History of Indian Science

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Indian literature provides us with considerable layered evidence related to the development of science. The chronological time frame for this history is provided by the archaeological record which has been traced in an unbroken tradition to about 7000 BC. Prior to this we have records of rock paintings that are believed to be as old as 40000 BC. The earliest textual source is the Rig Veda which is a compilation of very early material. There are astronomical references in this and the other Vedic books which recall events in the third or the fourth millennium BC and earlier. The recent discovery that Sarasvati, the preeminent river of the Rig Vedic times, went dry around 1900 BC due to tectonic upheavels implies that the Rig Veda is to be dated prior to this epoch. According to traditional history, Rig Veda is prior to 3100 BC.

Indian writing goes back to the beginning of the third millennium BC. The later historical script called Brahmi evolved out of this writing. The invention of the symbol for zero appears to have been made around 50 BC to 50 AD.

Vedic science

Briefly, the Vedic texts present a tripartite and recursive world view. The universe is viewed as three regions of earth, space, and sky which in the human being are mirrored in the physical body, the breath (*prana*), and mind.

In the Vedic world view, the processes in the sky, on earth, and within the mind are taken to be connected. The Vedic seers were aware that all descriptions of the universe lead to logical paradox. The one category transcending all oppositions was termed *brahman*. Understanding the nature of consciousness was of paramount importance in this view but this did not

mean that other sciences were ignored. Vedic ritual was a symbolic retelling of this world view.

Knowledge was classified in two ways: the lower or dual; and the higher or unified. The seemingly irreconciliable worlds of the material and the conscious were taken as aspects of the same transcendental reality.

The idea of complementarity was at the basis of the systematization of Indian philosophic traditions as well, so that complementary approaches were paired together. We have the groups of: logic (*Nyaya*) and physics (*Vaisheshika*), cosmology (*Sankhya*) and psychology (*Yoga*), and language (*Mimamsa*) and reality (*Vedanta*). Although these philosophical schools were formalized in the post-Vedic age, we find the basis of these ideas in the Vedic texts.

The Sankhya and the Yoga systems take the mind as consisting of five components: *manas, ahankara, chitta, buddhi*, and *atman*. Manas is the lower mind which collects sense impressions. Ahankara is the sense of I-ness that associates some perceptions to a subjective and personal experience. Once sensory impressions have been related to I-ness by ahankara, their evaluation and resulting decisions are arrived at by buddhi, the intellect. Chitta is the memory bank of the mind. These memories constitute the foundation on which the rest of the mind operates. But chitta is not merely a passive instrument. The organization of the new impressions throws up instinctual or primitive urges which creates different emotional states. This mental complex surrounds the innermost aspect of consciousness, which is called *atman*, the *self*, or *brahman*.

Physics and chemistry

The Vaisheshika system considers nine classes of substances, some of which are nonatomic, some atomic, and others all-pervasive. The nonatomic ground is provided by the three substances ether, space, and time, which are unitary and indestructible; a further four, earth, water, fire, and air are atomic composed of indivisible, and indestructible atoms; self (*atman*), which is the eighth, is omnipresent and eternal; and, lastly, the ninth, is the mind (*manas*), which is also eternal but of atomic dimensions, that is, infinitely small.

The atoms combine to form different kinds of molecules which break up under the influence of heat. The molecules come to have different properties based on the influence of various potentials (*tanmatras*).

Heat and light rays are taken to consist of very small particles of high

velocity. Being particles, their velocity is finite.

The gravitational force was perceived as a wind. The other forces were likewise mediated by atoms of one kind or the other.

Indian chemistry developed many different alkalis, acids and metallic salts by processes of calcination and distillation, often motivated by the need to formulate medicines. Metallurgists developed efficient techniques of extraction of metals from ore.

Geometry and mathematics

Indian geometry began very early in the Vedic period in altar problems as in the one where the circular altar (earth) is to be made equal in area to a square altar (heavens). Two aspects of the "Pythagoras" theorem are described in the texts by Baudhayana and others. The geometric problems are often presented with their algebraic counterparts. The solution to the planetary problems also led to the development of algebraic methods.

Binary numbers

Binary numbers were known at the time of Pingala's *Chhandahshastra*. Pingala, who lived about the fifth century BC used binary numbers to classify Vedic meters. The knowledge of binary numbers indicates a deep understanding of arithmetic.

Astronomy

Using hitherto neglected texts, an astronomy of the third millennium BC has been discovered recently. Yajnavalkya (1800 BCE ?) knew of a 95-year cycle to harmonize the motions of the sun and the moon and he also knew that the sun's circuit was asymmetric.

Astronomical numbers played a central role in Vedic ritual. Part of the ritual was to devise geometrical schemes related to the lengths of the solar and the lunar years. The organization of the Vedic books was also according to an astronomical code. To give just one example, the total number of verses in all the Vedas is 20,358 which equals 261 x 78, a product of the sky and atmosphere numbers of the Vedic ritual!

The second millennium text *Vedanga Jyotisha* of Lagadha went beyond the earlier calendrical astronomy to develop a theory for the mean motions of the sun and the moon. This marked the beginnings of the application of mathematics to the motions of the heavenly bodies. An epicycle theory

was used to explain planetary motions. Later theories consider the motion of the planets with respect to the sun, which in turn is seen to go around the earth.

Cosmology

The doctrine of the three constituent qualities: *sattva, rajas*, and *tamas*, plays a very important role in the Sankhya physics and metaphysics. In its undeveloped state, cosmic matter has these qualities in equilibrium. As the world evolves, one or the other of these become preponderant in different objects or beings, giving specific character to each.

The recursive Vedic world-view requires that the universe itself go through cycles of creation and destruction. This view became a part of the astronomical framework and ultimately very long cycles of billions of years were assumed. Indian evolution takes the life forms to evolve into an increasingly complex system until the end of the cycle. The categories of Sankhya operate at the level of the individual as well. Life mirrors the entire creation cycle and cognition mirrors a life-history.

Cosmological speculations led to the belief in a universe that goes through cycles of creation and destruction with a period of 8.64 billion years. Related to this was the notion that light traveled with a speed of 186,000 miles per second. Since these numbers were not obtained throught experimentation, the accuracy of these figures must be seen as remarkable coincidence.

Grammar

Panini's grammar (5th century BC) provides 4,000 rules that describe the Sanskrit of his day completely. This grammar is acknowledged to be one of the greatest intellectual achievements of all time. The great variety of language mirrors, in many ways, the complexity of nature and, therefore, success in describing a language is as impressive as a complete theory of physics. It is remarkable that Panini set out to describe the entire grammar in terms of a finite number of rules. Scholars have shown that the grammar of Panini represents a universal grammatical and computing system. From this perspective it anticipates the logical framework of modern computers.

Medicine

Ayurveda, the Indian medicine system, is a holistic approach to health that builds upon the tripartite Vedic approach to the world. Health is maintained

through a balance between three basic humors (*dosha*) of wind (*vata*), fire (*pitta*), and water (*kapha*). Charaka and Sushruta are two famous early physicians.

Indian surgery was quite advanced. The caesarian section was known, bone-setting reached a high degree of skill, and plastic surgery was known.

The Medieval Period

Astronomical texts called siddhantas begin appearing sometime in the first millennium BC. According to tradition there were 18 early siddhantas of which only a few have survived. Each siddhanta is an astronomical system with its own constants. Some of the famous astronomer-mathematicians that arose in India's long medieval period are listed below.

Aryabhata In his book *Aryabhatiyam*, Aryabhata (born 476) sketched his mathematical, planetary, and cosmic theories. The parameters of *Aryabhatiyam* have, as their origin, the date of Friday, 18th February, 3102 BC. Aryabhata took the earth to spin on its axis; this idea appears to have been his innovation. Aryabhata was aware of the relativity of motion as is clear from this passage in his book,"Just as a man in a boat sees the trees on the bank move in the opposite direction, so an observer on the equator sees the stationary stars as moving precisely toward the west."

Brahmagupta Born in 598 in Rajasthan, Brahmagupta wrote his masterpiece, *Brahmasphuta Siddhanta*, in 628. His school, which was a rival to that of Aryabhata, has been very influential in western and northern India. Brahmagupta's work was translated into Arabic in the eighth century at Baghdad and it became famous in the Arabic world as *Sindhind* and it influenced Islamic astronomy.

One of Brahmagupta's chief contributions is the solution of a certain second order indeterminate equation which is of great significance in number theory.

Bhaskara Belonging to the Karnataka region, Bhaskara (born 1114), was an outstanding mathematician and astronomer. Amongst his mathematical contributions is the concept of differentials. He was the author of Siddhanta Shiromani, a book in four parts: (i) Lilavati on arithmetic, (ii) Bijaganita

on algebra, (iii) Ganitadhyaya, (iv) Goladhyaya on astronomy. He epicyclic-eccentric theories of planetary motions are more developed than in the earlier siddhantas.

Madhava Subsequent to Bhaskara we see a flourishing tradition of mathematics and astronomy in Kerala which saw itself as a successor to the school of Aryabhata. Of these, Madhava (c. 1340-1425) developed a procedure to determine the positions of the moon every 36 minutes. He also provided methods to estimate the motions of the planets. He gave power series expansions for trigonometric functions, and for pi correct to eleven decimal places.

Nilakantha Somayaji A very prolific scholar who wrote several works on astronomy, Nilakantha (c. 1444-1545) found the correct formulation for the equation of the center of the planets and his model must be considered a true heliocentric model of the solar system. He also improved upon the power series techniques of Madhava. The methods developed by the Kerala mathematicians were far ahead of the European mathematics of the day.

Another noteworthy contribution was by the school of New Logic (*Navya Nyaya*) of Bengal and Bihar. At its zenith during the time of Raghunatha (1475-1550), this school developed a methodology for a precise semantic analysis of language. Its formulations are equivalent to mathematical logic.

The Modern period

Entering its modern era with the arrival of the English, India in the last two centuries has witnessed a renaissance of its science and a proper appreciation of the past achievements.

Some of the most important scientists born in the 19th century who made international mark are Jagadish Bose (1858- 1937) in electromagnetics and plant life, Srinivas Ramanujan (1887- 1920) in mathematics, Chandrasekhar Venkata Raman (1888- 1970) in physics, Meghnad Saha (1893-1956) in astrophysics, and Satyendra Bose (1894- 1974) in quantum theory. More recent contributions of Indian science are part of the story of the contemporary world science.