From astronomy to medicine and from metallurgy to mathematics, ancient India’s contributions to the world of science are many. Throughout the ages, there came people from different racial, geographical and religious backgrounds all of whom made a direct impact on the socio-economic life and indirectly on the scientific aptitude and attitude.

Indian science and technology dates back to prehistoric human activity at Mehrgarh in present day Pakistan and continues through the Indus valley civilization. The Indus Valley civilization is a term used to refer to the cultures of the Indus and Ghaggar-Hakra rivers stretching from Neolithic Mehrgarh period down to the Iron Age or Indo-Gangetic tradition. The mature phase of this civilization was the Harappan civilization (3300-1300 BC), followed by the Vedic civilization (2000-600 BC).

**Mehrgarh Culture (7000-3300 BC)**

Mehrgarh is one of the most important Neolithic sites of the world and lies on the ‘kachi plain’ of today’s Balochistan located near the Bolan pass, to the west of Indus valley and between the present day Pakistani cities of Quetta, Kalat and Sibi.

Mehrgarh shows evidences of tools with local copper ore, containers made with bitumen, domestication of plants and animals and tanning. Bitumen is a mixture of organic liquids that are highly viscous, black, sticky, soluble in carbon disulfide and composed of highly condensed polycyclic aromatic hydrocarbons.

In April 2006, the journal *Nature* announced that the oldest evidence in human history for the drilling of tooth in vivo, that is, in a living person, was found in Mehrgarh around 7000 BC. It involved curing tooth-related disorders with drills operated by skilled bead craftsmen. These interesting findings provide evidence of a long tradition of a type of proto-dentistry in an early farming culture.

At Neolithic Mehrgarh, flint drill heads were found in stone assemblages associated with beads of bone, steatite, shell, calcite, turquoise, lapis lazuli and carnelian. Using models of these drill tips, methods for drilling based on the ethnographic literature were constructed and it was found that a bow drill tipped with a flinthead required less than a minute to produce similar holes in human enamel. Presumably, the know-how originally developed by skilled artisans for bead production was successfully transferred to...
drilling of teeth in a form of proto-dentistry. A modern reconstruction of this form of dentistry has shown that the methods used were reliable and effective.

**Harappan Civilization (3300-1300 BC)**

The size and prosperity of the Indus civilization grew as a result of innovations in irrigation and drainage systems, which eventually led to more planned settlements. This irrigation system also included artificial reservoirs at Girnar dating back to 3000 BC and an early canal irrigation system from 2600 BC onwards.

By 2800 BC private bathrooms, located on the ground floor, were found in many houses of the Indus civilization. Pottery pipes in walls allowed drainage of water and there was, in some cases, provision of a crib for sitting in toilets. ‘Western-style’ toilets were made from bricks and wooden toilet seats were used on top. The waste was transmitted via the extensive drainage systems in their settlements.

Large-scale sanitary sewer systems were in place by 2700 BC. The drains were 7-10 feet wide and 2 feet below ground level. The sewage was then led into cesspools, built at the intersection of two drains, which had stairs leading to them for periodic cleaning. Plumbing using earthenware plumbing pipes with broad flanges for easy joining with asphalt to stop leaks was in place.

The world’s first dock at Lothal in 2400 BC was built away from the main current to avoid silt deposition. Contemporary oceanographers believe that Harappans must have had knowledge relating to tides, hydrography and maritime engineering in order to build such a dock equipped to berth and service ships.

Using weights and measures, the inhabitants developed a system of standardization. This technical standardization enabled gauging devices to be effectively used in angular measurement and measurement for construction. In case of some devices, calibration was also found with multiple subdivisions.

Evidence of an early furnace, animal drawn plough and ovens has been discovered from excavations at Balakot (in present day Pakistan). Furnaces might have been used for the manufacture of ceramic objects. Malhar, Dadupur, Raja Nala ka Tila and Lahuradewa archeological sites present in Uttar Pradesh (U.P.) show implements from the period between 1800 BC-1200 BC.

In the development of swords as weapons of war, those found at Mohenjo-daro have a tang and rivet to hold the handle exactly as found in Palestine, where such implements were associated with the Hyksos (1800-1500 BC). Copper harpoons found in the Indus Valley were similar to those found in Europe and elsewhere in Asia.
Swords have been recovered in archeological findings throughout the Ganges-Jamuna Doab regions of India consisting of bronze but more commonly copper. Copper axes were also discovered at Harappan sites (Harappa, Shahi-tump and Chanhu-daro) but were similar to those found at North Persian sites (Hissar III, Shah Tepe, Turang Tepe) and Akkadian sites (Assur, Slate B cemetery).

Early iron objects found in India can be dated to 1400 BC by employing the method of carbon dating. By the early 13th century BC, iron smelting was practiced on a bigger scale in India. In case of southern India especially present day Mysore, iron was employed on a large scale as early as 11th to 12th centuries BC.

Vedic Civilization (2000-600 BC)
The Vedic civilization was based in the northern and northwestern parts of the Indian subcontinent. Scholars place the Vedic period in the second and first millennia BC continuing up to the 6th century BC.

The religious texts of Vedic period provide evidence of the use of large numbers as high as $10^{12}$ (1200-900 BC). Vedanga Jyotisa details several important aspects of time and seasons, including lunar months, solar months and their adjustment by lunar leap month of Adhimasa. Twenty-seven constellations, eclipses, seven planets and 12 signs of the zodiac were also known at that time.

In the 8th century BC, an Indian mathematician, Baudhayana composed the Sulba Sutra giving rules for the construction of altars which contained several important mathematical results. The famous Pythagorean theorem is believed to have been invented by Baudhayana first. He solved the problem of finding a circle whose area is the same as that of a square as well gave the formula for the square root of two.

Literature of the Vedic period in India offers early records of veterinary and human medicine. Leprosy is mentioned in the Sushruta Samhita (6th century BC), which also mentions cataract surgery performed with a special tool called the Jabamukhi Salaka where a curved needle was used to loosen the lens and push the cataract out of the field of vision. The eye would later be soaked with warm butter and then bandaged. Though this method was successful, Sushruta mentioned that it should only be used when necessary.

During the 5th century BC, the scholar Panini made several discoveries in the field of phonetics, phonology and morphology. Metal currency was minted in India before 5th century BC with coins being made of silver and copper, bearing animal and plant symbols on them.

Post Mahajanapadas (400 BC-400 AD)
This era was an interesting era of Indian history. Alexander invaded the northwestern part of the Indian subcontinent and the first United Kingdom was established under the rule of Chandragupta Maurya, a student of Chanakya. The Maurya Empire maintained diplomatic relations with the Greek world as Chandragupta married the daughter of Alexander's general, Seleucus. This era thus shows prominent impact of European science and culture on the Indian subcontinent.

The Arthashastra written by Chanakya in the 4th century BC mentions the construction of dams and bridges. The use of suspension bridges using plaited bamboo and iron chains was also seen in this period. Apart from trade and commerce, the book also discusses about agriculture, working of mines and factories, horticulture, irrigation, waterways, ships, navigation, fisheries and slaughterhouses.

The contacts between India and the western world, which Chandragupta Maurya had established, continued during the reign of his son Bindusara and grandson Ashoka.
Ashoka was a great builder. His famous many-pillared hall at Patliputra was dug out by archeologists and is still in a marvelous state of preservation. The wooden logs that were used to build it are as smooth and perfect as the day they were laid, more than two thousand years ago. This would be surprising anywhere, but in India it is more so, for the climate wears them away and insects eat them up. There must have been some kind of special treatment for the wood used in such constructions.

Institutions created specifically to care for the ill appeared in early India. King Ashoka is said to have founded at least 18 hospitals around 230 BC, with physicians and nursing staff, the expense being borne from the royal treasury. Ashoka erected two kinds of hospitals—for people and for animals. Where there were no healing herbs for people and animals, he ordered they should be bought and planted.

Though the evidence of the first rock-cut step wells in India dates back to 200-400 AD, the step wells constructed at Dhank (550-625 AD) and stepped ponds at Bhiramal (also known as Shrimal) are still preserved in proper shape. Step wells are wells in which water can be reached by descending a set of steps. It can be multistoried also, in which a bullock turns the water wheel to raise the water in the well to the first or second floor.

The city of Mohenjo-daro also had wells and they may have been the predecessors of these step wells, as around 700 wells were discovered in just one section of the city. Leading scholars believe that the people of the Indus valley civilization invented cylindrical brick-lined wells.

By the beginning of the Common Era, glass was being used for ornaments and casing. New techniques were added in this field because of the contact with the Greco-Roman world. The Satavahanas period further reveals short cylinders of composite glass, including those displaying a lemon-yellow matrix covered with green glass.

Before the beginning of the Common Era, Wootz steel originated in India. Wootz steel was widely exported and traded throughout ancient Europe and the Arab world, and became particularly famous in the Middle East, where it was known as Damascus steel. Archaeological evidence suggests that this manufacturing process was already in existence in South India even before the Christian era.

The bow instruments used in the second century in textile are also a gift to the world from India. These carding devices are called Kaman and Dhunaki and would loosen the texture of the fiber by means of the vibrating string.

Early use of diamonds as gemstones originated in India. Golconda served as an important center for diamonds in central India. Diamonds were exported to
Literature written at the beginning of the third century describes strength, regularity, brilliance, ability to scratch metals and good refractive properties as the desirable qualities of diamond.

The Iron pillar of Delhi constructed at the time of Chandragupta II Vikramaditya (375-413 AD) is still a marvel because of the metals used in its construction. The pillar is 98% pure wrought iron and is a testament to the high level of skills achieved by ancient Indian metallurgists in the extraction and processing of iron. It has attracted the attention of archeologists and metallurgists as it has withstood corrosion for over 1600 yrs in the open air.

The pillar’s resistance to corrosion is explained by a passive protective film at the iron-rust interface. The presence of second phase particles (slag and unreduced iron oxides) in the microstructure of the iron, that of high amounts of phosphorus in the metal and the alternate wetting and drying existing under atmospheric conditions are the three main factors in the three stage formation of that protective passive film.

India is one of the probable places of origin of the spinning wheel. The device may have reached Europe from India in the 14th century AD. The Charkhi in some parts of the region was also driven by waterpower. The Ajanta caves yield evidence of a single roller cotton gin in use by the 5th century AD.

This period was the golden age of Indian mathematics and astronomy where many Indian scholars contributed...
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The decimal number system also originated in India. Other cultures discovered a few features of this number system but the system, in its entirety, was compiled in India, where it attained coherence and completion. By the 9th century AD, this complete number system was in existence in India.

The concept of 0 as a number, and not merely a symbol for separation is attributed to India where practical calculations were carried out using zero, which was treated like any other number by the 9th century AD, even in case of division.

Bhaskara-II or Bhaskara Acharya was head of an astronomical observatory at Ujjain, the leading mathematical center of ancient India. Bhaskara-II mainly contributed to the field of mathematics, arithmetic, algebra, trigonometry, calculus, astronomy and engineering. Conceptual design for a perpetual motion machine by Bhaskara II dates to 1150 AD. He described a wheel that he claimed would run forever. He used a measuring device known as Yasti-yantra. This device could vary from a simple stick to V-shaped staffs designed specifically for determining angles with the help of a calibrated scale.

Rasarathna Samuccaya written during the 8th century AD gives elaborate description of various complex metallurgical processes. It explains the existence of two types of ores for Zinc metal, one of which is ideal for metal extraction while the other is used for medicinal purpose.

India also became a major center for production and processing of Indigotina tinctoria, a variety of indigo that was used and domesticated in India for use as a dye.

Evidence of microbial inoculation and variolation for smallpox is found in the 8th century, when Madhav wrote the
Nidāna, a 79-chapter book that lists diseases along with their causes, symptoms, and complications. He included a special chapter on smallpox (Masûrikā) and described the method of inoculation to protect against smallpox. Treatment was done by inoculation with year-old smallpox matter. The inoculators would travel all across India pricking the skin of the arm with a small metal instrument using “variolous matter” taken from pustules produced by the previous year’s inoculations. The British doctor J.Z. Holwell based on observations made during his residence in Bengal in an account to the College of Physicians in London in 1767 confirmed the effectiveness of this system.

Indian war rockets were formidable weapons before such rockets were used in Europe. They had bamboo rods, a rocket-body lashed to the rod, and iron points. They were directed at the target and fired by lighting the fuse, but the trajectory was rather erratic. The use of mines and counter-mines with explosive charges of gunpowder is mentioned for the times of Akbar and Jahângir.

Later, Hyder Ali, prince of Mysore, developed war rockets with an innovation. He used metal cylinders to contain the combustion powder. Although the hammered soft iron he used was crude, the bursting strength of the container of black powder was much higher than the earlier paper construction. Thus a greater internal pressure was possible, with a resultant greater thrust of the propulsive jet.

Hyder Ali’s son, Tipu Sultan, continued to develop and expand the use of rocket weapons, reportedly increasing the number of rocket troops from 1,200 to 5,000. In battles at Seringapatam in 1792 and 1799, these rockets were used with considerable effect against the British.

Fathullah Shirazi, a Persian-Indian polymath and mechanical engineer who worked for Akbar in the Mughal Empire, invented the auto-cannon, the earliest multi-shot gun in 1582. The scholar Sadiq Istahani of Jaunpur compiled an atlas of parts of the world. The 32-sheet atlas is part of a larger scholarly work compiled by Istahani during 1647 AD.

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Ali Kashmiri ibn Luqman (1589-90 AD) invented the Seamless celestial globe, which was later produced in the Mughal Empire. Before they were rediscovered in the 1980s, it was believed by modern metallurgists to be technically impossible to produce metal globes without any seams, even with modern technology. These Mughal metallurgists pioneered the method of lost-wax casting in order to produce these globes.