observations, interpretations and predictions gave birth to systematic branch of knowledge, which further spread into various branches of sciences. These natural sciences can be divided as ancient (or traditional) and modern. There are three main traditions in ancient sciences: East Asian (mainly Chinese), South Asian (mainly Indian) and Ancient Mediterranean-Islamic-European science.

Astronomy

The early man first encountered the motion of sun, moon, stars and seasons leading to the knowledge of astronomy and from food, diseases, health, etc. to medicine. So it is not surprising that in most cases, especially traditional sciences, most ancient branches are astronomy and medicine. India also has a long history of astronomy (*jyotisha-shastra*) and medicine (*Ayurveda*). Astronomy consists of mathematical astronomy (*ganita-jyotisha*) and astrology (*phalit-jyotisha*). The history of Indian astronomy can roughly be divided into the following periods [3]:

1. Indus valley civilization period (c. 2500 B.C.–c. 1700 B.C.)
2. Vedic period (c. 1500 B.C.–c. 500 B.C.)
3. *Vedāng* astronomy period (roughly around sixth and fourth century B.C.–third and fifth century A.D.)
4. Period of introduction of Greek astrology and astronomy (roughly second or third century A.D.–fourth century A.D.)

[2] The *gana-sangh* or *gana-rajya* has the connotation of *gana*, referring to those who claim to be of equal status, and *Sangh*, meaning an assembly or *Rajya* referring to governance.

5. Classical *Siddhānta* period or classical Hindu astronomy period (end of fifth century–twelfth century A.D.)
6. Coexistent period of the Hindu astronomy and Islamic astronomy (thirteenth/fourteenth century–eighteenth/nineteenth century A.D.)
7. Modern period or coexistent period of modern astronomy and traditional astronomy (eighteenth/nineteenth century onwards)

The Aryans appeared in north-west India in c.1600 B.C. They produced four *Vedas*, namely, the *Rigveda*, the *Samaveda*, the *Yajurveda* and the *Atharvaveda*; each consists of the *Samhita*, the *Brahmana*, the *Aranyaka* and the *Upanishad*. The *Rigveda-Samhita* was composed in north-west India (present Punjab state) during c. 1500 B.C. and c. 1000 B.C. Basically it is a religious text, but it contains some astronomical knowledge. Its early portion deals with calendrical knowledge which was related to the local climate of India, annual monsoon and seasons. Agriculture was already developed by the Indus valley civilization, and there is a possibility that Aryans must have acquired some agricultural and calendrical knowledge from non-Aryans of India. The later portion of *Rigveda-Samhita* mentions the intercalary month of the year.

During c. 1000 B.C. and 500 B.C. (later *Vedic* period), the Aryans advanced towards the east, area between the *Ganga* and *Yamuna* rivers, where they composed later *Vedic* texts (except *Rigveda*). The *Atharvaveda* and *Yajurveda* explicitly mentioned the intercalary month. They also give the complete set of *nakshatras* (lunar mansions). The *nakshatras* were used to indicate the position of the full moon. The *Vedanga* (limbs of the *Vedas*) works were produced towards the end of the later *Vedic* period. The *Vedanga* consists of six divisions, namely, phonetics, metrics, grammar, etymology and ceremonial. In this period, astronomy (which was called *jyotisha* in *Sanskrit*) was established as independent learning. The *Jyotisha Vedanga* (or *Vedang jyotisha*) of Lagadha (first millennium B.C.) is the fundamental text of this learning. It contains a system of astronomy for calendar making. It is a lunisolar calendar. At the middle and at the end of the 5-year cycle, called *yuga*, two intercalary months were inserted. The *Vedang jyotisha* was composed sometime between the sixth and fourth century B.C., and the place was at the latitude 27–29° N, in north India without apparent foreign influence [3]. The Greek horoscopic astrology, zodiac signs, 7-day week, etc. entered India around the second or third century A.D. At this time, Greek mathematical astronomy was almost unheard of in India, and the *Vedang* astronomy was in use. Around the fourth century or so, Greek mathematical astronomy was introduced in India.

The end of the fifth century A.D. to the twelfth century A.D. is called *classical Hindu astronomy* period or *classical Siddhanta* period. The *Siddhanta* is the fundamental treatise of mathematical astronomy in *Sanskrit*. This period produced several renowned astronomers, namely, Aryabhata, Varahamihira, Bhaskara I, Brahmagupta, Lalla, Vatesvara, Manjula, Sripati and Bhaskara II. Some of their works are still considered to be an authority on the subject by traditional Hindu calendar makers.

The Kerala (south India) School also produced several good astronomers, namely, Madhava, Paramesvara, Damodara, Nilakantha, Jyesthadeva, Achyuta Pisarati, Puthumana Somayaji and Sankara Varman.

The *Jyotirmimansa* of Nilakantha has a unique place in the history of Indian astronomy, as it is the only work which focuses on epistemological issues concerning the science of astronomy and mathematics. It falsifies the claim of many scholars that Indian astronomy did not have a scientific methodology worth the name, in contrast to the Greek tradition [4].

From thirteenth/fourteenth century to the eighteenth/nineteenth century is the period of coexistence of Hindu astronomy and Islamic astronomy, which started after the establishment of Islamic dynasties.

Mathematics

Mathematics is found in scattered form – in sacred texts – the *Samhitas*, the *Kalpasutras* and the *Vedangas*. Information about enumeration, arithmetical operations, fractions, properties of rectilinear figure, (present) Pythagoras' theorem, surds, irrational numbers, quadratic and indeterminate equations, etc. is available in the *Sulbasutras*, which is the part of *Kalpasutras*. The *Brahmanas* and some *sutras* contain material about progressive series and permutations and combinations.

From town planning, architectural expertise and other aspects of civilization of Mohenjo-daro and Harappa, it can be concluded that Indus valley civilization had developed good degree of skills in measurements and computational techniques [5]. Vedic Hindus, like the Egyptians, adopted 10 as the basis of numeration. The various recensions of the *Yajurveda Samhita* give names as large as 10^{12}. The *Taittiriya Samhita* gives names as *eka* (1), *dasa* (10), *sata* (10^2), *parardha* (10^{12}), etc. The Jain mathematical work, the *Anuyogadvara Sutra* (c. 100 B.C.), mentioned large numbers up to 29 places and beyond. The fundamental arithmetic operations with elementary fractions are clearly indicated in *Vedic* texts. The *Rigveda* gives names of fractions such as *ardha* (one half) and *tripada* (three fourths). The *Maitrayani Samhita* mentions *pada* (one fourth), *sapha* (one eight), *kustha* (one twelfth) and *kala* (one sixteenth). The *Sulbasutras*[3] contains several instances of addition, subtraction, multiplication, division and squaring of fractions. The recurrence of arithmetic and geometric series with the correct statement of the results of their summation strongly suggests that the *Vedic* Hindus probably possessed some method of finding the summation of such series. The mathematician of the later period such as Mahavira, Bhaskara II, Narayana and others has framed general *formulae* for obtaining sums.

The various *Sulbasutras*, as parts of the *Srauta-sutras*, are *Brahmanic* geometrical manuals for the construction of sacrificial altars. The texts give several rules such as how to construct a straight line perpendicular to another straight line, a square with a given side, a rectangular with given sides and an isosceles trapezium of a given altitude, face and base. According to *Baudhayana's* definition, the theo-

[3] The word *Śulba* means a cord, a rope or a string, and its root *śulb* means measuring or act of measuring.

rem of the square of the diagonal (in modern language Pythagoras' theorem) is 'The diagonal of a rectangle produces by itself both (the areas) produced separately by its two sides' [5]. By actually drawing the squares on the diagonal and the sides of a rational rectangle, dividing them into elementary unit squares and then counting them, *Vedic* Hindus might have arrived at the truth of this theorem.

The altar geometry of *Sulbasutras* contains the beginning of algebraic notions such as quadratic equations, indeterminate equations, surds, conception of irrational numbers and determinations of their approximate values.

Unfortunately a Jain mathematicians' work of pre-Christian era is not recorded; however, from a few fragments or insertions in canonical or other types of non-mathematical literature, their achievements can be assessed. About the first century B.C., the *Sthananga Sutra*, a Jain canonical work, listed several mathematical topics, which used to be developed at that time. These topics are *samkhyayana* (science of numbers), *parikrama* (fundamental operations), *vyavahara* (subjects of treatment), *rajju* (geometry, like *Sulba*), *rasi* (heap, solid mensuration), *kalasavarna* (fractions), *yavat-tavat* (equations, algebra), *varga* (square, quadratic equations), *ghana* (cube, cubic equations), *varga-varga*, etc.

The period of the second to eighteenth century A.D. is characterized by a wealth of material rich in range, depth and quality of mathematical investigations. The primary interest was problems concerning the reckoning of time. In India, like other civilizations, the substantial development of mathematics was related to astronomical works, for example, accurate positioning of the moon, sun and other planets and stars, calculations of their motions, predictions of their paths and positions and so on. This leads to refinements in algebraic solutions of indeterminate problems and various arithmetical operations. The expansion of trade and commerce, within as well as outside India, also must have played a vital role in the development of mathematics. Many mathematicians, from different schools, have done commendable works, for example, Aryabhata I, Bhaskara I, Brahmagupta, Mahaviracharya, Aryabhata II, Sridharacharya, Sripati, Bhaskara II, Narayana and many commentators. The Kerala school also produced many noted mathematicians: Govindsvamin, Sankaranarayana, Suryadeva Yajvan, Madhava, Paramesvara, Nilakantha, Citrabhanu, Sankara Variyar, Jyesthadeva, Achyuta Pisarati, Puthumana Somayaji and Sankara Varman.

A lot of work has been done on the manuscript that existed, scattered fragments, cross-references, translations, interpretations, chronology and so on [5]. For example, Madhava [4] gave the infinite series for $\tan^{-1} x$ in *Kriyakramakari* as

$$\tan^{-1} x = x - \frac{x^3}{3} + \frac{x^5}{5} - \ldots\ldots$$

which is the Gregory-Leibniz series for $\tan^{-1} x$. Similarly, the infinite series for the sine and cosine functions given in *The Yuktidipika* are attributed to Madhava as

$$\sin\theta = \theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!} - \ldots\ldots$$

and

$$\cos\theta = 1 - \frac{\theta^2}{2!} + \frac{\theta^4}{4!} - \ldots\ldots$$

These results were used by Indian mathematicians more than 350 years before their rediscovery in Europe.

Medicine

It is quite obvious that medical knowledge must have grown out of necessity of overcoming pain, injury and sickness. The native medical science of India is known as *Ayurveda*. *Ayus* means ‘span of life’ and *Veda* means ‘unimpeachable knowledge’.

The evidence shows that medical knowledge possessed by Indus valley civilization was further developed by Aryans in their own ways. The evidence of existence of a high level of social sanitation and of public hygiene is observed from the archaeological excavation of pre-Aryan civilization of Mohenjo-daro, Harappa and many other sites in and outside the Indus valley. The water-proofed walls of baths, lined with impervious bitumen, arrangements for draining and refilling public bathing tanks through conduits, enclosed bathrooms and water-closets made of brickwork connected with central water supply and drainage, garbage chutes emptying into external masonry receptacles (presumably cleared on a municipal basis), an efficient and elaborate drainage system running beneath the paved streets, spaced brickwork manholes of drains with removable lids and soak pits suggestive of sanitary privies of modern invention, all show a remarkably high level of public health activity and universal consciousness of sanitation without parallel in contemporary civilizations and, in fact, most other civilizations of historic times [6].

The beginnings of the *Ayurveda* are traced first in *Rigveda* and then in the *Atharvaveda*. In earliest *Samhitas* of *Vedic* period, one can find logical speculations on the origins of diseases, use of healing drugs, treatment and surgery. The art of healing was not only a skill but also a social system including the power of magic, ideas gained by experience and experiments, compassion to human suffering, philosophical speculation and so on. This art of healing was a part of the sacramental duties of priests. Medical science was an *Upanga* (part) of the *Atharvaveda*, and *Ayurveda* was an *upveda* (secondary *Veda*) forming part of the *Rigveda*.

Vedic literature contains anatomical and physiological terms, methods of treatment, theories of the origin of life and of diseases, etc. It is a medley of accurate knowledge, rational ideas, superstitions and faith in supernatural. In spite of irrational notions, it contains so much of rational observations, inferences and accurate medical knowledge that it was almost at the level of science. At this time, there was no classification of anatomical and physiological information or diseases.

In succeeding centuries, it developed as a comprehensive and rational medical system. The knowledge of this science mainly comes from surviving written treatises, namely, *Bhela Samhita*, *Charaka Samhita* and *Susruta Samhita*.

The *Bhela Samhita* is fragmentary and does not provide a full exposition of Ayurvedic medical knowledge. The *Charaka* and *Susruta Samhita*, followed by commentaries and treatises in later centuries, provide complete representative works on *Ayurveda*. This period is in between A.D. 100 and third to fourth century A.D. The *Charaka Samhita* mainly deals with anatomy, physiology, aetiology and prognosis, pathology, treatment, objectives, influence of environmental factors, medicines and appliances and procedure and sequence of medication. The *Susruta Samhita* also follows more or less the same pattern, but it gives importance to surgery. It contains fundamental postulates, pathology, embryology and anatomy, therapeutic and surgical treatment, toxicology and specialized knowledge of earlier sections.

The curing of diseased conditions and the maintenance of health are not the only aims of *Ayurveda*. It is also concerned with harmonizing secular conduct and spiritual pursuit through a realization of the true relationship between the complex of the body, mind and soul and the eternal universe. There is a rigorous standard for the training of physicians and a meticulous code of personal ethics and social conduct for the medical profession [6].

Around the thirteenth century or so, the classical treatises of *Charaka* and *Susruta* had become hoary with age. It was necessary to revise the matter and restore its parts which were lost or misplaced. The intellectual efforts and active research needed in this direction, unfortunately, due to various reasons, were not in sight and it led to decay. The ruling people adopted Unani (originally *Arabic*) medicine and neglected *Ayurveda*. Slowly the prestige and popularity of *Ayurveda* were lost during the following centuries.

Decline and Fall

There are various reasons for the arrest of growth leading to decline and fall of ancient Indian science:

1. There was steady rise in rigidity of caste system, in which society was divided into four major sections, namely, *Brahmins* (learning/teaching professionals), *Kshatriya* (warriors/kings, etc.), *Vaishya* (trade, involved in commerce, etc.) and *Shudra* (people involved in various services). In the initial phases, the system was according to profession or ability to do a certain task, where cross-profession was also possible. Later on it became so rigid, that, according to birth in a certain section, one had to follow that profession only, irrespective of whether he is capable to do it or not! No cross-profession was allowed. Any intelligent youth eager and enthusiastic to learn was not allowed to acquire knowledge and pursue it further, if he did not belong to *Brahmin* family. There may be some merits of caste system, according to wise men of the prevailing society, but it arrested the progress.
2. One of the side effects of the caste system was that the learning/teaching process became mechanical. This rote learning resulted in slowing the growth and finally halting.

3. The traditional Indian learning-teaching process was oral. A student had to learn by heart from his teacher and, when he became teacher, pass on that knowledge to his disciples. This oral tradition restricted knowledge to some people. The probable reason was that knowledge should not fall in the wrong hands. He may exploit it for wrong reasons or misuse it against innocents. After stringent tests only, the teacher (or *Guru*) used to impart that knowledge to deserving disciples. This factor also limited growth.
4. Religious taboos (which may have some merits, according to wise men of the prevailing society) about crossing the sea or leaving the seashore (for any reason) stopped the process of exchange of knowledge with other civilizations.
5. The essence of religion was on *self-salvation*. Thinking about society at large became secondary or less important. The ideology of 'live with your sufferings or as it is or you are destined for this etc. (instead of finding solution) for better 'other world' (rebirth or life after death)' stunted society as a unit. 'Learn to tolerate, remain as it is, do not revolt, suffering is the punishment of your deeds of previous birth etc.' – this kind of thinking or ideology imbibed by scriptures and religion (which entered in it time to time) might had merits from the stability point of view of society in the beginning, but it killed curiosity, thinking, adventures, etc. in the long term. It was one of the obstacles of growth.
6. Due to regular monsoon cycle on the continent, easy and ample availability of food made people lazy and inactive. Often the hardship of life forces people to search for various options and 'necessity becomes the mother of invention'.
7. It was also the responsibility of rulers or administrators to monitor the progress of society by way of cultivating existing as well as forming new branches of knowledge. The absence of far-seeing vision of leaders and their advisers was also one of the factors.

Modern Science in British India

The discovery of direct sea route to India in 1498 was a major breakthrough for Europeans. The voyages to India were of great commercial value for Portuguese, Dutch, British and French. The British were more successful on all fronts. The 1757 battle of *Plassey* laid the foundation of the British colonial empire. For building, expanding and consolidation of empire, geographical and intellectual knowledge of the local terrain was very important. Several texts and travelogues appeared, about what was best in India's natural resources and technological traditions, that could be most advantageous to rulers, for example, W. Robertson, John Capper, Huge Murray, G. R. Wallace, J. M. Honigberger, F. Buchanan, B. Heyne, M. Martin, R. Heber and M. Jacquemont [7]. The East India Company immediately realized the importance of geographical, geological and botanical knowledge. For example, in January 1800, while proposing a survey of Mysore, Mackenzie stated his object was 'to obtain as soon as possible a clearer and better defined knowledge of the Extent, Properties, Strength and Resources of a Country … to elucidate many objects of Natural History, connected with commercial views and therefore interesting to the Company, exclusive of the advantage in the improvement of scientific knowledge' [8].

Rennell published his surveys as *A description of the Roads in Bengal and Bihar* (1779), *Memoir of a Map of Hindusthan* (1788) and *Memoir of a Map of Peninsula of India* (1793). Around 1799, Major Lambton proposed a project of Geographical Survey from Coromandel to the Malabar Coast based on geodetic principles. Colonel Wellesley pushed the project with the influence of his brother Lord Wellesley, the then Governor General. Thus, the Great Trigonometrical Survey of India (GTSI) was created. For maritime power, marine surveys were important. In 1770, Ritchie was appointed as the first Hydrographical Surveyor to the Company, and in 1809, a full-fledged Marine Survey Department was established in Bengal with Captain Wales as the first Surveyor General. Later on Horsburgh, Dominicetti, Ross and Haines surveyed coasts of peninsular India and the coasts and archipelagoes from Malaya to Madagascar.

Wallich, an avid plant collector, surveyed Bengal, Bihar, Assam and Nepal. In the mid-1830s, he carried to England 30 barrels of dried plants. He listed 40 scientists and institutions for further study of samples. It was the largest botanical collection brought to Europe by a single man. The botanical investigations continued in Calcutta and Madras. In 1848–1850, J. D. Hooker surveyed Bengal, Sikkim, Nepal and the Khasi Hills, and in 1855 he published his work as *Flora Indica* and the *Himalayan Journal*. Thus, administrators realized the commercial, military and scientific importance of botanical investigations.

The colonizers also recognized India's potential as an agricultural country. Experiments on tea and cotton were carried out.

The economic value of geological investigations was of immediate concern to the East India Company. In 1808, Lord Minto ordered investigation into the Raniganj coalfield. Colebrooke prepared a report on Sylhet coal and Franklin on coal mines in Palamu. Herbert investigated about occurrence of coal within the Indo-Gangetic tract of mountains. In 1845 Lieutenant Newbold published an article on minerals of south India, especially on manganese ore.

In India coal was known from time immemorial, but there was no recorded history of coal. Probably ample quantities of wood were available; therefore, nobody was bothered about it. John Sunner and S. G. Heatly discovered it in 1774 near Sitarampur in Bengal and requested Warren Hastings' permission for coal mines. The steam navigation and iron works necessitated the search for coal. In 1836, the Company appointed a committee for the investigations of the coal and mineral resources of India. This committee stands as a milestone in the evolution of colonial science in India, because here for the first time various types of coal and minerals were listed along with map illustrations of the sites as well and also for the first time the question of employing trained geologists in India to investigate coal formation in the country was raised [8].

In 1846, D. H. Williams was appointed as Geological Surveyor to the Company. He prepared two reports, one on the Damodar Valley and the other on the Ramgarh coalfields. In 1850, Thomas Oldham, who was earlier Director of the Geological

Survey of Ireland, established the continuous Geological Survey of India. He laid the foundations of stratigraphical classification in Indian geology.

For such a vast country, transportation and communications were the backbones of administration. The period of 1830s and 1840s was of technological revolution. For example, steamboats and railways were the major means of mass transportation. In India, these were largely initiated and financed by merchants for expansion of trade. Telegraph came to India ahead of railways basically for political reasons. Fast communication was the need of effective control on expanding imperial activities.

The electric telegraph was officially proposed in 1849. The need was so pressing that Calcutta, Agra and Attock and also Agra, Bombay and Madras were connected within a short span of 15 months from the start in November 1853. The telegraph played a crucial role in the revolt (mutiny) of 1857.

Sir John Laird Mair Lawrence who as chief commissioner 'saved Punjab' during the mutiny and later served as Viceroy of India said, 'The telegraph saved (British) India'. If the mutiny had come 10 years previously when the railways and the telegraph had not yet been introduced, it might have succeeded [9].

In the charter of 1813, it was mentioned that the grant of Rs. 1 lakh should be spent on education for introduction and promotion of knowledge of the sciences, among the inhabitants of British India. But it was not clear as to what kind of education should be imparted.

Hospital assistants, surveyors and mechanics were needed for fast-growing medical, survey and public work departments. Training local youths was much cheaper than hiring from abroad. Therefore, perhaps the government paid more attention to engineering than any other branch of science. The Calcutta medical college was opened in 1835 and an engineering class at Hindu College in 1843. An engineering college at Roorkee was established in 1847. But overall engineering and technical education remain confined to produce overseers, surveyors and mechanics.

In British India, there were people, like William Carey, Rev. Alexander Duff and David Hare, who tried to introduce western education in India. Warren Hastings set up the first educational institute, Calcutta Madrassa, in 1781 to impart English education. In the same year, with the initiative of Sir William Jones, *The Asiatic Society* was set up. The *Sanskrit College* at Varanasi was established in 1792.

Social reformers like Raja Rammohan Roy strongly demanded a more liberal and enlightened system of instruction including mathematics, natural philosophy, chemistry, anatomy, etc. with other modern sciences. Thus, the *Hindu College* was established in 1817 to promote liberal education. The Hindu College was renamed *Presidency College* in 1857. The *University of Calcutta* was founded on 24 January 1857, *University of Bombay* on 18 July 1857 and *University of Madras* on 5 September 1857.

The renaissance took place, when Indians of great mental abilities rediscovered their own heritage, helped to some extent by the western angle of vision. Raja Rammohan Roy, Iswar Chandra Vidyasagar, Bankim Chandra Chattopadhyay, Rabindranath Tagore, Swami Vivekananda and Aurobindo were some of those great minds who rediscovered India's philosophical and literary heritage and brought about the Bengal renaissance [10].

The real growth of modern science started from Mahendralal Sircar who is rightly called the *father of modern science* in India. He was born in a poor family at Paikpara near Calcutta (Kolkata). By education he was M.D. (medicine) of Calcutta University, but studied on his own the basic experimental sciences of physics and chemistry. He initiated a *science movement* in August 1869 by starting it as a science class at his residence every Sunday. He distributed an 8-page printed pamphlet to the public and the press. There was enthusiastic response from several newspapers. Over Rs. 80,000/- were received as donations. Thus, the Indian Association for the Cultivation of Science (IACS) came into being on 29 July 1876 with Mahendralal as the Secretary. The foundation stone at 210, Bow Bazar Street (Calcutta), was laid by Sir Richard Temple, the Lt. Governor of Bengal. Mahendralal relentlessly pursued his efforts at a time when there was no crowing for the pursuit of science [11].

IACS shifted to new premises in 1884. In the beginning, the staff included Mahendralal and Fr. S. J. Lafont, a Jesuit priest of St. Xavier's College. Asutosh Mukherjee developed his interest in science through the lectures of Mahendralal Sircar and Fr. Lafont. Later, Asutosh delivered lectures at IACS on Mathematical Physics from 1887 to 1890. P.N. Bose, student of Fr. Lafont of the Geological Survey of India, delivered lectures on Geology. It is said that P.N. Bose educated Jamsetji Nusserwanji Tata on the iron deposits of the area, which resulted in the establishment of the Tata Steel Mill at Jamshedpur in 1911 [9]. R. C. Dutta delivered popular lectures in *Bengali* for 14 years.

Sir P. C. Ray, then student of Presidency College, attended the IACS lectures and later delivered the lectures. J. C. Bose, professor of physics, Presidency College, assisted Mahendralal Sircar from 1886 to 1888 and delivered lectures at IACS.

Mahendralal could not raise funds for appointing paid lecturers and research scholars. He was very much disappointed. His reports in the IACS annual meetings during 1899–1903 were full of agony and lamentation that his mission had not succeeded. He felt Bengal had neglected its own institute of scientific research, which was 30 years old [11].

IACS remained a forum for popular and college-level lectures. The IACS was recognized by Calcutta University as a teaching centre in 1893.

Sir C.V. Raman, then Indian Government Official, did his part-time research in physics at IACS, which lead him to a Nobel Prize in Physics. Though IACS failed to materialize as a research institute, it played an important role in the development of Indian science.

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