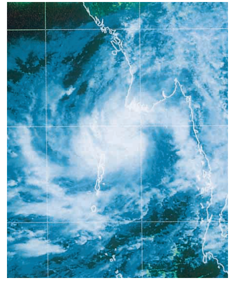
Photo: H.Y. Mohan Ram

OUR HERITAGE

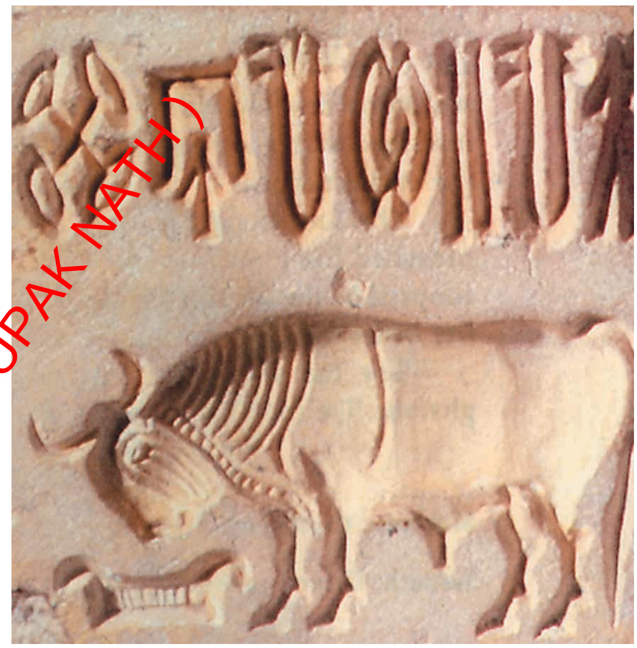
The Indian civilization, among world's oldest and richest, has a strong tradition of Science and Technology. Our contributions to astronomy, mathematics, medicine and practical arts are not adequately acknowledged in the Western World, either due to ignorance or prejudice. This chapter gives glimpses of the history of our achievements in ancient India.



Our Heritage

The Indus Valley Civilization, also called the Harappa Culture that flourished for nearly eight centuries (c. 2750-1900 BC) was, according to some, the youngest but by far the largest of the three most ancient civilizations. It was noted for its efficient town planning with interlinked drainage system, dwelling houses built with standardized burnt bricks, tiled flooring, wheel-turned ceramics, terracotta craft, spinning and weaving, bead-making, and more importantly, copper-bronze casting by the cire-purdue or lost-wax process. Within this civilization flourished many towns and cities including Mohenjo-daro, Harappa, Chanhu-daro, Kalibangan and Lothal, which have revealed an agriculture-based economy with granaries and other storing techniques that made for an enriched community life. While there is wide-ranging archaeological data concerning the technical skills of the people, there is little or no information about their scientific ideas relating to astronomy, mathematics, medicine and the like. This is because their script, found on nearly 3,000 seals, sealings and other inscribed objects, is yet to be deciphered satisfactorily.

The story, however, is different from about 1500 BC with what are called the Vedic people whose literary compositions provide an insight into their culture-specific scientific tradition. The *Ṛgveda*, the earliest of the Vedas, describes in detail the natural law or order called *ṛta* as the governing principle of the universe and its events. Even the Vedic gods were not exempt from this law. In course of time, this principle gave rise to the concepts of truth (*satya*) and *dharma*, the cultural kernel of Indian society. The Vedic seers were also keen observers of the sky. They were well aware of the motion of the Moon, the path of the Sun, occurrence of eclipses and solstices, and had developed luni-solar calendars with methods of intercalation. More importantly, they formulated a stellar frame of reference, in terms of 27 or 28 *nakṣatras* or asterisms (star groups) lying along or near the ecliptic, in order to follow the path of the Moon and Sun. One of the six auxiliaries of the Vedas -- and the earliest Indian astronomical text -- going by the name of *Vedanga Jyotisa* had developed a concept of a cycle of five years for luni-solar and other time



Sealing of a Bull, that is impression of the original seal, Indus Valley, c. 2500-1500 BC.

adjustments, with intercalation at regular intervals. Later, Indian astronomers adopted a huge cyclic period of 43,20,000 years. At the beginning of this mega-cycle, *yuga*, the planets were supposed to be in conjunction and, after going through integral numbers of revolutions in relation to the earth, would accordingly again be back in conjunction.

Indian mathematics too had its origin in the Vedic practices. The *Śulba Sūtras*, a component of another Vedic auxiliary called the *Kalpa Sūtras*, deal with the construction of several types of brick altars for sacrificial performances with the elucidation of certain geometrical problems involving the so-called Pythagorean theorem, squaring a circle, equivalence in area of geometrical figures, irrational numbers and the like. Yet another Vedic auxiliary, *Chandaḥ* (metrics) postulated a triangular array for determining the type of combinations of *n* syllables of long and short sounds for metrical chanting. This was later mathematically developed into a pyramidal expansion of numbers. Such an exercise, known as Pascal's triangle, appeared centuries later in Europe among Renaissance mathematicians. In the Vedic period, number-reckoning on an ascending decimal scale, even up to 1018 (but word-numerals), was developed along with arithmetical and geometrical series. The Jainas and Buddhists too had conceived of very large numbers.

Astronomy and Mathematics

During the three centuries before and after the Christian era, astronomy became based on mathematics. There came up a new class of astronomical texts called the *Siddhāntas* (final solutions), in which the now familiar twelve signs of the zodiac gradually replaced the *nakṣatras* system, along with new astronomical methods for determining mean longitudes, planetary motions, eccentric and epicyclic models, and trigonometrical aspects, all of which point to possible Hellenistic or Greco-Roman influences. The five noted *Siddhāntas* are the *Paitāmaha*, the *Vasiṣṭha*, the *Pauliśa*, the *Romaka* and the *Sūrya*. Of these, the last (the *Sūrya Siddhāntā*) is the most accurate, according to Varāhamihira (early sixth century A.D.) who in his *Pañca siddhāntika*, summarized their contents. In any case, this text which underwent some modifications continues to be used as a major basis for traditional calendrical computations even to this day.

Some leading astronomers-cum-mathematicians of this age were Āryabhaṭa I (c.5th AD); Bhāskara I (c.7th), Brahmagupta (c.7th-8th); Lalla (c.8th), Vaṭeśvara (c.10th); Āryabhaṭa II, Śrīdhara and Śrīpati (c.10th-11th) Bhāskarāchārya II (c.12th.), Mādhava (c.14th), Ganesadaivajna (c.15th) and Nīlkaṇtha Somayāji and Paramesvara (c.16th). Āryabhaṭa I gave the value of pi (3.1416 approx.), a value used even today; worked out trigonometrical tables, areas of triangles and other plane figures; arithmetical progression, summation of series and indeterminate equations of the first order. He also expounded the theory that the earth rotates upon its own axis; and the period of one sidereal rotation determined by him is almost equivalent to the modern value. He rejected the traditional Rāhu-Ketu postulate regarding the occurrence of eclipses and provided a scientific explanation instead. Varāhamihira, too, rejected this mythical idea, despite being an astrologer influenced by Hellenic ideas of the twelve zodiacal signs and associated concepts .

Brahmagupta, however, believed in the Rāhu-Ketu postulate and refused to subscribe to Āryabhaṭa's

A thousand years before the time of Copernicus (1473-1543), Āryabhaṭa (b 476 AD) in India made outstanding contributions to astronomy and mathematics. His contributions include: the determination of the diameter of the earth and the moon, the proposal that the earth rotated on its axis to explain the daily motions of the fixed stars; the solution of quadratic equation; defining the trigonometric functions; stressing the importance of Zero; and determining the value of pi up to the fourth decimal place.

Photo: P.N. Tandon

Photo: H.Y. Mohan Ram

Top: An astronomical observatory in Jaipur, built by Maharaja Sawai Jai Singh.
Bottom: Sun dial in the astronomical observatory in Delhi, built by Maharaja Sawai Jai Singh in 1724.

exposition of the earth's rotation, or to his scientific explanation of the eclipses. Nevertheless, he made remarkable contributions towards solving indeterminate equations of the second order -- an equation that appeared in Europe a thousand years later as Pell's equation. His lemmas in this connection were rediscovered by Euler (1764) and Lagrange (1768). Brahmagupta is regarded as the first mathematician to enunciate a formula for the area of a rational cyclic quadrilateral. His works, the *Brahmasphuṭa Siddhānta* and the *Khaṇḍakhādyaka*, were translated into Arabic in the Caliphate at Baghdad under the titles *Sindhind* and *Arkand* respectively. The tradition of astronomy and mathematics continued in the years to come, preceding similar developments in Europe by a couple of centuries in such areas as determination of the precision of equinoxes, parallax, mean and true motions of planets, permutations and combinations, solving quadratic equations, square root of negative numbers and trigonometrical series brought out by Mādhava and others of the Kerala school of mathematics. The twelfth century witnessed the most notable astronomer-cum-mathematician, Bhāskarāchārya II. His cyclic (*cakravāla*) method for solving indeterminate equations of the second order has been hailed by the eminent German mathematician Hermann Henkel as the finest thing achieved in the theory of numbers before Lagrange.

The decimal place-value system, using nine digits and zero, had been developed in India by about the fourth century AD. It may be noted that the Indian *Brāhmī* numerical forms, along with the decimal place-value system, were also well known in the Arabic world. George Sarton, the renowned historian of science, has observed: *Our numbers and the use of zero were invented by the Hindus and transmitted by Arabs; hence the name Arabic numerals which we often give them*. In this transmission, al-Khwārīzmi (c.9th), a Central Asian mathematician who worked in Baghdad, played a seminal role through his work on arithmetic. Al-Kindi and Al-Bīrūnī (c.11th) were the other exponents not only of the Hindu numerical system, but of Indian astronomy as well.

In the eighteenth century Sawai Jai Singh II, a rare Maharaja imbued with scientific zeal, erected huge masonry observatories in Banaras, Mathura, Ujjain, Delhi, and in his capital city of Jaipur.He derived his inspiration from the Maragha school of observatory of Ulugh Beg at Samarqand. The observatories at Jaipur and Delhi, still in good condition, are a testimony to the importance Jai Singh attached to observational astronomy. He was ably assisted by his court-astronomer, Jagannātha Paṇḍita, and possibly by some Jesuit missionaries in his compilation of astronomical tables called Zize-Muhammad-Shāhi, which he dedicated to the Mughal emperor Muhammad Shah.

Surgical instruments described in Suśruta Saṃhitā an ancient Indian text on surgery.

Medicine

The science of the body and mind was, and continues to be as important as the science of the heavens. With its origin in the healing art of the Vedic times, Ayurveda emerged as the medical science par excellence by about the fifth century BC. It derived its theoretical sustenance from the philosophical systems namely the *Sāṃkhya* and the *Nyāya-Vaiśeṣika* that dealt with certain integrated concepts of man and nature, as also human nature itself. Its foundational matrices for systemized medicinal principles and practices was intimately connected with the five elements called the *pañcamāhabhūtas* -- earth or *pṛithvī*; water or *ap*; light or *tejas*, air or *vāyu* and *ākāśa*, or ubiquitous principle; and these formed an integral part of the two philosophical systems.

The forte of Ayurvedic thought structure is its integral methodological approach towards the physiological processes within the human body as well as the factors influencing them from outside. In this respect, the doctrine of five elements proved to be of immense value. On it was based the postulate of three humours (*tri-dhātu-tri-doṣa* concept) that encompassed not only the metabolic and other physiological processes in the body, but also the pathogenesis of diseases. According to Ayurveda, health is the equilibrium or harmony of the three humours, while their imbalance makes for the diseased state. Ayurveda emphasizes the body-mind concord and the need to examine the patient as a whole, advocating both curative as well as health promotive measures. Its diagnostic procedure is elaborate and its materia medica extensive, comprising largely herbal but also mineral and animal sources.

Behind its effective materia medica lies a rare expertise in intricate preparation of medicinal formulations of a composite character -- a careful selection of the right plants and other ingredients, processing them with equal care, prolonged heat treatment in certain cases, and above all, the right dosage and dietary regimen in consonance with an accurate diagnosis. Ayurveda describes five basic treatments called the *pañcakarma*, which aim at toning the bodily tissues for effective drug action or surgical operation, as also for conditioning the body for medical care. To the Ayurveda, the antidote is necessary but not sufficient, for its aim is to completely eliminate the vitiating roots of the disease.

The two great classics of Ayurveda, the Caraka (c.2nd AD) and *Suśruta Saṃhitās* (c.4th AD), present a vivid and cogent account of the medical knowledge and surgical practices respectively that were in vogue about 1800 years ago and continue to be used in Ayurveda today. Medical historian D.Guthrie records, *It was in surgery, above all, that the ancient Hindus excelled.* The *Suśruta Saṃhitās* which accords pride of place to surgery describes more than three hundred different operations and 121 surgical instruments (20 sharp and 101 accessory) such as tongs, forceps, scalpels, catheters, syringes, speculums , needles, saws, probes, scissors and the like. The outstanding feats of ancient Indian surgery related to laparatomy, lithotomy and plastic operations. The *Suśruta Saṃhitās* is regarded as the earliest document to give a detailed account of rhinoplasty (plastic reconstruction of the nose). It was not before the eighteenth century that plastic surgery

Bronze statue of a dancing girl excavated at Mohenjo-daro, c. 2500-1500 BC.

made its appearance in Europe. The Roman physician, Celsus (c. 1st AD), gave a vivid account in his medical treatise of lithotomy that was practised in India at that time. Later, another noted physician, Galen of Pergamum who lived in Rome, made no secret of his borrowing material relating to ointment for the eyes and the Indian plaster from Indian sources.

Transmission

Indian medical knowledge and surgical practices were known not only in the Arabic world but in South-East Asia, Tibet and China as well. The Abbasid Caliphate in Baghdad encouraged the translations of the works of Caraka, Suśrutā, Mādhava and Vāgbhaṭa in the 9th and 10th centuries AD. Al-Razi, the well known physician of that time, incorporated Ayurvedic practices into his comprehensive medical work *al-Hawi*, that later in the thirteenth century was translated into Latin by Moses of Farachi and became a standard medical compendium in Europe in the middle ages.

Said al-Andalusi, an Arab astronomer and historian of science of the 11th century AD, evaluated the scientific achievements of eight cultures up to his time, namely, Hindus, Greeks, Romans, Phoenicians, Egyptians, Chaldeans, Hebrews and Persians. He accorded first place to India and wrote appreciative terms about the scientific inventions of the Hindus as well as their philosophical wisdom. The reason was not far to seek. India had made notable advances in the fields of astronomy, mathematics and medicine. Further, Indian texts on astronomy, mathematics and medicine were well known to Arabic savants and, through their works, to learned persons of Latin in medieval Europe.

This transmission was not one sided. Medicine knows no barriers of region or religion. Around the 13th and 14th centuries, the Greco-Arabic system of medicine entered India with the Muslims and began to flourish, especially under the Mughal rule. Muslim rulers encouraged both the Unani (the name in India for the Greco-Arabic medicinal system) and Ayurveda. *Hakims* and *vaidyas* worked together in hospitals established by Muslim monarchs. While several Unani treatises written in India listed a considerable number of Ayurvedic practices, the two diagnostic methods of Unani, namely, the pulse and urine examination, were adopted by Ayurvedic practitioners and added to their diagnostic base of *tridoṣa* and other factors.

Techniques

As for technical skills, artisans and craftsmen played an important role in enriching the socio-cultural life of the people over the centuries, thanks to their expertise in metallurgy and metal working, dyes and pigments, casting exquisite copper-bronze icons, pyrotechnics, cosmetics and perfumery. Generally, artisans and craftsmen occupied a low position in the caste-ridden social hierarchy. Even so, some, like the metalsmith achieved recognition through excellence in their techniques. As early as in the fourth century BC, the metalsmith had perfected the complex process of extracting zinc from its ores by the downward distillation method that required exceptional care in the type of furnance, retorts and a reducing atmosphere as well as temperature management, as evidenced by the archaeological finds at Zawar in Rajasthan. It may be noted that it was only in the 18th century that the same process was adopted in Britain, and patented too.

In the Classical Age of India, the metallurgy of iron and copper assumed macro-dimensions. The famous Iron Pillar of the late 4th and early 5th centuries AD, which is seven metres high and weighs over six tonnes, now stands serene near Qutab Minar, Delhi, having amazingly withstood the ravages of time and clime, remaining rust-free for over 1,500 years. Essentially made of wrought iron (99.7 per cent iron) and forge-welded out of iron blocks of appropriate sizes, the Pillar has 0.144 per cent of phosphorus that aids anti-corrosion and contains no manganese and only negligible sulphur, the composites that would cause corrosion. This technique was not short-lived either. In the eleventh century, a much larger iron pillar was forge-welded and now lies free of rust in two or three pieces at

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Iron Pillar at Delhi which has remained rust-free for over 1,500 years.

Dhar in Central India. In the 13th century, several iron beams were fabricated for use in constructing the temples at Puri and Konark in Orissa. The Iron Pillar of Delhi, however, remains unparallelled. Even in 1881, British economic geologist V.Ball recorded: *It is not many years since the production of such a pillar would have been an impossibility in the largest foundries of the world, and even now there are comparatively few places where a similar mass of metal could be turned out.* In the field of copper metallurgy too, the huge fifth century copper statue of the Buddha, over two metres in height and one tonne in weight, (now in the museum in Birmingham) is a remarkable product of macro-technology.

An equally remarkable micro-technology, namely, the production of high quality steel now known as Wootz steel (an iron-carbon alloy with 1.3 to 1.6 per cent carbon was also in use). This production technique was particularly prevalent in South India and emerged as an accomplished metallurgical technique by about the 6th century, after which Indian steel was sought after for the production of what was termed the Damascus sword in West Asia, around the 10th century AD. Metallurgists in the Universities of Stanford and Iowa State (USA) have investigated Wootz steel with a view to reproducing the ancient Indian process. The former have even patented a process for the production of Utah-High-Carbon steel (1.3 to 1.6 per cent carbon) that could be used for certain automobile and aeroplane components.

A veritable index to India's scientific tradition is the appreciably large number of manuscripts, mostly in Sanskrit, that have been preserved in over a hundred repositories both in India and abroad. They encompass the disciplines of astronomy, mathematics, medicine, and also such techniques as metal-working including iconography, dyeing, cosmetics and perfumery. While the major texts have been studied, a considerable number of manuscripts remain unexplored. In any case, they have fostered scientific pursuits for over a millennium.

India Meets Western Science

With its long scientific tradition, India did not view western scientific ideas and technical practices as something alien to its own ethos. Instead, it gradually began to participate in the new movement when western science was introduced into India by the British in the latter half of the eighteenth and in the nineteenth centuries. Despite the oppressive colonial regime, in the early decades of the twentieth century Indian scientists came up with outstanding contributions even in the frontier areas of science of the time.

In the mid-seventeenth century the Governor of Dutch Possessions on the Malabar coast, Henrich Van Rheede Drakenstein (1637-1692), investigated a number of plants and seeds with the help of some European medical men as well as medical practitioners of Malabar. His work *Hortus Malabaricus* was published in 12 volumes (Amsterdam: 1683-1703; with 794 plates). This botanical work was of immense value to the then famous Swedish botanist Karl Linnaeus in the nomenclature of Indian plants in his *Species Plantarum*.

The turning point in the history of botanical investigations in India was the inception of the Royal Botanic Garden in 1787 at Sibpur near Calcutta. By then the British had established their political supremacy, having won the Battle of Plassey (1757). There were several distinguished botanists like William Roxburgh, Buchanan Hamilton, Nathaniel Wallich, William Carey, George Govan, J.F.Royle, C.B. Clarke and George King, whose botanical investigations in India added a veneer of excellence to global botany and their voluminous publications enriched botanical knowledge of the times.

To further their political ambitions that also required a thorough geographical knowledge of the new land, the British colonial masters undertook a topographical survey and soon developed what was known as the Great Trigonometrical Survey of India. In the first half of the nineteenth century, William Lambton in the south and George Everest along with Andrew Waugh in the north, emerged as the most notable surveyors. Waugh was able to determine the heights of major Himalayan peaks, which numbered about 80. He named the highest of these peaks (29,002 ft. above mean sea level) Mount Everest after the Surveyor-General of India. Among Indian technicians who worked with George Everest and Andrew Waugh, special mention needs to be made of Radhanath Sikdar and Mohsin Husain. The former was noted for his mathematical acumen and computing ,while the latter was a versatile maker of mathematical instruments who reconstructed a theodolite (now preserved in the Victoria Museum at Calcutta) that was used by Waugh and his associates.

The mineral wealth of India was indeed a source of special attraction for the British. In course of time, the Deccan, Central and North India, as well as the Himalayas, were explored for their mineral wealth and geological formations alike. Palaentological studies too were undertaken in the Siwalik Hills region by Hugh Falconer and the engineer Proby Cautley . Falconer brought to light the remarkable fossile fauna of the sub-Himalayan range, which earned him a distinguished position among palaentologists. The Geological Survey of India was established in 1851. Several geologists like Thomas Oldham, W.T. Blanford, H.B. Medlicott, William King and Thomas Holland made oustanding contributions to Himalayan geology, and to the discovery of large deposits of iron and other ores. Earthquakes were also studied. Towards the end of the nineteenth century there were two Indian officers in the Geological Survey of India, P.N. Bose and P.N. Dutta. The former mapped the Vindhyas and the igneous rocks of Raipur and Balaghat areas, while Dutta discovered the vast deposits of manganese ore in the Bhandara and the Chhindwara riverine area. Bose was also instrumental in discovering the extensive and rich deposits of iron ore in Mayurbhanj. Later, on his advice, the pioneering industrialist Jamshed Tata and his son Dorab Tata took active steps for the establishment of an iron and steel factory in the first Indian industrial enterprise -- in Jamshedpur - where TISCO is still located today.

Meteorological and astronomical studies also made some progress during this period. A notable development was the study of the law of storms, and the term 'cyclone' was coined by H. Piddington for the serpent-like coiling of a severe storm. The India Meteorological Department was established in 1875. H.T. Blanford, John Eliot and Gilbert Walker were among the noted meteorologists. A bright Indian assistant, Ruchi Ram Sahni, was associated with the preparation of daily weather reports. As for astronomical studies, as early as in 1792, an observatory was established in Madras on the initiative of William Petrie, a member of the Madras Government. John Goldingham, T.G. Taylor, H.Warren and others compiled a star catalogue of about 11,000 stars. N.R. Pogson made discoveries of asteroids and variable stars, with which C. Raghoonathachary was also associated. In 1900, the Solar Physics Observatory came up at Kodaikanal in Tamil Nadu. From the older observatory in Poona, called the Maharaja Takhatsingh Observatory, K.D. Naegamvala made significant observations of the solar phenomena, and especially of the eclipse that occurred in 1898. Evershed, who succeeded to the Directorship of the Kodaikanal Observatory in 1911, studied solar prominences and their penumbra, and discovered the radial motion in sunspots.

English Education

In 1813, when the Charter of the East India Company was renewed, a provision was made for not less than one hundred-thousand rupees each year to be spent by the Company on educating the natives. But the real turning point came when some liberal Indians like Raja Ram Mohun Roy advocated the introduction of scientific subjects. In 1935, the colonial government adopted English as the medium of instruction, and began to encourage the promotion of western learning, including science. The first three universities were established in 1857 at Calcutta (January), Bombay (July) and Madras (September). The new universities functioned only as affiliating and examining bodies in the faculties of law, science, medicine and surgery and civil engineering, besides the arts while their courses in scientific and technical education was determined by the exigencies and self-interest of the colonial government. Towards the turn of the nineteenth century, there were five universities, including the two established in Lahore (1882) and Allahabad (1887); about 170 colleges, mostly concentrated in cities, among which were some 40 professional colleges -- about 30 for law and four each for medicine and engineering; besides some medical, engineering, agricultural and industrial schools. However, the foundation laid for scientific and technical education left much to be desired.

The colonial government did promote field investigations to some extent and set up a few scientific institutions besides the scientific survey organizations. These were mainly intended to further British exploitative commercial interests and political hegemony. There emerged, nevertheless, a few isolated endeavours towards creative science, like the law of storms and cyclones by H. Piddington; the theory of isostasy by A. Pratt; the concept of Gondwanaland relating to continental dynamics; the discovery of the carrier of malarial parasite by Ronald Ross, and the Evershed Effect in solar physics. Unfortunately these endeavours did not generate critical discussion nor did they lay a solid foundation for the promotion of research, fundamental or applied. The colonial government's attempt at introducing western science in India was a formal one. But its real introduction was undertaken by Indian pioneering scientists and other leaders who provided critical inputs and inspiring leadership as well as an innovative climate, starting from the last quarter of the nineteenth century.

Scientists as Pioneers

In 1876 Mahendra Lal Sirkar (1833-1904), an enlightened medical practitioner, established the Indian Association for the Cultivation of Science at Calcutta, recognizing that the time had come when Indians themselves should cultivate science and imbibe its rationality. It was in this institution that over fifty years later, C. V. Raman (1888-1970) conducted his epoch-making research on light-scattering, now known as the Raman Effect (1928) that earned him the Nobel Prize in Physics (1930). In Bombay, a rare visionary and industrialist, J. N. Tata (1839-1904) in pursuit of his avowed objective of national regeneration, endeavoured to set up a university for imparting higher education to Indian students. The path was by no means easy. It eventually took the form of the Indian Institute of Science at Bangalore (1909-1911), which began to play a seminal role in the subsequent growth of science and technology in India.

Asutosh Mookerjee, a brilliant mathematician, became the architect of the Calcutta University in the early decades of the twentieth century, opening up various avenues of postgraduate teaching and research. It was he who persuaded scholars and scientists from diverse regions of the country to join the faculty or accept the chairs offered. Earlier, towards the closing years of the nineteenth century, Jagadis Chandra Bose (1858-1937), the first Indian Professor at the Presidency College in Calcutta, became a trendsetter in stretching the capabilities of Indian scientists. He devised his own instruments with ingenuity and succeded in the generation, transmission and reception of electromagnetic waves of wavelengths between 5 mm and 25 mm -- a pioneering contribution of that time. He demonstrated his experiment at the Royal Institution in London, but was disinclined to patent his discovery. J.C. Bose also demonstrated that not only animal tissues but also plant tissues, under different kinds of stimuli, would produce similar responses. He also set up an institute, the Bose Institute at Calcutta.

P.C. Ray (1861-1944), an outstanding chemist, built up a school of chemical research and initiated effective steps towards the establishment of certain chemicals, especially in the pharmaceutical industry. C.V. Raman, too, energized a flourishing school of research in physics, both at Calcutta and at Bangalore where he held the posts of Director (1933-37) of the Indian Institute of Science and Head of the Department of Physics till 1948. He established a research institution, the Raman Research Institute at Bangalore, with his Nobel Prize money and other resources.

Contemporaneous with Raman were other scientific leaders who laid a solid foundation for scientific research. The most notable among them were Srinivasa Ramanujan (1887-1920), K.R. Ramanathan (1893-1985), M.N. Saha (1893-1955), P.C.Mahalanobis (1893-1972), S.N.Bose (1894-1974), S.S.Bhatnagar (1894-1955) and K.S. Krishnan (1898-

The old building of the Asiatic Society which also housed INSA offices from 1935-1945.

1961). Ramanujan became a legendary figure in mathematics and his mathematical acumen is still a marvel. M.N. Saha earned international acclaim for his theory of thermal ionization and radiation, which explained the ordered sequence of the spectra of stars. His classmate, S.N. Bose, a brilliant theoretical physicist, developed a method of statistics of an assembly of photons in a six-dimensional phase, which was later extended by Einstein, now known as the Bose-Einstein Statistics. The discovery of particles that followed this are now called 'bosons' in honour of S. N. Bose. K. R. Ramanathan worked on the scattering of light and also made outstanding contributions to meteorology. P.C. Mahalanobis was renowned for his originality in theoretical statistics and later played a prime role in socio-economic planning. S.S. Bhatanagar made a distinct mark in magneto-chemistry, its principles and applications. K.S. Krishnan, who was intimately associated with the discovery of the Raman Effect, was noted for his significant work on the properties of crystals.

The University system had expanded, although not to the desired extent, from five at the beginning of the twentieth century to seventeen on the eve of Independence. Several research institutions, including those for agriculture, had also come up. During this period, the freedom movement that had gathered momentum was a source of inspiration to scientists to pursue original research, despite the regressive colonial ambiance. The freedom movement was led by Mahatma Gandhi and his chosen political heir, the charismatic Jawaharlal Nehru who, though not a laboratory scientist, had a broader vision of science, its rational methods, and applications for the benefit of people . In his book, *Discovery of India*, which he wrote during imprisonment, he exhorted: *Who can ignore science today? The future belongs to science and to those who make friendship with science*. India's friendship with science is in no small measure due to Nehru, since he was convinced that science and science alone could lead poverty-stricken India into prosperity. He emphasized the importance of the scientific method or temper as he called it, insisting that it should permeate all sections of society. He was instrumental in setting up a sub-committee on Technical Education and Development Research (1939) under his chairmanship of the National Planning Committee (1938) and this was in the thick of the freedom movement.

In the middle of 1939, Homi Bhabha, who had done outstanding research on cosmic rays in Copenhagen and Cambridge, was in India for a short recess at the Indian Institute of Science at Bangalore. World War II which broke out soon after prevented his return to England. Bhabha set up a Cosmic Research Unit at the Indian Institute of Science and the Tata Institute of Fundamental Research at Bombay in 1945. Three years before this, the Council of Scientific and Industrial Research had been set up with Bhatnagar as its Director. When Nehru took over as India's first

Prime Minister in 1947, Bhabha and Bhatnagar played pivotal roles in strengthening the country's scientific and technological base. Bhabha thought of 'Big Science' (then nuclear physics and energy) and Bhatnagar conceived of 'Science in a big way' through a chain of national laboratories. Both received unstinted support from Nehru. In perspective, it is evident that the Indian scientific pioneers, Nehru, and other leaders laid a viable scientific foundation well before Independence for the multi-level growth of science and technology in Independent India. It is , nevertheless, significant that traditional astronomy co-exists with modern astronomy; traditional medicine is in some manner complementary to modern medicine. Likewise, traditional technologies have carved a place for themselves among the plethora of new and sophisticated technologies.

In several ways, India's past is also its present.