Science Horizon

ODISHA BIGYAN ACADEMY

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Special Issue :

'THE CONTRIBUTION OF ANCIENT INDIA TO THE FIELD OF SCIENCE & TECHNOLOGY'

GUIDELINES FOR CONTRIBUTING ARTICLES FOR THE MAGAZINE

1. "SCIENCE HORIZON" aims at developing the scientific outlook of students as well as the general people and seeks to give them information on scientific developments. It is published as a monthly magazine.
2. The authors desirous of writing and contributing articles to the magazine should first assimilate the ideas of the theme and present it in simple language and popular style.
3. The authors are requested to write clearly on one side of A/4 size paper. The relevant pictures in 4cm X 6 cm size are welcome. Photo copies of manuscripts are not accepted for consideration.
4. Each article will be ordinarily of two to three printed pages in A/4 size papers.
5. The article shall be profusely illustrated with pictures.
6. At the end of the article the author should give the references and suggestions for further reading.
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8. Matter translated from other languages and illustrations should indicate the original sources otherwise those would not be accepted. The articles which are not published, can not be returned to the authors.
9. As far as practicable the articles should be based on contemporary science and must be easily comprehensible to students at the secondary level.
10. The writers should present difficult concepts of science through stories of everyday life, heart-rendering songs, pictures, satirical cartoons or attractive dramas.
11. All units in the articles should be given in the metric system.
12. The title of the article should be brief and attractive. Moreover, subtitles may be given in long articles. The writings should be coherent and cohesive.
13. There should not be repetition of specific words. While ensuring the contemporary spirit of the writing, it should reflect some valuable lesson for the society. It is also necessary to avoid mistakes in spelling, language use and factual details.
14. The Editor & the Editorial Board of "Science Horizon", Secretary of the Academy or Odisha Bigyan Academy shall not be responsible for the views of the authors.

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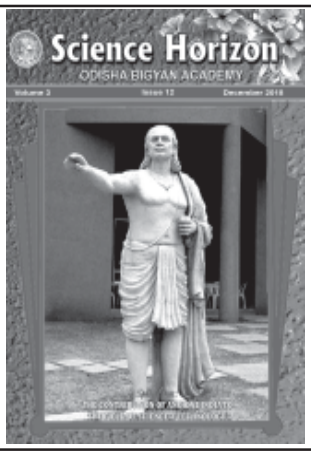

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The Cover Page depicts : **Statue of Aryabhata on the grounds of IUCAA, Pune** *Cover Design :* ***Kalakar Sahoo***

EDITORIAL

IMPACT OF ANCIENT INDIAN SCIENCE AND CULTURE IN THE MODERN PERIOD

India's history and culture are based on a rich tradition of spiritual as well as rationalistic scientific thoughts and innovations of global significance to an extent which no contemporary people from elsewhere have surpassed in their ingenuity and grandeur. The extraordinary intellectual and highly influential contributions of the ancient Indians to the fields such as Mathematics, Astronomy, Architecture, Civil Engineering, Metallurgy and Mineralogy; Physics, Chemistry and Medical Science as well; have created and strengthened the fundamentals of modern science and technology. According to Frederich Von Schlegel, a great German Philosopher:- *"India is not only at the origin of everything; intellectually, religiously or politically and even the Greek heritage seems pale in comparison."* Voltaire, a French historian and philosopher considered - *"the origin of human kind in the East on the banks of the Ganges, as opposed to the account found in Genesis. ...As India supplies the wants of all the world but is herself dependent for nothing; she must for that reason have been the most early civilized of any country. ..... If the question was to decide between India and Egypt, I should conclude that the sciences were much more ancient in the former."* Voltaire's views of Indian Science as more ancient than Egyptian Science has been proved right by the evidences from the recent excavations (1974-2000) in Mehergarh on Kachi Plane of Baluchistan to the west of Indus River; which unfolds the Neolithic Culture (7000-3200 BC) as a precursor to the Indus Valley civilisation almost 3500 years before.

Our rich heritage had been marginalized in our education system ever since the colonial period and also in the media portrayals of India and its culture. This is because the colonial Indologists focused on our nation as a backward region in need of being civilised by the superior western colonialists and hence science and the progressive intellectual activities were depicted as the exclusive domain of the Europeans only. As a result, the glorious civilisation was wounded to such an extent that, although India was shoring high as the *'golden sparrow'* of the globe ushering in a scientific as well as spiritual culture to keep it in the forefront of the knowledge hub for centuries, when the whole western world was in darkness long before the age of renaissance; it was reduced to an *'Area of darkness'* according to the nobel-laureate *V.S. Naipaul* with a populace of shrunken psyche and unthinking mindset bearing the colonial legacy. However, it has now been widely accepted that Modern Science and Medicine would have been unrecognisable and far more primitive without the immense contribution of ancient Indian intellectuals like *Kanada, Pingala, Varahmihira, Aryabhatta, Bhaskar-I, Brahmagupta, Bhaskar-II, Charaka* and *Sushruta* etc. of the Vedic and the post Vedic era. They invented our everyday essentials such as the base-ten number system with Zero as numeral so as to be able to introduce very small-smaller than the smallest (*Anorayian*) as well as the very large– larger than the largest (*Mahoto-Maheeyan*) numbers needed to describe Nature with all its aspects starting with particles like atoms to celestial bodies and the universe at large. They could conceptualize the implication and the significance of the most abstract entity in Mathematics such as Zero and Infinity, which was very unique to the Indian culture. Without the aid of any distant vision equipment like telescopes; they could acquire astounding knowledge of various constellations, planetary motions, spherical shape of Earth with the duration of its rotational and orbital motion in a heliocentric system. They also developed metallurgical methods of extraction and purification of metals. The ancient Indians in the Vedic period developed a sophisticated system of medicine and

surgery with its mind-body approach known as 'Ayurveda' with detail anatomical and surgical knowledge of human body including cataract surgery and the so-called plastic surgery.

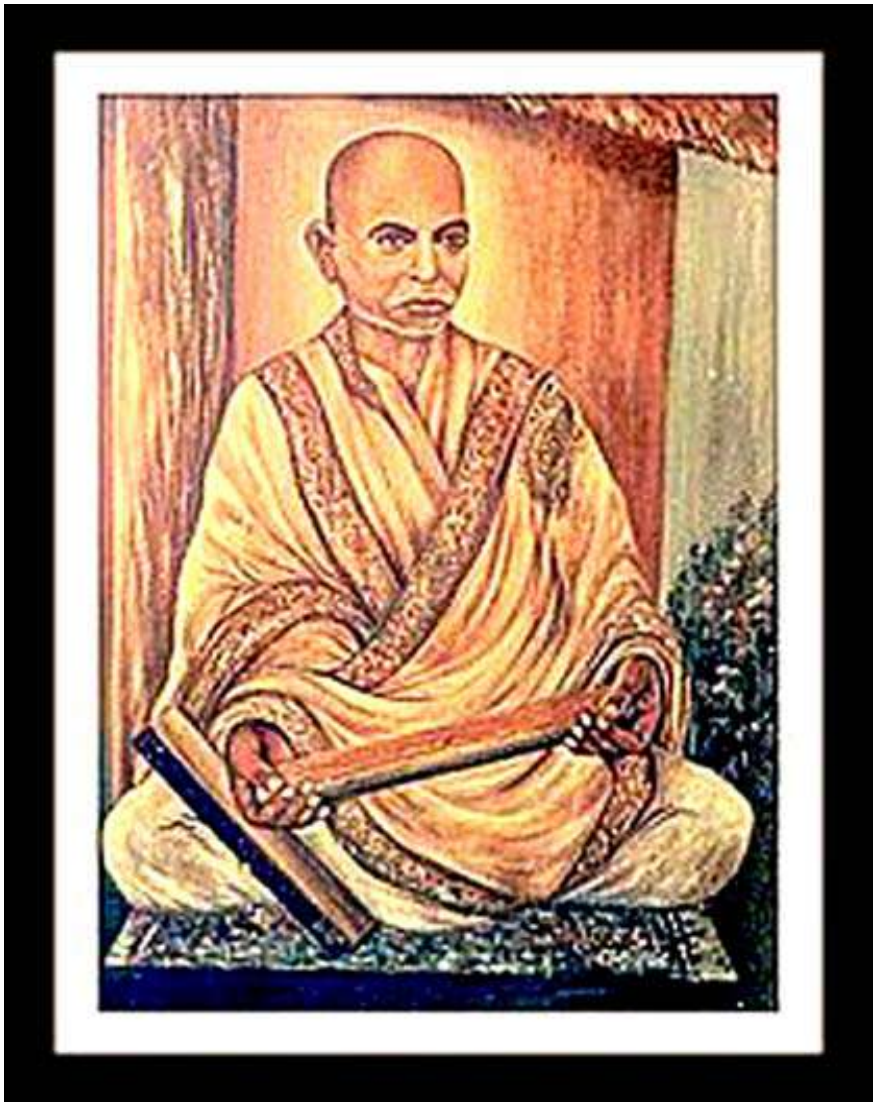
Ancient Indian culture as a unique one can be attributed to its most fundamental Vedic concept of *'Vasudhaiba kutumbakam'* meaning the whole world is like one family because it was realised that everything living and non living are connected via an all encompassing network of relations emanating from that one source - the '*Brahman*' an abstract concept of infinite potentialities, since He the God said – *"Eko-ham bahu syami"* meaning – 'I am the one; let me become many'. This taught the tolerance towards freedom of expression to exchange ideas, opinions and knowledge regarding all aspects of nature like space, time, matter and energy including even the material body with immaterial mind and soul etc. Therefore there was no conflict and separation between rational thinking of *'Science and technology'* and spiritual pursuits for the sacred and the sublime. The core disciplines of science such as physics, mathematics, astronomy and medicine were all considered sacred. Kanada, a proponent of the atomic concept in his *'Vaisheshika Sutra'* said that a person can achieve salvation by studying physics. Similar was the belief of Aryabhatta about a millennium after, for the study of Astronomy expressed in his '*Aryabhattiyam*'. All the other sciences mentioned earlier were also considered sacred and divine. In Agni Purana, god of fire said – *"Now I shall describe the system of veins and arteries (Nadi-chakra) that are to be found in the human body, a knowledge of which leads to the knowledge of the divine."* According to *'Chhandogya Upanishad'* and *'Manduka Upanishad'* of the Vedic tradition, secular knowledge (*Apara-Vidya*) together with the spiritual knowledge (*Para-Vidya*) was considered to be helpful in achieving salvation. Therefore, the spiritual basis of the ancient Indian culture had never been a hindrance to the progress in science and technology. This is the reason for which the sages and seers, the scholars and the intellectuals of ancient India could contemplate deeply and holistically to arrive at several abstract concepts such as *'Sunya and Ananta'* meaning Zero and Infinity while searching for the '*Parama*' – the ultimate source of everything. They could envisage the existents' kinship in the non-existent (*Suny-Brahma*) along with the subtle reality – the cosmic consciousness. This concept has inspired the quantum physicists like *Erwin Schrodinger, J.R. Oppenheimer, Werner Heisenberg, David Bohm* and *Brian Josephson* etc. of the modern era to shape the new science of 20th Century. The science fraternity of the present world, to a large extent, have realised by now to shed the traditional western '*materialistic paradigm*' with a reductionist approach in science and to adopt a new *'post-materialistic paradigm'* in a holistic view in order to unfold the darkest secrets of nature in the 21st Century and beyond.

Thus India had a past certainly to boast of with a pride of place going to its ingenious culture. The most important and indestructible wealth being considered as knowledge, an individual with a quest to acquire it was believed to be truly on the path of enlightenment and liberation. Such was the social ethos of ancient India providing a fertile ground for intellectual achievements par-excellence. India's younger generations of scientists, technocrats and innovators must be groomed in the same spirit to lead India for restoring its pride of place. Therefore, it is important for everyone to know our rich and glorious past to imbibe the same vision as that of our ancient sages and scientists who could achieve great heights with the available resources of their time. They were the people of great vision, value, wisdom, purity of mind and compassion. Their contributions to science cannot be wished away anymore by saying that – those scientific-foreknowledge or mere speculative ideas acquired through intuition or any mystic means may be mere coincidences only. A proper perspective for our younger generation is the need of the hour.

■

Dr. Niranjan Barik

OUR TRIBUTE TO SAMANTA CHANDRASEKHARA, THE LEGENDARY ANCIENT ASTRONOMER OF ODISHA ON HIS 183rd BIRTH ANNIVERSARY ON 13th DECEMBER



BORN ON 13TH DECEMBER 1835 - HEAVENLY ABODE ON 11TH JUNE 1904

PATHANI SAMANTA : THE TYCHO BRAHE OF EAST

Samanta Chandrasekhara, popularly known in Odisha as Pathani Samanta was the last siddhantic astronomer of India. He was born on 13th December, 1835 in the royal family of the erstwhile princely state of Khandapara in Odisha. Since the age of ten , he started observing stars in the sky and began reading *Lilavati, Bijaganita, Jyotisha, Vyakarana* and the ancient astronomical treatises like *Surya Siddhanta* and *Siddhanta Siromani* from the family library. At the age of fifteen, he checked the predictions of the Siddhantas with his own observations and found some anomaly. Then he prepared some instruments like *mana -yantra, chakra yantra, chapa yanta, gola yantra* etc. He also observed the movement of planets, sun, moon etc. and wrote his masterpiece Siddhanta Darpan in 1869 when he was thirty four years old. It is written in Sanskrit in verse form. It is composed of 24 chapters having 2500 slokas out of which 216 slokas he had taken from ancient books and the rest are his own.

Jogesh Chandra Ray, Professor of Physical Science in Ravenshaw College, Cuttack came in contact with Samanta and could know about his talent and his book. With his help, *Siddhanta Darpan* was published in Calcutta (now Kolkata) in 1899. Prof. Ray wrote a long preface in the book. The cost of printing of the book was Rs.1250/- at that time and it was met by the generous contributions of the king of Athamullick and Mayurbhanj. After that, Samanta's fame spread throughout the country and abroad. The British Government conferred on him the title of Mahamahopadhyaya. He breathed his last at Puri on 11th June, 1904.

In his treatise, Samanta Chandrasekhara has written that 'Earth is the centre of the universe and Sun and moon rotate around it while other planets rotate around the Sun'. Same view had been given by the Danish astronomer Tycho Brahe (1546-1601) in sixteenth century, although Samanta was unaware of this. Hence, Samanta is called theTycho Brahe of East.

The famous science journals *Nature* had reviewed *Siddhanta Darpan* in its issue Vol.59, 9 March, 1899, No.1532 and another journal *Knowledge* had reviewed it in its issue Vol.XXII, January-December, 1899, P.257-258. The two reviews are reprinted here.

■

Compiled by Editor

Reprinted from "KNOWLEDGE" Vol. XXII, January-December, 1899, P.257-258

SIDDHANTA DARPANA : A Treatise on Astronomy

Mahamahopadhyaya Samanta Sri Chandrasekhara Simha

Edited with an introduction by Jogesh Chandra Ray, M.A.,

Professor of Physical Science, Cuttack College (Calcutta, 1897).

Of all the numerous works on astronomy that have been published within the last few years, this is by far the most extraordinary and in some respects the most instructive. It is written in Sanskrit by a Hindu of good family of Khandapara in Orissa and it is a complete system of astronomy founded upon naked eye observations only, and these made for the most part with instruments devised and constructed by the writer himself. Those who read the sixty pages of the introduction in English, which the fellow countryman of the author, Prof. Chandra Ray, of Cuttack College, has written, will certainly regret that the barrier of an unknown tongue debars them from a more intimate acquaintance with the very striking personality that Prof. Ray described. The work to which Chandrasekhara has devoted himself, and which he has carried out with very conspicuous success is this: The native Hindu almanacs agreed in their computations. Chandrasekhara, therefore, has re-determined the elements of the old *Siddhanta*, but has rigorously continued himself to the ancient methods, his principal instrument of observation being a tangent-staff, devised by himself, of a thin rod of wood twenty-four digits long, with a cross-piece at right angles to it. With these, crude means he has obtained an astonishing degree of accuracy; his values for the inclinations of the orbits of the nearest planets are correct to the nearest minute in almost every instance. The ephemerides computed from his elements are seldom more than a few minutes of arc in error, whilst the Bengali almanac may be in error as much as four degrees. To Hindus, for whom their religious observances are regulated by astronomical configurations, this work by none of themselves, a strict follower of the severest laws of their religion, and conducted throughout solely by traditional Hindu methods, is of the highest importance, as it removes the confusions which had crept into their system, without in the least drawing upon the sources of western science. But the work is of importance and interest to us westerns also. It demonstrates the degree of accuracy which was possible in astronomical observation before the invention of the telescope, and it enables us to watch, as it were, one of the astronomers of hoary, forgotten antiquity actually at his work before us to-day.

Reprinted from "THE NATURE" Vol. 59, 9 March, 1899, NO.1532, P.430-431

A Modern Tycho

SIDDHANTA DARPANA : A Treatise on Astronomy
Mahamahopadhyaya Samanta Sri Chandrasekhara Simha
Edited with an introduction by Jogesh Chandra Ray, M.A.,
Professor of Physical Science, Cuttack College (Calcutta, 1897).

Any one who reads the very interesting introduction of sixty one pages that Prof. Ray has attached to this Sanskrit work will regret very much his inability to faith on the work that follows. For therein is contained the results of the patient and industrious inquiry of one who, unaided by the accumulated knowledge of Western astronomers, resolutely set himself to solve the problem of celestial mechanics by the aid of such instruments as he could fashion himself, and where the time honoured clepsydra supplied the place of the sidereal clock. The only assistance he seems to have had were the similar rough observations Bhaskara (born 1110) and some still older observers. ***Prof. Ray compares the author very properly to Tycho. But we should imagine him to be greater than Tycho***, for without the same assistance, without the encouragement of kings and the applause of his fellows, he has advanced his favourite science quite as effectually as did the Danish astronomer. It is especially curious to notice that the system at which Chandrasekhara ultimately arrived, and the explanation he offers of it, bears a very considerable resemblance to that which Tycho taught. The author has never been able to convince himself that the Earth turns on its axis, or that it goes round the Sun but to the planets he assigned heliocentric motion, much as Tycho did.

We get some notion of the success that attended the work, and of how much it is in one man's power to accomplish, if we examine the differences between the values he assigns to some of the constants of astronomy and those in use with ourselves. The error in the sidereal period of the Sun is 206 seconds; of the Moon, 1 second: Mercury, 79 seconds: Venus, about 2 minutes: Mars, 9 minutes: Jupiter, an hour: and Saturn, rather more than half a day. The accuracy with which he determined the inclination of the planets to the ecliptic is still more remarkable. Mercury offers the largest error, and that is only about two minutes. In the case of the Solar orbit the greatest equation to the centre is only 14 seconds in error. In the Lunar theory, the revolution of the node has been concluded with an error of about 5.5 days, less than the thousandth part of the whole period: while he has independently detected and assigned very approximate value to the evection, the variation, and the annual equation.

The main object that Chandrasekhara had before him, seems to have been to correct the calendar, and regulate the daily ritual of the Hindu religion. No two almanacs, Prof. Ray tells us, agree; but any attempt to introduce the Nautical Almanac and its acknowledged accuracy would prove unsuccessful. The necessary corrections and unification must, to be acceptable, come from within and be

the work of a Hindu, uninfluenced by foreign education.

The work of Chandrasekhara has received the sanction of the honoured Rishis, and the adoption of the corrections which he has shown to be necessary will exert upon native society a beneficial influence, whose importance can be hardly overrated in a community where a correct almanac is an indispensable equipment of every household. We should like much to linger over Prof. Ray's remarks on the subject of precession and his chronological deductions. These and many other points are discussed with great ability, though Prof. Ray modestly disclaims any special astronomical capacity. The effect is to leave us at every page with a higher opinion of the author laboriously recording his observations on a palm-leaf, and unselfishly devoting his life to the services of his countrymen, who do not appreciate the nobility of the effort and the entirety of his devotion. We are in full sympathy with the editor when we writes thus of the author, of his privations and his star-gazing.

"What has he done after all?" - asks the impatient critic. To him I would say - Is it not enough to find in this man a true lover of science, who, regardless of other people's unfavourable opinion of his work, their taunts and dissuasions, has devoted his whole life to the one pursuit of knowledge; who has shown the way to original research amidst difficulties serious enough to dishearten men in better circumstances: who has employed his time usefully, instead of frittering it away like the usual run of men of his rank on a work which guides the daily routine of millions of his countrymen. **W.R.P.**

SATANANDA : A FORGOTTEN PREMIER ASTRONOMER FROM ODISHA

Mr. Himansu Sekhar Fatesingh[1]
Dr. Ramesh Chandra Parida[2]

The dazzling stars that brightened the sky of astronomical science in ancient India and could spread their light beyond its boundaries were the immortal astronomers, like Apastamba, Aryabhatta-I, Arabhatta-II, Varahamihir, Brahmagupta and Bhaskaracharya-II. The list would remain incomplete without the name of Satananda, the premier astronomer of Odisha , then known as Utkal. Being shy and introvert he was not so widely known as many others belonging to his tribe, in fact, he was, in the words of Wordsworth " a violet by mossy stone, half hidden from the eye" as his contributions to the field was in no way less important. This apart, he was also a mathematician of repute, as both these sciences co-existed in those days.

Satananda or better known as Satanandacharya was born in 1068 AD in Puri, then considered as the seat of intellectual capital of the Eastern India and now famous for the Jagannath Temple. His father Shankar was also an astronomer and mother Saraswati was a home-maker. Influenced by his father from very childhood, Satananda was greatly fascinated by astronomy, which was considered as one of the most advanced branches of science in those days. He was taking great

interest in regularly observing the sky to study the movements and positions of the stars and planets. Therefore, only at the young age of 31, he could write his famous book on astronomy "*Bhaswati*" or " *Bhaswati Karana*". Besides, he had also written some more books on the subject of which " *Satananda Sangraha*" and "*Satananda Ratnamala*" were well known. At that time, the boundary between astronomy and astrology was invisible; in fact, the latter was constituting a significant part of the former. Therefore, in all these books, written in Sanskrit, one can find the confluence of these two along with mathematics.

The "*Bhaswati*", Satananda's master piece was written in 1099 AD and his research work was greatly influenced by the "*Surya Siddhanta*". He had made necessary corrections and alterations in it to bring coordination and to avoid contradictions between the views of Varahamihir and his findings. In this book, Satananda had discussed in detail the positions and movements of the stars and planets, the timings of their rising and setting and many other important aspects. He had used the decimal system of calculations in it and correctly determined the timings of solar and lunar eclipses, including their various phases. Generally, the astronomical books in Sanskrit are categorized as Siddhant, Tantra and Karan. The Siddhants are descriptive and voluminous, whereas, Tantra and Karans are symbolic and brief. Satananda's " *Bhaswati* " belongs to the Karana category. It contains only 128 verses or Shlokas against 2500 in the famous "*Siddhanta Darpan*" of Samanta Chandra Sekhar, more popularly known as Pathani Samanta of Odisha. Still it is an invaluable treatise on astronomy and mathematics. On each of its 8 chapters, different aspects of these sciences have been briefly discussed.

The " *Bhashwati*" was widely used in preparing almanacs in ancient Odisha (or Utkal) and many parts of the eastern and northern India. Before Pathani Samanta's immortal creation the "*Siddhanta Darpan*" it was serving as the guide to determine the timings of all the everyday religious works at Lord Jagannath's temple in Puri.

A number of versions of the "*Bhashwati*" were published in Sanskrit and Hindi from time to time. In 1832, Pandit Sadashiv Pandya of Banaras (Varanasi) had prepared a hand written note of it, which was widely circulated in northern India to determine timings of movement and positions of the stars and planets. Its first printed edition was published by the Akhabar Press in 1923 and the second and the third editions by the Vinayak Press and the Bharat Jeevan Press in 1942 and 1949 respectively. All these presses were inVaranasi.

Pandit Matruprasad Pandya wrote a new version of the " *Bhashwati*" following Pandit Sadashiv and thereafter, Acharya Ramachandra Mishra of the Banaras Hindu University prepared a complete new edition of it, which was published by the *Chaukhamba Sanskrut Sansthan*, Varanasi in 1968. Its second and the largest edition was brought out in 1985 by

the same press. The "*Bhashwati*" was widely circulated not only in many parts of India, but also in Nepal. The famous Nepalese Royal astronomer Laxmi Pati Pande (1758-1813 AD) had written notes on the "*Bhashwati*" and the Nepali meanings of its verses or Shlokas. In 2006, a research paper with the title " A History of Mathematical Sciences in Nepal" (Jha A., Adhikary P.R. and Pant S.R.: Journal of Science, Engineering and Technology, 2(1), 2006) was published by the researchers of the Tribhuban University, Nepal, in which they had mentioned that long ago, when no mathematics books were written in their country, the students were going to Varanasi to learn the subject. There they were learning Bhaskarachary's "*Siddhant Shiromoni*", *Leelabati* and algebra along with Satananda's " *Bhashwati*", which was later translated in to Nepalese language in 1400 AD. Then, in 1494 AD, the famous teacher Daibgnya Bhabhadra from Jumla (Nepal) had made the *Balabodhini Tika* of the "*Bhashwati*" book , which helped in teaching addition, subtraction, multiplication and division and the related mathematatics. It was the first text book to be published in that language and was included in the mathematics syllabus of many educational institutions. At that time, it was very popular in Nepal among the students as well as teachers of mathematics and astronomy.

Although, Satananda's " *Bhashwati*" was widely acclaimed as a classic in many parts of India and Nepal, it was not so well known in Odisha, its state of origin. It might be due to the fact that the text was written in Sanskrit, which was inaccessible to common people and no attempt was made to translate it in to the local language. As a consequence, now it has been almost forgotten here. However, only a hand written palm leaf script of it is preserved by the state museum and a copy of its Hindi version is available in the library of Sanskrit University, Puri. Therefore, it should be immediately translated and published in Odia and also in other languages, so that the rare scientific heritage is not lost forever and it can reach the common people.

■

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"The medieval alchemists said there were four states of matter. Earth, Water, Air, and Fire. On the other hand, we know that there really are four states of matter: Solid, Liquid, Gas, and Plasma. Thank Gof for progress."

Kelvin Throop III

"The simplest schoolboy is now familiar with truths for which Archimedes would have sacrificed his life."

Ernest Renan

A BRIEF PERSPECTIVE ON SCIENCE & TECHNOLOGY IN ANCIENT INDIAN CULTURE

Sashibhusan Rath

Prelude:

Fundamentally science is a process which accepts the new and rejects the old at the same time. However, interestingly all new is not accepted, nor all old is rejected. Science does not proceed in a neat, linear fashion with discoveries and/or inventions following one another and slotting into place. For any developing society often a suitable procedure is crafted to sift grain from chaff, so that there is clarity for the posterity about the authentic historical log of a culture, structures, inventions, discoveries made by it over centuries with empirical evidences, if any in support of different claims.

A Profile of the Bygone Era:

Understanding of S&T in our culture is important. If we do not realize that the Indian culture was rich in S&T, the pride that is required for developing a nation, that is commited for the purposes of establishing peace in the world and making man's life happy, would be missing. The pride is necessary. That confidence is necessary. The element of pride is one of the most important one required for the developing that confidence. That we can do it, we did it, we are doing it, we will be able to do it, that kind of confidence is required. For this the correct understanding of Science and Technology during the aforesaid periods is important. More so the status of Science and Technology at that time.

The pride and confidence is necessary, but it should not obstruct in any way of our acceptance of what is good outside the country. What is available here is for the humankind and vice versa. There should not be any psychological barrier either way to accept whatever is good. World is in reality one, humankind is one. There is no fragmentation, no division.

Way back in 1946 renowned Indian physicist Meghnad Saha wrote in Caravan (74,6) that the pursuit of science in India is as old as her civilisation. The discoveries at Mohaenjo-daro and Harappa points to the existence of a highly organised life on the valley of the Indus as early as 3000 BC, which would not have been possible but for the cultivation of the science.

Joseph Needham and his team for the first time changed the perspective of S&T by focussing on the degree of contribution of non-European to the international Science and Technology. Euro-centric projection has been no longer valid and even European historians of Science and Technology were no longer accepted in totality.

Science and Technology (S&T) were not born in European culture alone. Their rapid growth in Europe is only a part of the story. Indian civilization and culture, like any other, had scientific ethos and technical base. This has not been fully understood. Besides some

very generalized ideas, which are either apologetic or chauvinistic, have held the scene for long. Hardly any study has been carried out on the nature of S&T and their various linkages with society. Further, the nature of changes in different periods of Indian history and different regions of the country have also not been relooked, nor their significance fully understood.

History of Science & Technology in India is classified under four periods:

i) Ancient period (from earliest to 12th century AD)
ii) Medieval period (1200-1800)
iii) Colonial modern period (1800-1947)
iv) Post Independence period (1947 onwards)

Ancient period will be focussed in this essay, broadly touching different aspects of science and technology.

Mathematics & Astronomy:

Although the concept of 0 (zero) and ruminations over it in India started from very ancient times in literature through the use of synonymous words like sunya, vyoma, akasha, bindu etc., as a numerical form it took shape sometime in first century AD, known as decimal placement. The place value of zero at the beginning of numerical system is zero and if placed in other positions it increased the value of the number by 10, 100, 1000, ... times. This Indian ingenuity has opened a new age in computations, which was adopted by all cultures and became universal by 15th century. It is one of the precipices of human adventure in number system and commercial activity.

Pure mathematics was applied to astronomical movements and calculations were made by the distinguished empiricists like Aryabhatta (476-550AD), Varahamihira (505-587AD), Brahmagupta (598-668AD), Lalla (720-790AD), Sripati (1019-1066), Bhaskara (1115-1185AD) and others bear ample testimony to the exactitude of ancient Indian astronomy. They were also mathematicians.

Aryabhatta, in his treatise *Aryabhattiyam* (499AD) advocated that earth was having an axial rotation and also defined a day from sunrise to next sunrise. He also calculated that when earth rotates around its own axis 1582237500 times the moon navigates around the earth 57753336 times, and the ratio is 27.3964693572 which is considered to be fundamental in astro-mathematics. He also wrote that moon and other planets look luminous due to the Sun. He defied the role of mythical Rahu and Ketu in the gross astronomical phenomenon of eclipses. He took interest in circumference and diameter relationship which is a constant and expressed in his treatise (Ganitapada,verse 10) that the ratio of circumference (paridhi) and moon's diameter(vyasa) is 62832/20000=3.1416 which is equal to pi.

Varahamihira brought the luni-solar calendar up to date after taking into account the accumulated precession.

Bhrahmagupta wrote a voluminous treatise titled *Brahma Sphuta Siddhanta* (628AD) rectifying the old *Brahma Siddhanta*. Some

chapters of his work are related to pure mathematics which show remarkable originality and depth. That is why he is regarded as one of the greatest ancient Indian mathematicians. Contrary to the belief in vogue then, Brahmagupta wrote in the 7thchapter of his treatise that the Sun was not nearer to earth in comparison to the moon. Earth was believed to be flat, static and empty within, which was defied by him and he wrote the Earth to be spherical and dynamic. He also wrote that just like the property of water was to flow so was the earth to pull whatever is there on it.

Lalla's noteworthy work is *Jyotisha ratnakosha*. His thoughts, however, were influenced by his predecessors. Lalla was a follower of Aryabhatta (the school of thought continued by Bhaskara I) but he did not believe in the axial rotation of earth put forth by Aryabhatta. Lalla wrote *Laghu Manasa* wherein he gave correction to the accumulated precession for the year 932 AD as 6 degrees 50 minutes, considered to be a correction to Varahamihira's calendar prepared in 550AD. Lalla worked on moon's motion , now referred to as lunar evection in modern astronomy.

Sripati's work *Siddhanta Sekhara* (1039AD) has been published by Calcutta University in two volumes. He was the first to give correction for the equation of time due to obliquity and the *agraantara* (correction related to rectify the east-west line indicated by gnomonic shadows)

Bhaskara II borrowed freely from Sripati and his predecessors. He published *Siddhanta Shiromani* (1150AD), the third and forth parts of which *Ganitadhyaaya* and *Goladhyaya* respectively are devoted to astronomy. He also took interest in circumference and diameter relationship and derived the value of pi as 3927/1250=3.1416. He is the last name in the field of ancient Indian astronomy. After him hardly there is anybody noteworthy barring those who contributed in recent times to the growth of astronomy on western lines.

Souramasa (Solar month) and Chandramasa (Lunar month):

Zodiac is divided into 12 rasis or constellations of 30 degrees each and these are given names *Mesha, Brisha, Mithuna, Karkata, Simha, Kanya, Tula, Vichha, Dhanu, Makara, Kumbha* and *Meena*. The instant the Sun enters any rasi, it is called samkranti of that rasi. The time taken by the Sun to traverse a given rasi is called the corresponding souramasa or solar month. These months are of unequal length on account of the unequal motion of the sun in the ecliptic.

The chandramasa of the lunar year bear the names *Chaitra, Vaisakha, Jyestha, Asadha, Sravana, Bhdrava, Aswina, Kartika, Margashira, Pausa, Magha* and *Phalguna*.

The solar year begins when the Sun enters zero point of the zodiac and ends when the sun returns to the same point. This interval is known as Saura Sambatsara (Sidereal solar year). This mean period was calculated by Bhaskara II to be 365 days, 15 *ghatis*, 30

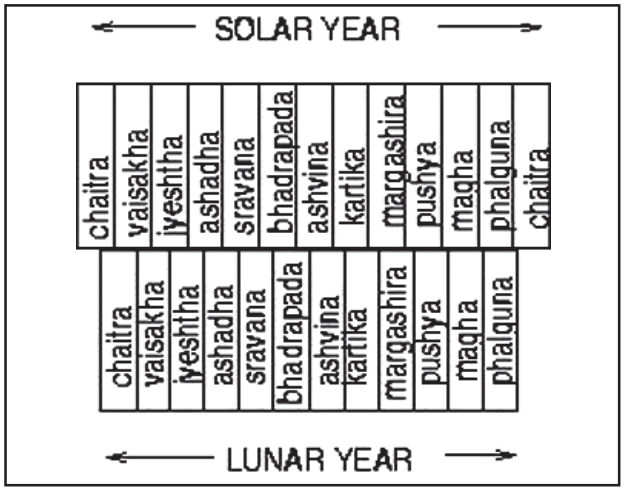
vighatis,22 paraghatis,30 sukhmaghatis. These are divisions of a day:

1 day=60 ghatis

1 ghati=60 vighatis

1 vighati =60 paraghatis

1 paraghati=60 sukhmaghatis



Physics& Atomism:

Kanada (Also known as Uluka Kanada, Kashyapa, Kanabhuk lived sometime between 6th to 2nd Century BC), legendary founder of the Vaiseshika system of Indian thought recognised those days the atomic (kana) constitution of nature and indestructibility of matter, which was different from soul. He was more interested in physics and chemistry rather than theology. He also advocated that atoms combine as diads and triads, to form sanghata (molecules). Four elements accepted then were earth, air, fire and water.

Commentaries were written by Prasatapada and Pakudha Katyayana who were contemporaries of Buddha (born sometime in 563BC). Jain thinkers used the word *anu* as synonymous to *kana* or what we call now as atom and added ether or space as fifth element but the emptiness of space was not acceptable. Both Ajivika Jains and Buddhists rejected it and replaced with life, joy and sorrow thus considering seven elements in total. All these happened much before Leucippus (around 465 BC) and Democritus (470-400BC). But Greek atomism was dormant till 17th century.

Chemistry& Ayurveda:

Use of medicinal plants had earliest mention in Ayurveda (Science of Life) compiled around 2500-1000 BC by a number of researchers. Charaka (6th century BC) dealt with medicine whereas Sushruta (6th century BC) contributed on surgery. Basics of chemistry was applied to ayurveda, for the well being of mankind.

May be they did not have the relevant theoretical knowledge of the chemical equation/ transformation that took place in the process they dealt with but they had sound empirical knowledge over centuries of chemical practice adopted by practical chemists: brewers, dyers, potters, glass makers, perfumers, metal-smiths etc.

Nagarjuna (8th century AD) , on the other hand discovered the process of sublimation, distillation etc and was the author of *Kakshaputantra, Rasharatnakar,* and *Arogya manjari*. It was in vogue till 1200 AD. Ayurvedic concept of kaya-kalpa (intricate method of rejuvenation based on extracts of specific salts from earth) is something still unexplored and has the key to disease free life, even revival of a degenerated body ! Subsequently ayurveda penetrated even to Egypt, Greece, Rome and Arabia.

Metallurgy:

Indian metallurgists attained excellence in this macro-technology of zinc, iron and copper. Around 400 BC, zinc was extracted by Indian metal-smiths using the downward distillation process, which needed optimum temperature so that oxidation does not occur. Only in 18th century AD Europe practised in similar lines to extract zinc.

Around the same time as zinc, Indian steel was also well known. Even Indian steel swords, famous for its edge and sharpness, were exported to West Asia. Damascus sword was made of pellets of Indian steel, which were imported through Persia (Iran).Woortz steel (also called crucible steel with about 1.3 to 1.8% carbon) made in Mysore, Canara, Malabar area has attracted interest of modern metallurgists even today.

Delhi Iron pillar (24ft height, 6 tonnes weight) is often cited as a marvel. It was made by ancient Indian iron-smiths using forge-welding technology in 5th century AD and remains corrosion-free even after 16 centuries of wear and tear! Selection of right quality iron ore and use of reducing agent in right proportion by them could produce the iron pillar of high quality, which is one of the ageless examples made in India. Those days Indian iron-smiths could go upto melting temperature of 1100 degree centigrade and therefore could not produce cast iron which needed 1400 degrees.Copper statue of Buddha (7ft height,1 tonne weight) at Sultangunj, Bihar made at around same time but excavated from Buddhist ruins in 1864 has special mention in travelogue of Hiuen Tsang who saw it during his visit in 7th century AD.

Other Disciplines & Technology:

Not known elsewhere , in addition to significant advances in different disciplines like mathematics, astronomy, chemistry, metallurgy, medicine, physics, botany etc technologies like brick making, granary near the ancient cities, three-storied architecture, irrigation, basement air conditioning, the rudimentary wheel etc. were in vogue and discovered from archaeological remains which are older than 3rd millennium BC.

By the time Aryans (the first invaders into ancient India from north-west) entered in 2nd millennium BC they saw craftsmen of copper, bronze, gold, stone and bone seal carvings and in addition grain, sugarcane, karpasa (cotton) were grown and exported to Mesopotamia. Mining of iron ore, inventions of bow-arrow, ploughshare, irrigation of water, ship building for commercial navigation, large rafts for transportation across rivers were the technological skills preserved even today but hardly encouraged for modernization.

Constraint of Language & Nomenclature:

Whether it is science or vigyan, its origin is from scientia or *gyana* (*jnana*) which means knowledge. It is an incessant and incisive search through the senses and logical mental analysis which are gate ways to coherent knowledge about man and nature, man and universe. In other words, it is Man-Nature-

Cosmos, triad that has been challenging the rational animal, called man.

Science has never represented a specific academic discipline or subject, but it is in the nature of an over-arching nomenclature, including under its umbrella subjects like physics, chemistry, botany, zoology, geology, astronomy and their subsidiaries, as well as their interlinks such as bio-physics, geo-chemistry, molecular biology and astrophysics and in recent times it has proliferated into further super specialised disciplines.

The saga of early human knowledge goes back to the ancient civilizations like Indian, Chinese, Egyptian, Mesopotamian. Mankind wherever engaged in thinking and experimentation, applying knowledge over the millennia have used their own language and nomenclature, which are often symbolic, coded, mysterious, which are even today not fully understood. The scientific text is in classical languages like Sanskrit, Prakrut, Brahmi, Pali, Arabic, Persian etc and many have been reflected in Indian rock edicts, linguistic riddles in hymns, suktas, mantras, incisive discourses in vedas and upanishads,Chinese Tao Te Ching Symbols, meaningful reed written alphabets, Egyptian hieroglyphs etc. Being culture specific, these too have evolved and therefore extremely difficult to decode for giving it a contemporary meaning. The units and dimensions used in ancient India has not been fully understood nor calibrated or standardised with modern CGS/ MKS system, which retards interest in reviving and relooking at the ancient inferences.

Epilogue:

Relations with India greatly contributed to the development of culture, writing, the arts and scientific knowledge in the neighbouring countries of South East Asia and other distant lands. Although Indian working style was contemplative and minimal use of apparatus, they were broad-minded enough to pass and share their knowledge and contribution with the ancient world, through scholar-emissaries, awakened brand ambassadors of what it created.

Decline in scientific enquiry in ancient India, especially in Medieval period, is often ascribed to uncertain political atmosphere, foreign invasions, internal warfare which was detrimental to peaceful pursuit of development of science and art too. Indian science and technology, in more sense than one, has been all embracing, truly global, which is consciously developing and evolving to greater heights giving new impetus to social change.

It is high time now to understand various ancient works in order to get a meaning of what all have been said and written. Words like *Brahma*(creator), *Vishnu*(preserver), *Shiva*(destroyer), *Pratika*(symbol), *Pratima*(model), *Purusha*(statics), *Prakruti*(dynamics), *Maya*(illusion), *Prasar* (space), *Kala*(time), *Mahakala* (cosmic time) and pairs like *Drashta-drushya* (observer and observed), *karya-karana* (cause and effect), *Mruta-amruta* (mortal-immortal) need to be ruminated for deeper meanings. It is not out of context to mention here that ancient Indians were masters in classification to have a holistic

view and identify exceptions if any. A time will come when India will be considered the original home of mankind and fountainhead of organic nature still surviving in close proximity with the source of life. Karl Jaspers, the German existential philosopher pointed out that in the three intellectual worlds :India, China and West, independent of each other, the same forces have been active to promote development, to consolidate that which had been achieved, and finally, to dissolve and regenerate it again!

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THE CONTRIBUTION OF ANCIENT INDIA TO THE FIELD OF SCIENCE AND TECHNOLOGY

Soumyaranjan Das

Today's Science is tomorrow's Technology"

One of the oldest civilizations in the world, the Indian civilization has a strong tradition of science and technology. Ancient India was a land of sages and seers as well as a land of scholars and scientists. Research has shown that from making the best steel in the world to teaching the world to count, India was actively contributing to the field of science and technology for centuries long before modern laboratories were set up. Many theories and techniques discovered by the ancient Indians have created and strengthened the fundamentals of modern science and technology. While some of these ground-breaking contributions have been acknowledged, some are still unknown to most.

Some contributions made by ancient Indians to the world of science and technology :

The Idea of Zero:

Little needs to be written about the mathematical digit 'zero', 'one of the most important inventions of all time'. Mathematician Aryabhatta had discussed about 'zero' and Brahmagupta had described the

mathematical operations like addition and subtraction using the digit zero. The concept of zero and its integration into the place value system also enabled one to write numbers, no matter how large, by using only ten symbols.

The Decimal System:

India gave the ingenious method of expressing all numbers by means of ten symbols - the decimal system. In this system, each symbol received a value of position as well as an absolute value. Due to the simplicity of the decimal notation, which facilitated calculation, this system made the uses of arithmetic in practical inventions much faster and easier.

Numeral Notations:

Indians, as early as 500 BC, had devised a system of different symbols for every number from one to nine. This notation system was adopted by the Arabs who called it the 'Hind numerals'. Centuries later, this notation system was adopted by the western world who called them the Arabic numerals as it reached them through the Arab traders.

Fibonacci Numbers:

The Fibbonacci numbers and their sequence first appeared in Indian mathematics as '*matrameru'*, mentioned by Pingala in connection with the Sanskrit tradition of prosody. Later on, the methods for the formation of these numbers were given by mathematicians Virahanka, Gopala and Hemacandra much before the Italian mathematician Fibonacci introduced the fascinating sequence to western European mathematics.

Binary Numbers:

Binary number system is the basic language in which computer programs are written. Binary basically refers to a set of two numbers, 1 and 0, the combinations of which are called 'bits' and 'bytes'. The binary number system was first described by the Vedic scholar 'Pingala' in his book '*Chhandashastra'*, which is the earliest known sanksrit treatise on prosody (The study of poetic metres and verse).

Chakravala method of Algorithms:

The *chakravala* method is a cyclic algorithm to solve indeterminate quadratic equations, including the Pell's equation. This method for obtaining integer solutions was developed by 'Brahmagupta', one of the well known mathematicians of the 7th century. Another mathematician Jayadeva later generalized this method for a wider range of equations, which was further refined by Bhaskara II in his '*Bijaganita*' treatise.

Ruler Measurements:

Excavations at Harappans sites have yielded rulers or linear measurers made from ivory and shell. Marked out in minute subdivisions with amazing accuracy, the calibration was about 1/16 inch (1.6 mm), traditionally used in the ancient architecture of South India. Ancient bricks found at the excavation sites have dimensions that corresponded to the units on these rulers.

A Theory of Atom:

One of the notable scientists of the ancient India was Kanad who is said to have devised the atomic theory centuries before 'John Dalton' was born. He speculated the existence of 'anu' or a small indestructible particle,

much like an atom. He further held that atoms of same substance combined with each other in a specific and synchronized manner to produce '*duyanuka*' (diatomic molecules) and '*tryanuka*' (triaotomic molecules).

The Heliocentric Theory:

Mathematicians of ancient India often applied their mathematical knowledge to make accurate astronomical predictions. The most significant among them was Aryabhatta whose book *'Aryabhatiya'*, represented the pinnacle of astronomical knowledge at the time. He correctly propounded that the Earth is round, rotates on its own axis and revolves around the Sun i.e. the heliocentric theory. He also made predictions about the solar and lunar eclipses, duration of the day as well as the distance between the Earth and the moon.

Wootz Steel:

A pioneering steel alloy matrix developed in India, Wootz Steel is a crucible steel characterized by a pattern of bands that was known in the ancient world by many different names such as 'Ukku', 'Hinduwani' and 'Seric Iron'. This steel was used to make the famed Damascus swords of yore that could cleave a free-falling silk scarf and a block of wood with the same ease. Produced by the Tamils of the Chera Dynasty, the finest steel of the ancient world was made by heating block magnetite ore in the presence of carbon in a sealed clay crucible kept inside a charcoal furnace.

Smelting of Zinc:

India was the first to smelt zinc by the distillation process, an advanced technique derived from a long experience of ancient alchemy. The ancient Persians had also attempted to reduce zinc oxide in an open furnace, but had failed. Zawar in the Tiri Valley of Rajasthan is the world's first known ancient zinc smelting site. The distillation technique of zinc production goes back to the 12th century AD and is an important contribution of India to the world of science.

Seamless Metal Globe:

Considered one of the most remarkable feats in metallurgy, the first seamless celestial globe was made in Kashmir by Ali Kashmiri ibn Luqman in the reign of the Emperor Akbar. In a major feat in metallurgy, Mughal metallurgists pioneered the method of lost – Wak casting to make twenty other globe masterpieces in the reign of the Mughal Empire. Before these globes were rediscovered in the 1980s, modern metallurgists believed that it was technically impossible to produce metal globes without any seams, even with modern technology.

Plastic Surgery:

Written by Sushruta in 6th Century BC, *Sushruta Samhita* is considered to be one of the most comprehensive text books on ancient surgery. The text mentions various illnesses, plants, preparations and cures along with complex techniques of plastic surgery. The *'Sushurta Samhita'*s most well known contribution to plastic surgery is the reconstruction of the nose, also known as 'rhino plasty'.

Cataract Surgery:

The first cataract surgery is said to have been performed by the ancient Indian physician Sushruta, way back in 6th Century BC. To

remove the cataract from the eyes, he used a curved needle, *'Jabamukhi Salaka'* to loosen the lens and push the cataract out of the field of vision. The eye would then be bandaged for a few days till it healed completely. Sushurta's surgical works were later translated to Arabic language and through the Arabs, his works were introduced to the western world.

Ayurveda:

Long before the birth of Hippocrates, Charaka authored a foundational text, '*Charakasanhita*', on the ancient science Ayurveda. Referred to as the Father of Indian Medicine, Charaka was the first physician to present the concept of digestion, metabolism and immunity in his book. Charaka's manual on preventive medicine remained a standard work on the subject for two millennia and was translated into many foreign languages, including Arabic and Latin.

Iron-cased Rockets:

The first iron-cased rockets were developed in the 1780s by Tipu Sultan of Mysore who successfully used these rockets against the larger forces of the British East India Company during the Anglo-Mysore Wars. He crafted long iron tubes, filled with gunpowder and fastened them to bamboo poles to create predecessor of the modern rocket. With a range of about 2 km., these rockets were the best in the world at that time and caused as much fear and confusion in the enemy. Due to these, the British suffered one of their worst ever defeats in India at the hands of Tipu.

Source: Magazine, Science Reporter.

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SCIENCE AND TECHNOLOGY IN ANCIENT INDIA

Basanta Kumar Das

Science and Technology (S&T) are just like two sides of a coin. The existence of one without the other is meaningless and baseless. The science in regional knowledge is Vigyan means specific knowledge. During medieval period it is known as sinz, sayens, siens means "knowledge". In western scenario "Science" came into use after 1300 A.D. which means knowledge acquired by "Study". It also includes studies of art. In India S&T is much older than modern science in European countries. During this period philosophy was also seen as a methodological study which led to knowledge. It was first referred to as "natural philosophy" where different philosophers, saints and Rishis have a lot of contributions, i.e. Aryabhatta, Varahamihir, Brahmapupta, Bhaskara, Lala, Boudhayana, Manaba, Pingala, Jabaneswar, Kanada, Mahaveer, Shreedhar, Shreepati, Bramhadev, Harishchandra, Charak and Sushruta etc. Technology follows science. If science becomes engine, then technology is compartments. Science may be individual, but technology includes team. The term science being used today commenced in the year 1931, just after the foundation of British Association for the Advancement of Science (BAAS). British philosopher William Vevel felt that there does not exist any sort of work for the personnel working in the field of science, then only he coined the term "Scientist".

"Technology" has the root from Greek word "techne" means skill, where as science's root comes from Latin word "Scientia" which means "knowledge". So Technology is the collection of techniques, skills, methods and processes used in the production of goods or services. It can also be defined as the study of knowledge of the practical, especially industrial, use of scientific discoveries or the application of scientific knowledge for practical purposes. The meaning of technology was first recorded in 1859.

Different branches of science are physics, astronomy, astrophysics, biology, computer science, optics, chemistry etc. Different branches of technology are mechanical technology, electronic, biotechnology, nanotechnology, nuclear technology, hyperloop technology, laser technology, eco-technology, robotics etc.

Science is nothing but well-trained and systematic wisdom, where as technology is the application of science or nature's laws to achieve certain targets, Newton's 3rd law of motion is used to build rocket technology for space travel. Science and Technology can be understood in different ways i.e. Science & technology as concept, S&T as method, S&T as title, critical thinking, criterion for demarcation, inquiry, thinking & doing, narrative, political, sociological, economical, cultural, logical, realistic, experimental and global etc.

There was acute symbol of S&T in Mahenjodaro & Harappa Civilization in general and from 1st century to till date in particular. During the regime of Kharvel, Ashok, Pratap Rudra Dev and Languda Narasinghadev, S&T was prominent, perfect and powerful in Odisha especially in so called Cuttack and Puri district area. Oral communicative skills transformed in to written formats especially on copper plates, barks, different leaves, stones, mud and mud pellets burnt by fire in 1200 to 1300 A.D.

They were composed of different concepts and themes on mathematics, astronomy, medical science, agriculture, technology of transport and sailing. Numismatics, sky watching, observation of different weather and climatic conditions were also their thrust area.

There were five communication philosophies in about 200 B.C., i.e. the main policies of communication (S&T) were basically divided in to five parts, i.e. (1)Sahridaya, (2)Sharing, (3) Rasa Utpathi along with Rasa Aswadan, (4) Sadharanikaran and (5) Asymmetrical.

According to *Chhandogya Upanishad* the four Vedas, contain history & epics, logic, arithmetic or rasi, units or *ekayana*, science of elements or *bhuta vidya*, military science or *ksatra vidya*, astronomy or *naksatra vidya*, knowledge related with fauna and flora (from grass to green forests). Invention of wheel, pulley, knife, pestle, mortar, cup, saucers, ladles, kettles, and spoons, bricks, cement, plaster were made in ancient India.

Fire Technology

The discovery of fire technology in ancient India is really radical, rational and reflective. The Atharvan was the first who discovered fire. Fire then led to boiling of milk and other milk products, like ghee. Then came domestication of animals and later from dead animals tanning technology came into existence.

Bricks Technology

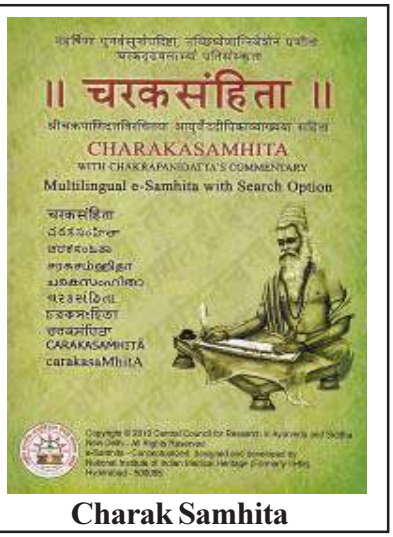
Bricks were produced in shapes and sizes using "Sulba Sutras" in rectangular, square, cube, round and other different geometrical sizes.

Metal Technology or metallurgy

Metals were extracted from ores. Different armaments and weapons were built for hunting and self defence. Even coins were made up of from silver, gold, copper, brass, bronze, aluminium, steel and other alloys during primitive period as well as Mohgul regime. Temple peaks were decorated by different types of *chakras* and *astadhatu*.

Charak Samhita preaches different aspects of curing diseases. Goutam Budha preached that one should not believe in what the teacher teaches without experimenting it practically and pragmatically.

An analysis of S&T in ancient India was attempted by Indian National Science Academy (INSA), New Delhi and the volume edited on title "A Concise History of Science in India" is very much useful. The best utility of *Charak Samhita* consisting of 150 chapters in eight categories 'materia medica' with over 600 drug compositions of plant and even of animal and mineral roots.



Charak Samhita

Ancient India contributed a lot to S&T in general and Zero in particular. The symbol zero plays a crucial, critical, creative and clear crystal role in the field of mathematics and different mathematical operations. Binary numbers are the cardinal and crucial basic language by the help of which computer programmes are written. The ancient vedic scholar, Pingala described this in his *CHHANDASHASTRA* in Sanskrit.

Similarly measurement system was there in ancient India, namely **"hasta"** used in different architecture of India especially in South India. Drainage system, use of bricks in construction of houses, temples, mosques, universities (Ratnagiri, Puspagiri, Udaigiri, Khandagiri, and Dhauligiri etc.) were in ancient India. In 19th Century John Dalton suggested 'atom' the smallest indestructive particle of matter just like an 'anu', which was propounded by Kanad Rishi much earlier. Kanad told about dwanuka and trayanuka (diatomic & triatomic). *Aryabhatiya* book narrates about astronomy

as well as eclipse of Sun & Moon. Wootz Steel is the contribution of ancient Indians. Medicines, Modakas, curing different ailments by ayurveda, water conservation, in sagar, Talab Bandhi, Jhalara, Bawaris, Taanka, Johads, Kund, Baoli, Zabo etc were too very popular in the past. Architectural designs were there which constructed and cooled the building or restshed at a time. There are different types of scientific & technological means in the field of S&T which is emerging day by day. But the importance on basic science is to be stressed upon. For that purpose different schemes and policies are adopted to attract the students, researchers and young scientists now. NISER, IISER, IITS, INSPIRE, KVPY and other different scientific institutions like CSIR, IIS, CDRL, CFTRI, ICMR, AIIMS, BARC, TIFR, DRDO, VP, NIC, ICAR and DST are designing different schemes to attract the scientists, students, researchers, Technologists and entrepreneurs to the new area & era of S&T. No doubt in future India will be S&T hub in the world, but a time will come when technological developments will cease if basic science scenario remains unchanged.

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SCIENCE & TECHNOLOGY IN ANCIENT INDIA AT A GLANCE

Bindu Balaya Dash

One of the oldest civilization in the earth, the Indian civilization has a strong tradition with impressive contribution to science and technology. Everybody knows India was a land of sages & seers, scholars, philosophers and scientists. In ancient India, many inventions were actively contributed to the field of science and technology by many notable scholars. The contributions of ancient Indian Civilisation in the fields of physics, chemistry, biology, medicine, mathematics, astronomy, environmental activities etc. are note worthy.

Physics :

The principle of atomism was explicitly stated by an Indian philosopher and sage named KANAD about 600 B.C., centuries before John Dalton was born. He speculated the existence of ANU or small indestructable particles, much like an atom. KANAD also said that ANU have two states- absolute rest & state of motion. He further held that atoms of same substance combined with each other in a specific and synchronized manner forming diatomatic molecules & triatomic molecules. It clearly indicates that physics was strongly discussed in ancient India. Another Indian philosopher PAKUDHA KATYAYANA the scholoar contemporary of Goutam Buddha, had propounded the ideas about the atomic constitutions of material world. Many other

scholars had also presented many fundamental ideas about physics in ancient India, which are now admitted by many modern physics scholars of the world.

The root concept of physics is derived from five basic elements mentioned by ancient Indian scholars around 3000 B.C. These five elements are earth, fire, air, water and space. The same time paramanu is made of two Sanskrit terms - *Parama*- meaning- ultimate or beyond, and *Anu* meaning atom. Thus the term *Paramanu* or the concept of atom was devised by Indian scholars.

Chemistry :

Not only physics, in ancient India many scholars had given ideas on chemistry. The principles of chemistry in distillation of perfumes, aromatic liquids, manufacturing of dyes and pigments, extraction of sugar etc. are invented by Indian chemistry scholars. In ancient India, perticularly in Bronze age chemistry developed. Basic idea of smelting reached ancient India from Mesopatamia and Near East. The principle of coinage dating started in ancient India around 8th century.

In Qutub Minar premises, a world heritage site in Delhi, stands an Iron pillar. The pillar is cast in Gupta period around 500 A.D. The pillar is 72.5 metres (240 feet) tall, tapering from the bottom, weighing about 6 tons. It has been standing in open place for the last 2000 years, bearing the pressure of wind, water, heat and weather. But still it is not rusted. It is due to the chemicals which were used in smelting iron for the pillar or use of rustless iron. Another pillar is at Beluru in Bangalore. It was built by the tribal people, not by any expert, and still it is not rusted. The Ashok pillar in Bihar made by king Ashok during 268 B.C. to 232 B.C., also has no rust till today. It proved the knowldge of chemistry in ancient India.

The technology for extracting zinc from zinc ore existed in India 4000 years ago. Zinc is converted to liquid at 997^0 C. The ore was heated to 1000^0 C. So there is a difference of 3^0 to collect zinc. The technology existed in India and it continued for 4000 years.

In ancient age zinc was used only by Indians & Indians exported it to other countries. One Chinese scholar stole the technology from India. Then another scholar stole it from China to England. In 1543 AD Britain first established the zinc distillery factory on India's technology.

Biology :

There is some special contribution of ancient India to Biology. In Vedic age to a small measure there existed the scientific study of plants and animals. The post vedic evidence in literature indicates that the systems of classification and nomenculture were wellknown. The art of development of plants and animals was being practised. Also knowldge of rotation of crops, manures, photosynthesis and respiration existed in modest style. Animal metabalism, blood circulation, nervous and reproductive systems, embroyogenesis were also known. With this countable diseases, pest of animals and plants - their preventive

and creative remedies were known in vedic age.

Medicine :

Sushruta who lived in Kasi was one of the most popular scholars among many Indian medical practitioners including Atreya and Charaka. He was the first scholar to study the human anatomy. Sushruta has described surgery & surgical systems of the body like *Chhedya* (Excisim), *Lekhya* (Sacrification), *Vedya* (Punctuing), *Esya* (Exploration), *Ahrga* (Extraction) *Usraga* (Evacuation), *Sivya* (Saturing) etc. Near about 6th century B.C. Sushruta, had written *Sushruta Sahmita* which is considered to be one of the most comprehensive text book on surgery. The book mentions the way of treatment on illness, surgery, preparations & cures along with complex techniques of plastic surgery. The most welknown contribution of Sushruta on surgery was the reconstruction of nose usually known as rhinoplasty. According to the evidence, the first cataract surgery is said to have been performed by the Sushruta. About 6th century B.C. the knowldge of removal of cataract from eyes already existed in India. For this system the physicians used curved needles called *Jabamukhi Salaka*, to loosen the lens and push the cataract out of the field of vision.

Ancient scholars like Atreyaa and Agnivesa have dealt with principles of Ayurveda as long back as 800 B.C. *CHARAKA SAMAHITA* by Charaka was a text book on Ayurveda. In this book Charaka has writen about physiology, etiology & embryology, concepts of digestion, metabolism, immunity. Charaka also theorized blindness from the birth is not due to any defect in the mother or father, but owes its origin in the ovum & the sperm. He has also mentioned about dental surgery in his book.

Mathematics :

The Vedic literature is replete with concept of zero (0). The techniques of algebra, logarithm, square root, cube root, etc. and concept of calculus already existed in India 300 years before Newton. Rigveda also contained mathematics near about 2000 BC.The mathematicians created symbol of zero (0) and its mathematical operations like addition, subtraction. The concept of zero (0) and its integrations into the place value system enabled to write numbers, no matter how large using symbols.

Ancient Indian mathematicians gave the ingenious method of expressing all numbers by means of ten symbols in the decimal system.

Aryabhatta has writen in his *Aryabhattiya*, the idea of algebra. He lived in Patna during 5th century AD. In 12th century AD Bhaskaracharya authored *Sidhanta Siromani*. Aryabhatta correctly propounded that the earth is round, rotates on its own axis & revolves around Sun. He further indicated the duration of the day and time about the solar and lunar eclipses, as well as the distance between the earth and moon.

Civil Engeering & Architecture :

The discovery of urban settlement of Mohenjodaro and Harappa indicates the existence of civil engineering and architecture in ancient India. The findings clearly indicates the level of engneering and architecture in ancient India.

There are many references to maritime activity by ancient Indians, particularly ship making. The ancient Indian scholars are founder of chess, ludu, snakes & ladders, and also playing cards.

According to evidence, the ship of Vaskodagama was the biggest ship in Europe at that time. But in India Kanha made a ship which was 12 times bigger than Vaskodagama's ship. So it indicates the ship making technology in ancient India.

Fine Art :

In Vedic literature there are references to fine art in ancient India. The deities in various temples, the painting in temple walls, the arts and sculpture in temples clearly talk about the ancient Indian technology on art, painting & sculpture. The natural corollary was emergence of music and other forms of performing arts. Vedas were recited & recitation gave rise to a finer study of sound & phonetics.

Astronomy :

Aryabhatta

In astronomy many scholars studied on stars, planets, Sun, moon, galaxy, group of stars etc. and gave important data, which was proved as correct in modern age. The Indian scholars had determined that earth rotates on its axis. In Yajurveda it is mentioned that the moon gets light from the ray of sun named SUSUMNA. Further it mentioned that, when the solar ray meets the moon, the ray becomes as cool as moon, then it gets reflected. It illuminates the darkness makes the night cool.

Conclusion :

Evidence shows that India was the leader of science in the world from the Vedic age to the 12th century. Bhaskaracharya-II was the best mathematician and astronomer all over world in 12th century. Pythagoras in the 6th century B.C. came to India and learned Indian mathematics. Then he went back to Greece. The *Baudhayana Sulba Sutra* and *Katyayana Sulba Sutra* of the Vedic Text contain the Phythagoras's Theorem. Geometrical theories were known to ancient Indians and find display in motifs on temple walls. The methods of graduated calculation was documented in a book named 'Five Principles' - *Panch Sidhanta* in 5th century A.D. A.L. Basham an English Indologist writes in his book, *'The Wonder That was India'* "that the world owes most to India in the realm of mathematics".

Yoga which is a science has been developed by the ancient Indians some thousands of years ago. There are many forms of yoga beginning with *Jyanayoga*,

Karmayoga, Bhaktiyoga, Rajayoga, Kriyayoga, Kuandaliniyoga etc.

The history of ancient Indian science is one of the longest of all. It begins in about 2500 B.C. Ancient India continued to contribute to original science. The history of science and technology in India begins with pre-historic human activity in the Indus Valley Civilization to early states and empires.The earliest textual source is the Rig Veda. Though science was at first mentioned in ancient India over the centuries, unfortunately many of which are lost.

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".....From seeds all motion springs;
by impulse hence
Through molecules minute of seeds conjoined,
Nearest in power, protruded, though unseen.
Hence urged again, in turn, through things create
Of ampler form, till soon the sense itself
The congregated action marks distinct. As in the lucid beam's light woof we trace
Still motion visual, though unseen its source.
Nor small the motive power of primal seeds."

Titus Lucretius Carus, Greek Philospher

PHYSICS AS CONCEPTUALIZED IN ANCIENT INDIA

Dr. Sadasiva Biswal

Prolegomenon :

Indian civilisation is one of the earliest civilisations of the world. So brilliant and advanced that it left an impact on other civilisations as well, viz. the Egyptian, Persian and Arabic. From the studies, it is evident that a scientific temperament was existent among the ancient Hindus. They had sound and accurate knowledge not only in the fields of metaphysics and religion, but also in sciences, such as mathematics, astronomy, physics, chemistry, biology, medicine and engineering. Studies show that they were aware of the systematic streamlined process of investigation of 'modern times'. The ancient Hindus were not at all strangers to the scientific spirit. They were perfectly familiar with *Anusandhana* or *Parishodhana*, which is nothing but the learned laborious investigation of the modern days. From all available sources of information, the methodology which clearly emerges is analogous to that followed in modern times as that of observation, information and authoritative expressions.

Logical reasoning and accuracy of observation were the fundamental principle of the Indian scientific age. This process probably had its roots even before the 6th Century B.C. The Shankhya and the Vaishesika schools had

fathered and developed this scientific spirit with its emphasis on direct observation, exact measurement and persistent enquiry. Thus the scientific thoughts existed and developed in ancient India, centuries before the European Renaissance. The works of scholars, such as Prashastap ada (3rd - 4th Century A.D.), Aryabhatta (5th Century A.D.), Brahmagupta (6th-7th Century A.D.), Shabar Swami (8th-9th Century A.D.), Vacaspati (9th Century A.D.), Udayana and Shreedhara Bhatta (12th Century A.D.), Gunaratne (14th Century A.D.), Damodara (16th Century A.D.) and the ancient seats of learning such as Takshashila, Vikramashila, Nalanda, Kanchi and Madurai testify to the continuous intellectual activity in ancient India. In fact, great Hindu Sages possessed 'authentic' scientific temper and never accepted 'assumptions' unless theoretical and applied validity was proved.

The present article deals with some of the ancient scientific ideas on physics latent in the vedic hymns. Long ago Vedic bards by their meticulous and continuous observations of various natural events have speculated and theorized many scientific reasonings which owe their relevance in the advancement of knowledge of science in a later period. In this respect, we can say that the *Vasisheshika Darshana* is one of the well known six systems of the vedic philosophy.

Contributions of the Indians to the basis of scientific knowledge :

The scientific perceptions of ancient Indian genius are reflected in the concepts of ultimate structure of matter, which was first propounded by the Indians. The evolution of elements which are the building blocks for forming diverse compounds has been discussed in various schools of philosophy in India. Ancient Indians had a fairly good understanding of measuring and mapping the course of heavenly bodies, agricultural techniques and analyzing the constitution of matter. The sources of various scientific perceptions can be traced in the Rigveda. One is simply wonderstruck to find in certain hymns a searching enquiry into the creation of the world. The song of creation is described in the 129th Sukta of the 10th Book of Rigveda. It is called the *NASADIYA SUKTA* - the hymn of creation of the Universe. Let us throw some light on Vedic cosmogony, i.e. the theory of creation, which is based on physical laws and mechanism.

Vedic Cosmogony :

The physics or the science of matter and energy was evolved with the evolution of philosophy of the origin of the existent from non-existent. Materialism is the oldest known philosophy. It is borne out of human experiences. Then philosophy is evolved as a man's attempt to have rational explanation of the Universe around himself as a part of the Universe.

The well known Purusa-Sukta of the Rigveda mentions that everything sprang from the body of a giant (Purusa), the supreme power. Besides, there are two other cosmogonic hymns in the Rigveda, which

explain the origin of the Universe as a kind of existent (*sat*) from the non-existent (*Asat*). Nasadiya Sukta as translated by A.L. Basam reads as follows;

"Then even, nothingness was not, nor existence. There was no air then, nor the heavens. Beyond it what covered in it? Where was it? In whose keeping?

Was there then cosmic water, in depths unfathomed?

Then there was neither death nor immortality, nor was there then the touch of night and day.

The one breathed windlessly and same sustaining. There was that one then, and there was no other.

At first, there was only darkness wrapped in darkness, all this was only unilluminated cosmic water.

That one which came to be enclosed in nothing, arose at last born of the power of heat in the begining desire descended on it.

That was the primal seed born of the mind. The sages who have searched their hearts with wisdom know that which is keen to that which is not.

And they have stretched thier cord across void and know what was above and what below.

Seminal powers made fortile mighty forces. Below was strenght and over it was impulses.

But after all who knows and what can say, whence it all came and how creation heappened?

The *devas* themselves are later than the creation. So who knows truly whence it has arisen?

Whence all creation had its origin, the creator, whether he fashioned it or whether he did not, the creater who surveys it all from highest heaven he knows even he doen not know."

Mainly two theories of the creation as the interpretations of the above verse appear in the vedic and post-vedic literature which are as follows;

(i) Water theory of creation

(ii) Shell theory of creation

Let us discuss each theory in the vedic perspectives.

Water theory of creation :

According to this theory, only water existed in the beginning. Then evolved the water borne organisms followed by the entire material world. With the advancement of science and human civilisation, this theory became the well known theory of evolution framed by the famous scientist Darwin.

Shell theory of creation :

This theory suggests the formation of the material world from a cosmic Nucleus, i.e. the Golden-egg termed as "Hiranyagarbha" in the Rigveda. The philosophy of creation links this to the supreme creator, prajapti, who has created the ether, air, fire, water, the earth and finally the life. The Golden-egg was considered as the source of all matter and energy. All discrete substances of the Universe were aggregated here in the Golden-egg with enormous energy. The primeval body of this cosmic nucleus was disintegrated by the Supreme spirit (the desire for creation). This was happened with a great explosion evolving sounds of high pitch.

According to *Chhandogya Upanisad*, the Universe came to exist after dismemberment of the cosmic egg. This explosion that brought about the creation is nothing but the Indra-Vrtra collision mentioned in the Veda. The modern scientific theory calls it the 'Big-Bang', the great explosion from which the creation has emanated.

Vrtra, the demon represents the inertia in physics. Actually inertia opposes the motion. Motion starts overcoming the inertia. Indra threw his Bajra on Vrtra and the demon was killed, i.e. inertia was overcome and the motion started. That means the material world began. When Indra hit the demon with his Bajra, a great explosion occurred evolving huge and tremendous sound. This was later termed as the 'Big-Bang' in modern science.

The interpretation of the epithet Haima or Hiranya (golden) as 'bright and reddish yellow' and the word 'water' as 'water-vapour' paves a way to the existence of a 'hot, fireball' at the beginning. The modern cosmological theories have accepted this as the starting point of the material world. This epithet of Haima or Hiranya is latent in all the Puranas.

In addition to the above two theories of creation, there are some other speculations prevalent in the cosmological hypothesis.

a) Cosmic dust hypothesis :

The Rigveda also refers to the existence of cosmic dust as the building material of the Universe. The concerned hymns are addressed to Vishwakarma who has designed this Universe by blasting and smelting.

b) Creation and dissolution :

The philosophy of the Puranas adheres to the notion of the cosmic cycle, i.e. Creation, preservation and dissolution. At the end of the definite period (Kalpas of the puranas), the material would dissolve and then re-creation starts. In the present concept of modern science, matter can be annihilated to become energy in accordance to the famous Mass-Energy relation of Einstein, i.e. $E=mc^2$. Thus, mass can be transformed in to energy and vice versa. According to the puranas, Brahma creates, Vishnu preserves and Lord Shiva destroys.

c) The law of Universal Gravitation :

The law of Universal gravitation is gleaned from the rk of the Rigvedic hymn. The cosmic order Rta governs the entire Universe. According to Murthy, Rta is the law of the Universe or the great cosmic order by which the whole of the manifest universe is working. This, in other words, appears to be the law of gravitation in simple terms. Vedic god, Varuna is regarded as the Lord of this law. Griffiths holds that the Sun, the Earth, the Moon, the air, the water and the wind are all held in their position by this gravitational attraction, and so also all the celestial bodies. The vedic concept of the attraction of celestial bodies, though brought out by Bhaskar II about the 12th Century A.D. did not pave the way for formulation of the theory of gravitational attraction in India. That was left to Kepler, Galileo, Copernicus and Newton in Europe.

d) Unified field theory :

A number of geophysical agencies are traced in the Rigveda by Murthy. According to him, in Rigveda Indra stands for the natural geophysical phenomena. Indra represents the geomagnetic field that brings about earthquakes. Agni stands for geothermal field (heat energy), Varuna for the Universal law of gravitation and Maruta for the wind-energy, and so on. Thus, there exist a number of forces which govern the Universe. These are electrical, magnetic, gravitational and nuclear forces. The Vedic seers observed that all these forces are the different aspects of one and the same fundamental force. This ultimate reality is arrived at and is identified with Brahman. Many years after, modern scientists also thought of unifying all these forces which govern the Universe. According to today's physics, four fundamental forces governing the Universe are;

i. Gravitational force

ii. Electromagnetic force

iii. Weak nuclear force

iv. Strong nuclear force

Nobel physicist Abduls Salam has become successful in unifying the electromagnetic force and weak nuclear force. Also Steven Weinberg, independently has succeeded in unifying the above two forces. Salam predicted his unified theory in 1968, but got Nobel Prize in 1979 alongwith Sheldon L. Glashow and Steven Weinberg.

Thus, the Salam-Weinberg theory reduced the four fundamental forces in to three, namely the strong nuclear force, the electro-weak force and the gravitational force, Salam believes that a further extension of the gauge principle is likely to relate the strong interaction to the 'electro-weak'. Lastly gravity will be taken up to show that all the four forces of nature have a common origin, the ultimate goal of a physicist which was also a speculation made long before by the Vedic Seers regarding the 'Unit Source' of all creation.

e) Space-Time Continuum :

In the Vedas, the word '*antariksha*' means the space extending outward from the

earth. The Vedic bards considered the duo of the earth and sky when they spoke of *Dyavaprthivi* in many Suktas. The earth and the sky are connected by space having air and atmosphere. According to the *Taittiriya Upanisad*, it is characterized by the quality of sound. It is noted to give rise to the earth through vayu, agni and apas.

The word Kala in the Vedic literature generally means time. The general division of time like *bhuta* (past), *bhavat* (present) and *bhavishyat* (future) exists in the Vedas. Other divisions of time like *ahan, masa, paksha, Sambatsara* or *paribatsara, muhurtta* and a larger time interval *yuga* are also in the Vedic literature.

The concept of space and time is significant in astronomy and astrology. There is relative importance of space and time in Indian philosophy. Space and time are taken as separate entities by the *Nyasa-Vaisheshika* School. Both are eternal and all-pervasive. They are co-existing with the entire matter, all events and actions. Space, time and matter all have sprung from one cosmic and primordial source called *prakrti*. The other view predicts two levels of space and time, viz. *Akhanda* and *sakhanda*. The *akhanda* is one continuous block of time and space, while the *Sakhanda* is the divisible space and time. The first represents the nature of *Prakrti* and the second symbolizes *akasha* under certain conditions. As illustrated by Murthy, each moment is all pervasive but not eternal. Every moment perishes to room for the next moment. Time is envisaged as a close associate of continuous evolution of matter and is known intuitively. The reflection of Brahman is the space.

Modern science defines space as a medium for light to propagate and that bend near celestial objects. The concept of space as gleaned from the theory of relativity of Einstein, is four-dimensional (x, y, z, t) where time has been taken as one of the dimensions, i.e. space is dependent on time. Hence, the space-time continuum is the most fundamental concept that holds this modern scientific thoughts and explanations. This is the object that generates and destroys the material or visible Universe.

f) Vedic way of calculating the speed of light :

In order to calculate the speed of light by the units of distance and time used by the Vedic people, we will follow Sayanacharya's interpretations of the Vedic hymns. Sayanacharya was a minister in the Court of Bukka of the great Vijaya Nagar Empire of Karnataka in South India in early 14th Century. He comments in his Rigvedic commentary on a particular verse;

'taranir vishvadarshate
jyotishkradasi Surya,
Vishvamaa bhsirochanam
tatha ca smaryata yojananam
sahashre dve dve sate dve ca
yojane ekena nimishardhena
kramaman'.

Which means - swift and all beautiful thou, O Surya, maker of the light, illuminating all the radiant realm traversing 2202 yojanas in half a nimisha". Referring to this, Raghava Rao says that Sayana gives us concrete idea about the speed of light which travels in half nimesha 2202 yojanas. One nimesha is equal to $16/75^{th}$ of second. Hence the speed of light can be calculated as follows.

In 1/2 nimesh, i.e. $\frac{8}{75}$ second,

light travels 2202 yojanas.

1 yojana = 4 kosas

1 kosa = 2000 dandas or fathoms

1 danda = 2 yards

1 yojana = 2 x 2000 x 4 yards

= 16000/1760 miles

= $\frac{100}{11}$ miles ($\because$ 1 mile = 1760 yards)

2202 yojanas = $\frac{100}{11}$ x 2202 miles

travelled by light in 8/75 seconds.

So in 1 second, light travels:-

$\frac{100}{11}$ x 2202 x 75/8 = 1,87,670 miles

In this manner, the speed of light comes as 1,87,670 miles/second, the modern value being 1,86,000 miles/second. In fact, in 1887, Michelson and Morley conducted experiments to determine the absolute speed of the earth through the hypothetical 'either' medium which helped in determining the speed of light.

Conclusion :

To sum up, we can say that the speculations of the Vedic seers regarding the origin of the Universe, the physical phenomena occurring in the nature and the universal law governing the Universe, all are quite relevant to the modern concepts developed in today's science.

Ostensibly, the science of matter and energy depicted in the Vedas has relevance with our present day science adhering to some crude notions of the Vedic seers. From Big-Bang to Big-Vision, the vedic literature is the storehouse of such concepts and speculations which explain scientific terms formulated long after; starting from Newton's law of gravitation to Einstein's mass-energy relation, the Vedas present pre-scientific knowledge, which, later on, is defined as "Science". The magico-religious phenomena described in the vedic literature gave rise to the growth of ancient Indian science, which forms the root of all development in science in true sense.

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GLIMPSES INTO ANCIENT INDIA'S MATHEMATICAL HERITAGE

Prof. Ramasankar Rath

Not many college students as well as teachers teaching mathematics in India are well informed about the contributions of ancient Indian mathematicians. We know very well the importance of zero as a number and the decimal system in mathematics. Both of these basic contributions were of the ancient Indians, though the exact time of their discoveries have not been known. In the Vedic ages, i.e. several hundred years after the decline of the Sindhu Civilization, Hindus used to perform Yagnyas on altars made of bricks. Many such altars were built in right triangular shapes whose sides were of lengths in the proportions 3:4:5, 5:12:13, 15:36:39. Also the actual lengths were $5\sqrt{3}$, $12\sqrt{3}$, $13\sqrt{3}$ units in some cases. This means that they were aware of the Pythagorean formula as well as the irrationals. In some Sulva Sutras like the Bodhayan, Apasthamba and Katayan, the formula for $\sqrt{2}$ was known in the form as given below which gives its value correct to five places of decimal.;

$$\sqrt{2}=\left[1+\frac{1}{3}+\frac{1}{3\times4}-\frac{1}{3\times4\times34}\right]$$

Boudhayan Sulva sutra describes a special type of altar called '*Garudasayana*' required for a specific Yagnya which had to be of area $7\frac{1}{2}$ square 'Purna' (a unit of measure). For

this construction the solution of a particular indeterminate equation was necessary. Boudhayan and Apasthamba described the procedure in two different ways.

A Jain saint Upaswati of the Kusumpur school fo mathematics lived in 150 A.D. In his book '*Tatwarthagama Sutra bhasya*' mention has been made of the approximate values of π as $\sqrt{10}$. Another book on mathematics named '*Sthananka sutra*' written by a Jain Saint, believed to be as old as of 300 B.C., contained ten chapters entitled *Parikarma, Byabahara, Rajju, Rasi, Kalasbarna, Yabat Tabat, Varga, Ghana, Varga-Varga* and *Vikalpa*. The first covers the four basic arithmetic principles and the second their applications. *Rajju* covered geometry and *Rasi* the measuring procedures. *Kalasbarna* was on fractional numbers, while *varga* was on squares and *Ghana* on cubes. *Yabat-Tabat* meant algebra and *Vikalpa* was equivalent of the modern words permutations and combinations. The combination procedures have been used in Pingala's *Chhanda Shastra (*Prosody*)* as also in the *Sushruta Sahmita* of 6th Century B.C. In the latter, mention has been made of '*Sadrasa*' (six basic types of tastes) asserting that a total of 63 mixed tastes of food can be prepared from it. On analysis we find that they pointed to

$$\sum_{m=1}^{6} {}^{6}C_{m} = 63,$$

when the binominal co-efficients

$${}^{n}C_{m} = \frac{n!}{m!(n-m)!}$$

In 1887, during an excavation in Bakhsali of Peshwar (Pakistan) a manuscript written in 'Sharada' lipi of Gatha language (probably of fourth century A.D.) was discovered where a formula given was:-

$$(a^2 + r)^{1/2} = a + (r/2a) - (r/a)^2 / 2(a + r/2a)$$

.

This indicated their knowledge about surds well before Bhaskara's time who mentioned $\sqrt{41}$, $\sqrt{105}$, $\sqrt{889}$ in his '*Lilavati*'. Pingala wrote a book named '*Chhanda Shastra*' (Prosody) in verse form which contained seven chapters basically devoted to compositions of music, where he defined terminologies like *Pada, Laghu, Guru, Prastara* through which he explained the procedure of conversion of a number from its decimal to binary form. Leibnitz's remark that this procedure was of Chinese origin is not correct, since '*Chhanda Shastra*' was a much older text than Fu Hsi's 'Book of Changes' containing the pictorial 'Hexagram' which led Leibnitz to such a remark.

First ten centuries of the Christian era is usually known as the classical age of mathematics. The four most distinguished mathematicians of India who lived in this age were Aryabhata (first), Varahamihira, Brahmagupta and Bhaskaracharya (2nd). It is true that their mathematics mostly centred on the study of the positions of planets and stars

and hence they were basically astronomers in the real sense. Even so they have richly contributed to the progress of mathematics in general. Aryabhata born in 476 A.D. near Pataliputra (modern name Patna) in his famous book '*Aryabhatiya*' written in Sanskrit devoted thirty three 'Sloka's to mathematics which centred on Pythagorean theorem, square and cube roots of numbers, arithmetic progression, geometry, quadratic equation and the solution of linear indeterminate equation by a method which he called '*Kuttaka*'. However most of these contents were already there in the Bakhsali manuscript, the only original part of it for which we can give credit to Aryabhata are the approximation for the value of π, preparation of sine and cosine tables and '*Kuttaka*'. His reputation was mostly due to his very good astronomical observations and accurate calculation that the earth rotates 1582237500 times about its axis in exactly the same time during which the moon orbits 57753336 times around the earth. This ratio 27.3964693572 is till now, regarded as one of the most accurate calculations in astronomy.

Varahmihira the next born reputed astronomer-cum-mathematician of the classical age (date of birth 505 A.D.) in his famous work, '*Pancha Sidhantika*' stated five important principles of astronomical calculation named *Paulisha, Romaka, Vashistha, Saura* and *Brahma* among which he proved Saura as yielding the best results. His calculations predicted that during '*Krantipata*' meaning the position of the Sun on the earth's equator, earth's rotation rate around the Sun falls to its minimum. He was the author of two other famous works *Vrihat Jataka* and *Vrihat Sanhita*. One of his striking predictions was the existence of some invisible power behind the rotation of the planets around the Sun in prescribed orbits as also the falling of objects on the earth.

Brahmagupta born in 598 A.D. in Sindhu province (of the present Pakistan) during the reign of Vyaghramukha is regarded as the best of mathematicians of the classical age. His outstanding work '*Brahmasphuta Sidhanta*' was translated into 'Arabic' language by Al-Fazri under the name *Hind-Sind*. His depth of mathematical knowledge in Varga-prakriti was evident from his discussion on the nature and solution of the quadratic indeterminate equations through an entirely new procedure called '*Bhavana*' of his own invention. He was the first mathematician to give a general method of solution of the linear Diophantine equation ax + by = c, with a, b, c as integers. While Diophantus himself had given only a particular solution, Brahmagupta had found all its integral solutions. This has been mentioned by Boyer in his book 'China and India'. Brahmagupta was the first mathematician to introduce 'zero' as a member of the number system. While the Babylonians used zero as only a local place-holder, Romans used it as a symbol of 'nothingness' in measuring quantities. His best contribution to geometry was a theorem on the area of a cyclic

quadrilateral. Bhaskaracharya (second) is regarded as the last of the reputed mathematicians of the classical age. Of the four chapters entitled *Lilavati*, *Bijaganita*, *Grahaganita* and *Gotadhyaya* of his famous work '*Sidhanta Siromani*'; the first chapter discusses, among other things, the solution procedure of a third or fourth degree algebraic equation by conversion into a quadratic one. Another speciality lay in his indication of the integration process emerging from the summation process of an infinite series as also the differentiation from the evaluation of instantaneous speed of an object by division of the time interval into a large number of equal subintervals and calculating it through a limiting process. Bhaskar lived during the period 1115-1185 A.D., was born in Bijapur of Karnatak and is believed to be the head of the famous astronomical observatory of Ujjain. He had great many contributions both to astronomy and the field of mathematics. Fermat had given a challenge to the mathematical community in 1657 A.D. for giving a general solution of Pell's equation of the type $x^2 - ny^2 = 1$. None till Euler's time had been able to answer his challenge. Bhaskar had given a solution of $61x^2 + 1 = y^2$, which was a particular case of that type of equations. It is striking to note that infinitesimal calculations (both differential and integral), Rolle's and Mean value theorems, and some theorems of spherical trigonometry have been discussed in his '*Siddhanta Siromani*'. As such many critics of his time rated him as a greater mathematician than Brahmagupta.

Other mathematicians who deserve mention are Mahavira Jain, author of '*Ganita Sarasangraha*' (850 A.D.); Sridhar, author of '*Patiganita*' (born 750 A.D.) and the algebraist Padmanabha.

For about four centuries after the death of Bhaskar II, there was almost a period of darkness in the mathematical activities in India. Kerala school of mathematics came to the scene only in the fourteenth and fifteenth century with books like *Tantrasangraham*, *Yuktibhasa*, *Karan padhati* and *Sadratnamala*, though in essence they were on astronomy. Madhaba is regarded as the founder of the Kerala School and had some innovative ideas on analysis and infinite series. Parameswara and his son Neelakantha Somayaji were his illustrious successors of the Kerala School. This school is remembered for its important contributions to the topics of convergence of power series expansions of trigonometric functions much ahead of European mathematicians.

Ancient Indian mathematics is often criticized for the absence of any formal proof in support of a mathematical assertion. Greek philosophers Plato and Aristotle and also Bertrand Russell and David Hilbert of the last century believed that mathematical truths should be regarded as the most believable among all sorts of truths, since they are deduced on the basis of a set of logical principles, which they called as their proofs. That in Indian mathematics also every assertion was supported by valid arguments is a statement

of fact. The name given here for proof was 'Upapatti', but the two differed both in their aims and methods. In '*Goladhyaya*' chapter of his work '*Siddhanta Siromani*', Bhaskar-II had stated clearly that the aim of Upapatti for establishing the truth of a mathematical assertion is two fold. One is to create a feeling of self confidence in its author about the correctness of the assertion and the other is to establish his own scholasticism before the entire mathematical community. As regards the method of proof in western mathematics, it starts with the acceptance of a few axioms as true statement on the basis of common experience and then it proceeds deducing a series of true statements, the succeeding ones from the preceding, through a logical reasoning process, till it reaches the asserted statement. Thus it contains two different types of truths, one the axioms which are self established type and the other the proved ones.

The misconception that ancient Indian mathematicians were ignorant of the importance of proof to a mathematical assertion arose because the westerners could not find any such thing in most of the translations of the text of the original manuscripts. The fact is that, the Upapattis were incorporated generally in a detailed form in the commentaries (Bhasyas) which were also often written by the authors, but the western translators did not feel it necessary to translate them along with the textual portion. In his commentary named '*Budhibilasini*' to the text '*Siddhanta Shiromani*' of Bhaskar II, Ganesh Daivagnya had remarked that Upapatti is really a summary of the text and requires special knowledge for preparing.

Some probable causes for which the westerners were virtually ignorant about the rich culture of ancient Indian mathematics are that, (a) Hindu tradition was to keep their treasure of knowledge as secret as possible from the commoners by expressing them in terse sloka form which required another equally knowledgeable person to explain in easier form; this required much labour, time and skill. This was the usual practice followed in case of religious scripts keeping them unexposed to those who, they thought should not know the valuable secrets about God unless they really sought it. (b) The second reason was the unavailability of materials for writing, which forced them to express knowledge in as short a form as possible through very difficult Sanskrit terms, capable of conveying a lot of meanings. (c) A third probable reason was communication and travel facilities from one region to another were not as easy as at present.

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"The ingenious number system, which serves as the basis of modern arithmatic, was used by the Arabs long before it reached Europe. It would be a mistake, however, to believe that this invention is Arabic. There is a great deal of evidence, much if it provided by the Arabs themselves that this arithmatic originaged in India".

Frnch Mathematician Historian - Jean - Etienne Montucla (1725-1799)

A BRIEF HISTORY OF ANCIENT INDIAN MATHEMATICS

Er. Mayadhar Swain

Mathematics has played a significant role in the development of Indian culture for millennia. Ancient Indian mathematicians had discovered many theories and formulas in mathematics, which were later discovered by the European mathematicians. But irony of the fact is that the history of mathematics gives credit to the European mathematicians for these discoveries. Many mathematical ideas originated in the Indian subcontinent have a profound impact on the world. In this article, a brief review of the outstanding innovations discovered by ancient Indian mathematicians is given.

Mathematics in Indus Valley Civilization (2600 BC - 1900 BC) :

Two of the most important cities, Harappa and Mohenjo-Daro of the Indus Valley Civilization provide evidence of a high degree of town planning, where construction of buildings followed a standardized measurement. This civilization had an advanced brick-making technology, where each brick had standardized for length, breadth and height. For trading purpose, the Harappans developed a standardized system of weights in which, initially, each weight was double the preceding one, then 10, 100 or 1000 times the value of a smaller weight. This shows that the Harappans could not only multiply a quantity by such factors, but also had an inclination for a decimal system of multipliers.

Sulva sutras (800 BC - 200 BC) :

The first Indian texts dealing explicitly with mathematics are the Sulva sutras. These texts are considered to date from 800 BC to 200 BC. There are eight Sulva sutras authored by different persons. Each Sulva sutras is named after its author. The most notable Sulva sutras are those authored by Baudhayana (800 BC), Manava (750 BC), Apastamba (600 BC) and Katyayana (200 BC).

The famous Pythagoras Theorem is in Baudhayan Sulva sutras. This was discovered in Europe by the Greek mathematician Phythagoras nearly 300 years after Baudhayan; but it is named after him. The twelfth century mathematician Bhaskaracharya gave an algebraic proof of this, as opposed to the geometric proof, the Greeks had given.

The Sulva sutras introduce the concept of irrational numbers which are not the ratio of two whole numbers. For examples, the square root of 2 is one such number. There have been given elaborate geometric methods to construct a square resulting from the addition or subtraction of two other squares, or having the same area as a given circle and vice-versa.

The mathematics of this period had been developed for solving practical geometric problems, especially the construction of religious altars.

Jain Mathematics (600 BC - 500) :

Jains investigated into colossal numbers and infinity in their study of cosmology. Besides several other fields of mathematics such as number theory, geometry, indices, computing with fractions and combinatorics were developed by them. Jains used square root of 10 as the value of pi, which remained popular in India for quite a few centuries. The recursion formula for binomial co-efficient and the 'Pascal triangle' were already known in this period.

Place-Value System and Zero :

The invention of place-value system and zero is the greatest contribution of India to the world. It was developed in India and transmitted to Europe through Arab. The Europeans could not know its actual origin and hence named it as Arabic decimal system; but when the actual source of its development was known, it is now called as Hindu-Arabic numeral system.

The decimal system was developed in India around 400 AD and by 600 AD, it was well in use. In this system, there are ten symbols, each symbol has an absolute value, but also has a value relative to its position. For example, the number 3 and 6 have a value of their own, but also have a value relative to their positions in the number 36. Of course, a place-value system of numbers was probably known to other civilizations. For example, the Babylonians used a sexagesimal place-value system as early as 1700 BC.; but the Indian system was the first decimal system. Further, there was no symbol for zero in the Babylonian System until 400 BC.

The great mathematician Laplace had told: "The ingenious method of expressing every possible number using a set of ten symbols (each symbol having a place value and an absolute value) emerged in India. The idea seems so simple nowadays that its significance and profound importance is no longer appreciated. Its simplicity lies in the way it facilitated calculation and placed arithmetic foremost amongst useful inventions. the importance of this invention is more readily appreciated when one considers that it was beyond the two greatest men of antiquity, Archimedes and Apollonius."

Classical Period (500 to 1200) :

The classical period in Indian mathematics started about 500 AD from Aryabhatta and continued to about1200 till Bhaskaracharya. Within this period a number of mathematicians had developed many formulas and theories in mathematics.

Aryabhatta (476 - 550) :

Aryabhatta was the teacher at Nalanda University (near today's Patna) and was the author of masterwork *Aryabhattiya*. It was the first work purely on mathematics and astronomy. Earlier to this, Indian mathematics was hidden behind religious texts. It covers several branches of mathematics such as algebra, arithmetic, plane and spherical trigonometry. Aryabhatta had systematically put all the knowledge of mathematics and

astronomy known till that time in this book and added his own discoveries also. The book written in 499 AD is too concise (just 121 verses) and the mathematical part is of only 33 verses. He has given only mathematical theories without any proof and example. It was difficult to understand so that more than twelve commentaries had been authored between 6th & 16th century explaining it.

The important part of *Aryabhattiya* is the precise tables of sines and the accurate value of pie (3.1416) known till that time. He had put algorithms for extraction of square roots and cube roots, which we are taught now almost similarly. He had devised a way of solving indeterminate equations of first degree with two unknowns i.e. ax - by = c. This method was known as *kuttaka* (pulverizing). For example, by solving 137x + 10 = 60y, he had found the values of x and y as 10 and 23 respectively.

In *Aryabhattiya*, Aryabhatta provided elegant results for the summation of series of squares and cubes:

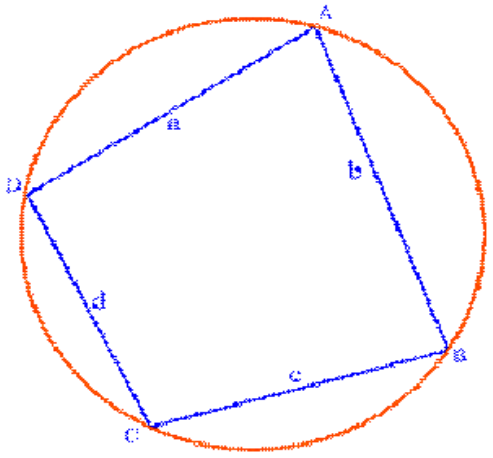
$$1^2 + 2^2 + \cdots + n^2 = \frac{n(n+1)(2n+1)}{6}$$

and

$$1^3 + 2^3 + \cdots + n^3 = (1 + 2 + \cdots + n)^2$$

Brahmagupta (598 - 670) :

Brahmagupta was the director of the observatory at Ujjain. His masterpiece is *Brahmasphuta Siddhanta*. He was the first person to find the formula for the area of the cyclic quadrilateral (i.e. inscribed in a circle).



If ABCD has sides of lengths a, b, c and d, then the area is given by

$$A = \sqrt{(s-a)(s-b)(s-c)(s-d)}$$

Where, $s = \frac{a+b+c+d}{2}$

It is to be noted that this formula was rediscovered in Europe in 17th century. He has given the formula for the diagonals of the ab

$$e = \sqrt{\frac{(ab+cd)(ac+bd)}{(ad+bc)}} \text{ and } f = \sqrt{\frac{(ad+bc)(ac+bd)}{(ab+cd)}}$$

Brahmagupta had introduced the concept of negative numbers and given formulas for its mathematical operations. He discovered the algorithm to solve second-order indeterminate equation (called Varga Prakriti) of type $Nx^2 + 1 = y^2$. For example, in his book he has solved $8x^2 + 1 = y^2$, to find five sets of values of (x, y) as - (1, 3), (6, 17), (35, 99), (204, 577) and (1189, 3363).

Bhaskar-1 (600-680) :

Bhaskara I was a contemporary of Brahmagupta and did pioneering work in trigonometry. His books are *Mahabhaskariya* and *Laghubhaskariya*. Particularly, he had discovered a remarkably accurate rational approximation for the sine function as :

$$\sin x = 16x(\pi - x)[5\pi^2 - 4x(\pi - x)]^{-1} \text{ for } 0 \leq x$$

Bakhshali Manuscript :

In 1881, a mathematical manuscript was found in the village Bakhshali (now in Pakistan) in the form of 70 leaves of birch bark. It is thought that the original work belongs to 7th century. Extensive mathematical calculation techniques are found here. It includes fraction, square root, progression, measure of time, weight and money etc.

Mahavira (800-870) :

Mahavira was a Jain scholar. He lived in the court of Rashtrakuta king (in today's Karnataka). He had authored the book *Ganita Sara Sangraha* written about 850. It was the first Indian book based only on mathematics (separated from astronomy). He had dealt with finite series, unit fraction, linear equation with unknowns, permutation & combination, quadratic equation and circumference of an ellipse. He was the first mathematician to devise standard formulas for combination as;

$${}^{n}C_{r} = \{n(n - 1)(n - 2) \times ... \times (n - r + 1)\}/1.2.3..r$$

Bhaskarachaya (114-1185) :

Bhaskaracharaya (also known as Bhaskhar II) was the director of Ujjain observatory. His masterpiece is *Siddhanta Siromani* (literally the crest jewel of the Siddhants). It consists of four parts and the mathematical parts are *Lilavati* and *Bijagantita*. He developed a still more effective algorithm (called chakravala or cycle) for the solution of indeterminate equation of second degree. For example, he has given the smallest integral solution of $61x^2 + 1 = y^2$ as x = 226153980 and y = 1766319049. It is to be noted that five centuries later in 1657 the French mathematician Pierre de Fermat offered the same equation as a challenge among European mathematicians. Bhaskaracharya has also given the notion of integration and derivative in calculus; but he could not develop it further.

Lilavati was a popular book and was the text book for about 700 years till the English introduced western education system in India. Even Akbar had it translated into Persian by his court poet Abul Faizi in 1587.

Kerala School of Mathematics :

It was earlier thought that after Bhaskaracharya the study of mathematics in India had dwindled. The reason is the invasion of foreigners on India and as a result lack of patronage to Indian scholars. But recently it was found that mathematics was studied and flourished in Kerala from the 14th to the 17th century. Kerala was far south of India and free from foreign invasion and so good atmosphere was there for its study. Among the Kerala mathematicians, Madhav (1340 - 1425), Nilakantha Somayaji (1444 - 1545) and Jyesthadeva (1500 - 1600) are notable. Madhav

discovered power series expansion for the sine and cosine functions as :

$$\sin(x) = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \frac{x^9}{9!} - \ldots$$

$$\cos(x) = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \frac{x^8}{8!} - \ldots$$

Earlier it was known as Newton series and now it is being called Newton - Madhav series. From it, he also found out the fundamental expansion of pi as:

$$\frac{\pi}{4} = 1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + - \cdots$$

In the history of mathematics, it is known as Gregory- Leibniz series, although they have rediscovered it much later to Madhav. Madhav gave a more rapidly convergent series for pi as:

$$\pi = \sqrt{12} \sum_{i=0}^{\infty} \frac{(-1)^i}{(2i+1)3^i}$$

$$\pi = \sqrt{12}\left(1 - \frac{1}{3 \cdot 3} + \frac{1}{5 \cdot 3^2} - \frac{1}{7 \cdot 3^3} + \cdots\right)$$

The value of pie as given by Madhav is 3.14159265358979324 is astonishingly correct up to 17 places.

Jyesthadeva found out the binomial expansion:

$(1 + x)^{-1} = 1 - x + x^2 - \ldots\ldots\ldots + (-1)^r x^r + \ldots\ldots$

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"The ingenious method of expressing every possible number using a set of ten symbols (each symbol having a place value and an absolute value) emerged in India. The idea seems so simple now-a-days that its significance and profound importance is no longer appreciated. Its simplicity lies in the way it facilitated calculation and placed arithmatic foremost amongst useful inventions. The importance of this invention is more readily appreciated when one considers that it was beyond the two greatest men of Antiquity, Archimedes and Apollonius".

PIERRE-SIMON LAPLACE (1749-1827)
(FRENCH MATHEMATICIAN)

THE INFINITY MIND

Ansuman Dash

In late nineteenth century a poor boy grew up in Kumbhokonam village of Tamilnadu who was mostly seen to roam around a local temple and silently kept looking at the idol of the goddess. He spent most of the time of his childhood in the temple writing series of numbers and calculations on the veranda of the temple. That boy later became a great mathematician and discovered many hidden nature of numbers and functions which include Riemann series, the elliptic integrals, hypergeometric series and his own theory of divergent series. However, initially he lacked the proofs of his equations. When asked by his superior in Britain, he told that he felt like the goddess of his village temple whispers the equations and numbers in his ears. This great mathematician is Srinivas Ramanujan whose contributions are overwhelmed in the mathematical society in the whole world. One pretty exciting discovery he made about number 1729 commonly known as Ramanujan number is that 1729 is the smallest number that could be expressed by the sum of two cubes in two different ways.

1. $1^3 = 1x1x1=1$

$12^3 = 12x12x12=1728.$

So $1+1728=1729$

2. $9^3 = 9x9x9=729;$

$10^3 = 10x10x10=1000.$

So $729+1000=1729$

Incidentally 1729 was the number of the taxi travelled by G.H.Hardy, the famous mathmatician in England to meet Ramanujan in the hospital. The next number with this property is 4104 as it can be expressed as the sum of 4096 + 8 (that is, $16^3 + 2^3$), and also the sum of 3375 + 729 (that is, $15^3 + 9^3$).

When discussing mathematics, this is worth to mention the contributions of the famous mathematicians of vedic and historic period who are Aryabhatta, Brahmagupta and Bhaskaracharya. Born in 5th century Aryabhatta has major contributions in the field of astronomical computations. Brahmagupta was born in 6th century and known for the use of zero as a number and also as a symbol (0) which stood for "nothing". He calculated the sum of the squares of the first n natural numbers as $n(n + 1)(2n + 1)/6$ and the sum of the cubes of the first n natural numbers as $(n(n + 1)/2)^2$. He also discovered the negative series numbers and obtained the result that:

Minus x Minus becomes Plus.

Bhaskaracharya was born in the twelfth century in today's Bijapur, Karnataka. His works in the field of mathematics were detailed in his book "*Siddhânta Shiromani*" which has four parts: *Leelavati*, *Bijaganita* (algebra), *Goladhaya* (trigonometry) and *Graha ganita* (planetary motion). *Leelavati* part mainly contains arithmetical terms, interest computation, arithmetic and geometric progressions. His book also mentions the concept of division by zero and infinity.

The contemporary attempt to discover the laws that govern the fundamental objects and to study the fundamental nature of reality dominantly known as metaphysics has roots in ancient india's philosophies or darsanas. The richness of ancient india's philosophical science can well be understood from the Vedas and Upanishads. The oldest texts in the world is India's Rigveda, the exact time of composition of which is unknown. The Rigveda contains the hymns devoted to various gods of nature . Importantly , Rigveda was not written, it was originally composed orally and transmitted to generations orally too. This is definitely amazing. As there was no method back then to keep historical record of their realization Rigveda was obviously the document of human mind then. It is believed that many of the verses of the original Rigveda were lost because the only mode of transmission of the contents was oral from memory. Later, Rigveda was followed by other three vedas known as Sam, Atharb and Jajur which were scripted. For scripting, the ink used during 4th century BC was developed in India and called masi , also popularly known as India Ink. The ink was originally carbon pigment ink and a mixture of several chemical components. Several Jain sutras in India were compiled in Carbon pigment Ink. The Great philosopher Swami Vivekanada has mentioned in his book " The Science and Philosophy of Religion" about the nature of the universe and the fundamental of soul. He possessed the idea that as the sun , reflected from millions of globules of water, appears to be millions of Suns, similarly all these souls of different beings, men animals etc are reflections, not real but illusion. There is but one infinite being in the universe whose appearance is delusional. In dream everything feels real and on waking up from dream it became an illusion. Once known it had lost its power of illusion. Similarly this illusion of the universe will break one day. The whole of this will vanish, melt away. This is realisation. All our knowledge is within the network of maya (illusion).

(Swami Vivekanada)

Every search first has been in the human mind. We see that a thought rises in the mind and it disappears into the infinity. Where it goes we never know. In Bhagavad-gita the observable reality are mentioned as the knower, the known and knowledge. In modern terms the knower is referred to as the observer, the known as that which is observed, and knowledge translates into the process, or method, by which something is observed. Vedanta provides a systematic and scientific study of these three aspects of reality. The last word of Advaita Vedanta is "TATTVAMASI" which means "That is You". The term establishes your existence in the universe : who you really

are ie the realization of fundamental nature of being. Everything is you. When you help someone it means you are helping yourself. You are doing it for yourself to yourself. In Hindu cosmology the universe is cyclically created and destroyed. The ancient philosophers of India rejected the idea that this world was created out of nothing. As they must have observed that only nothing can come out of nothing. That is, all work being done requires some material. Naturally the universe must have come out of something or some material. This theory also has been stated by the great sage Kapila, the father of cosmology in his Samkhya Philosophy one of the oldest one not only in India but in the world. These ancient Indian vedic theories have been the subject of metaphysics today.

TATTVAMASI: The Consciousness of being

Apart from the field of mathematics, philosophical science and metaphysics, Indian scientists have also contributed in every other field of science and technology. One of the prominent Indian scientist Sir Jagadish Chandra Bose proved that plants are also sensitive to heat, cold, light, noise and various other external stimuli. He invented a very sophisticated instrument called the crescograph, which could record and observe plants' minute responses to external stimulants. He also authored two famous books "Response in the Living and Non-living" (1902) and 'The Nervous Mechanism of Plants' (1926). In the field of medicine and biology the ancient Sanskrit text " *Sushruta Samhita"* and *"Charak Samhita"* are two important treatises written by ancient Indian physician Sushruta and Charak respectively. These texts contain description of more than 1100 illness, medicinal plants, a detailed study on anatomy, anaesthesia and surgery. Similarly, in the field of technology India have shown significant and remarkable advancement in ancient time in architecture, civil engineering, ship building and navigation .The paintings in the wall of Ajanta caves and the Sanskrit and Pali texts depict the navigation of historic time. The coastal regions were having commercial relations with several countries across the Bay of Bengal like Cambodia, Java, Sumatra, Borneo, and even up to China and countries across the Arabian Sea like Arabia, Egypt and Persia. For navigation an unique compass was used. The compass had an iron fish that floated in a vessel of oil and pointed to the North. This was known by the Sanskrit word *Maschya Yantra.*

Maschya Yantara: The compass

In the architecture of temple building symmetry and proportion were deliberately emphasized by architects. Most of the temples have the pattern of towers grouped among smaller towers, themselves grouped among still smaller towers (as shown in the picture below), that also depicts the endless repetition of universes in cosmology.

Smaller temple towers grouped in to a whole temple

The richness of architectural work can be seen in the stone carving work of many temples including the Sun temple of Konark and Modhera. In Modhera Sun temple, one of the stone carving depicts the delivery of baby inside water which suggests that the then civilisation was well aware about this scientific method. One interesting fact about the Modhera Sun temple was that it was exactly established on the line of tropic of cancer ie 23.3 degree latitude. With the limited resources back then our ancestors could have exactly calculated the point where they can pay tribute to the Sun god.

Every generation ahead should know the knowledge possessed by our ancestors and the discoveries and contributions made by them to the world society. This not only makes one feel proud but also makes one learn about the infinity nature of creativities from a thought of the mind.

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"Between the idea
And the reality
Between the motion
And the act
Falls the Shadow...
Between the conception
And the creation
Between emotion
And the response
Falls the Shadow...
Between the desire
And the spasm
Between the potency
And the existence
And the descent
Falls teh Shadow..."

T.S. ELLIOT

"The most beautiful thing we can exprience is the mysterious. He to whom this emotion is a stranger, who can no longer wonder and stand rapt in awe, is as good as dead: his eyes are closed".

Albert Einstein

PI (π) IN THE SKY OF ANCIENT INDIA

Bibhuprasad Mohapatra

Common mathematical symbol or mathematical constant Pi always appeals mathematicians and math lovers of the whole world. Mathematical symbol is a conventional sign used for the written notation of mathematical notions. The symbol used by mathematicians to represent the ratio of a circle's circumference to its diameter is the lowercase Greek letter 'π' (spelled out as pi), and derived from the first letter of the Greek word perimetros, meaning periphery or circumference. In primary mathematics, students are introduced to pi as a value of 3.14 or 3.14159. Though it is an irrational number, some use rational expressions to estimate pi as 22/7 or 333/106. Pi is so fascinating and undoubtedly the most interesting number that even Pi Day is observed worldwide with enthusiasm on 14th March (3/14). Many mathematicians are engaged to calculate the value of pi to so many decimal places through mathematical modelling, simulations and iterative algorithm. That's why mathematicians call Pi as "infinite decimal", the digits go on forever and ever after the decimal point.

Ancient India was a great repository of knowledge on different studies. Older generation persons (Septuagenarian or Octogenarian) used to say that all knowledge is there in the Vedas. Anyone who hears such words will have the first reaction that it is an over confident statement. Still we all are aware the contributions of ancient India towards science and technology. We can trace the value of pi in ancient Indian mathematics. Astronomical calculations in the *Shatapatha Brahmana* (4th century BC) use a fractional approximation for pi as 339 / 108 = 3.139. The ancient Jain school of mathematics preferred the approximation 3.1622. The mathematician Madhava arrived at more correct value of Pi in the 14 century.

The western mathematicians could get this value up to 16 digits accurately till the invention of computers. Some learned people claim that a Sanskrit verse or sloka in the 10th book of Rig Veda appears to be written for praising Lord Indra (Devraj or King of Gods) which contains the value of Pi. Any sloka in the ancient Hindu manuscripts has more than one meaning. The technical translation of that Sloka gives the value of Pi up to 31 digits accurately.

Vedic Numerical Code :

In Sanskrit, the following Vedic Numerical code was used in many slokas:

"कादि नव टादि नव पादि पञ्चक यदृयश्टक क्ष शुन्यम्"

"Kaadi nava Taadi nava Paadi panchaka Yadyashtaka Kshah sunyam"

Meaning or Decoding :

Kaadi Nava Starting from ka, the sequence of 9 letters represent 1,2,3,..9
Similarly Taadi Nava , starting from ta
Paadi panchaka (1-5), starting from pa
Yadyashtaka (1-8) starting from ya
And ksha represents 0

In detail

ka(क)-1, kha(ख)-2, ga(ग)-3, gha(घ)-4,gna(ङ)-5,
cha(च)-6, cha(छ)-7, ja(ज)-8,jha(झ)-9
ta(ट)-1, tha(ठ)-2, da(ड)-3, dha(ढ)-4,~na(ण)-5,
Ta(त)-6, Tha(थ)-7, Da(द)-8,Dha(ध)-9
pa(प)-1, pha(फ)-2, ba(ब)-3, bha(भ)-4, ma(म)-5,
ya(य)-1, ra(र)-2, la(ल)-3, va(व)-4, Sa(श)-5,
sha(ष)-6, sa (स)-7, ha(ह)-8, kshah (क्ष)-0.

Based on this numerical code, there's a sloka which was written in favour of both Lord Krishna & Lord Shiva contains the value of Pi:

गोपीभाग्य मधुव्रातः श्रुंगशोदधि संधिगः |

खलजीवितखाताव गलहाला रसंधरः ||

Gopeebhaagya madhuvraathah shrumgashodhadhi samdhigah, Khalajeevithakhaathaava galahaalaa rasamdharah.

ga-3, pa-1, bha-4, ya -1, ma-5, Dhu-9, ra-2, tha-6, shru-5, ga-3, sho-5, dha-8, Dhi -9, sa-7, Dha- 9, ga-3, kha-2, la-3, jee-8, vi-4, tha-6, kha-2, tha-6, va-4, ga-3, la-3, ha-8, la-3, ra-2, sa-7, Dha-9, ra-2

Putting the value accordingly, the value of pi will be -

3.14159265358979323846264338327 92…

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ORIGIN OF NUMBER SYSTEM

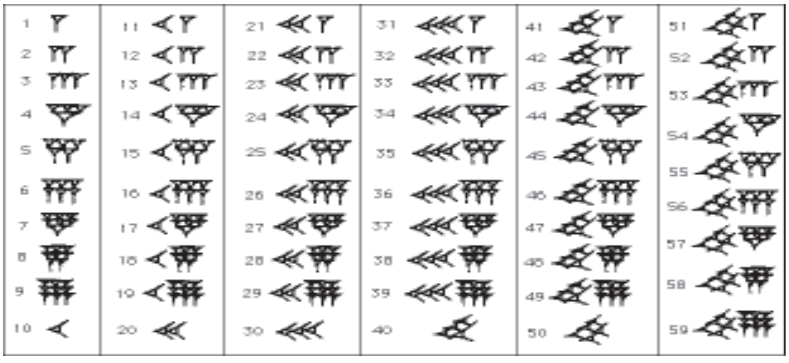
DebabrataBehera
Sujata Puspamitra

Mathematics is the root of science. Whatever was conceptualized and ever conceived under the realms of science has roots in mathematics. It is generally believed that the need for numbers, for that say counting, arose when man came out of the forest as an animal herder. With owning of possessions, man felt an imminent need to keep a count of them. They might have used pebbles or tokens to keep a tab if all their animals returned to shed which left in the morning.The invention of number system was never an accident and took a long path along the advancement of human civilization.

This rudimentary form of calculation sufficed the requirement for thousands of years, but with advancement of agriculture and trade maintaining large piles of pebbles and tokens became cumbersome. Hence the need to grouping numbers arose for easier representation of higher numbers. It is believed that the concept of systematic counting had evolved in Sumer, one of the earliest human civilizations. The Sumerians had symbols representing one unit, ten units, hundred units, and so forth. They would bake these into clay tokens and string them together to create larger numbers.The Egyptian civilization too had their symbols for different numbers. While their symbol for one was a line, the symbol

for ten was a rope and the symbol for a hundred was a coil of rope. They even had numbers for thousand and ten thousand. The Egyptians were the first to dream up the number one million, and its symbol which was a person on its knees, hands upraised in the air, in a posture of humility.

The token system continued for about thousand years but had been found wanting on several fronts. Its main drawback was that it was not a positional system, meaning that so long as the tokens were kept together it didn't matter what order they were placed in.The place value system was essential to apply operations to numbers. Babylonians are believed to be the first to develop the place-value system.They had two cuneiform symbols used for counting: a vertical line to represent one unit, and a chevron to represent ten units. Different combinations of lines and chevrons were arranged in precise positioning to create unique number representations up to the value of sixty.When one wonders why minutes and seconds are measured in units of 60, or why shapes like circles, rectangles and triangles are multiples of 60 degrees he/she can thank the Babylonians for their influence. There were many number systems evolved in many parts of the world. Most of them struggled to develop into an arithmetic system because of one main reason, for they lacked the concept of counting nothing:**zero**. To the rescue of



Babylonians number system

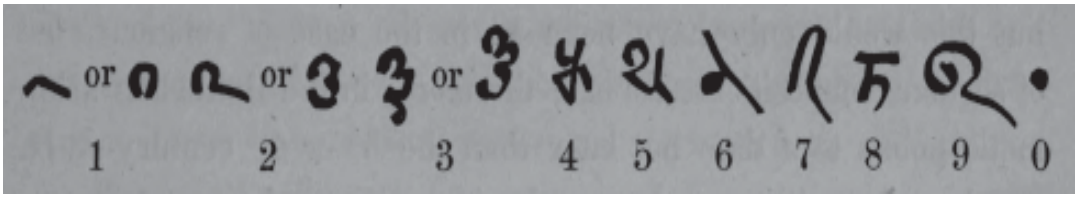
Chaturbhuj temple at Gwalior having one of the earliest depiction of zero

mathematics, a number system evolved around 500 AD that had the concept of zero and it included a symbol for it. The Hindu-Arabic numbers (0, 1, 2, 3, 4, 5, 6, 7, 8, 9) which is now the most widely accepted number system, was developed by Indian mathematicians. With the inclusion of a place-holder zero in a decimal number system, man found what could be adapted into modern mathematics.This number system was then learnt by Arabs who had trade relationship with India and they popularized it to further west.

In 1881, an ancient manuscript written on birch bark was discovered in Bakhshali (in present day Pakistan). The manuscript, written in sanskrit dating back between 3rd and 7th AD, is the oldest manuscript in Indian mathematics known till date. The most important feature of Bakshali manuscript is use of zero. It used numerals with a place-value system, using a dot as a place holder for zero. The dot symbol called the shunya-bindu means the dot of the empty place.The addition of zero to the natural numbers was so phenomenal that a separate term was coined for the counting numbers including zero, the whole numbers.

According to a popular myth, the original forms of today's numeric symbols had derived from the number of angles they contained which indicates their values. However, no evidence exists in support of this claim.

It took humans really long to create present day number system, the alphabets of mathematics. This had been a slow but constant process, of which we are even not sure if it has come to an end at all.



The numerals used in the Bakhshali manuscript

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"Whilst we use letters for calculation according to their numerical value, the Indians do not use letters at all for arithmetic. And just as the shape of the letters that they use for writing is different regions of their country, so the numerical symbols vary".

Al-Biruni (973-1050)
Iranian Scholar

VRIKSHAYURVEDA AND MAHARSI PARASARA

R.B. Mohanty

The science of Botany was quite developed in ancient India in understanding the plant kingdom, their importance and utility. There are sufficient proof available to show that agriculture, horticulture, medicines etc. were developed to a great extent during the Vedic Period (1500 BC – 500 BC). Even a holistic system of medical science called "Ayurveda" was developed during that period, which heavily depends on plants for preparation of medicines. The great scholars who have contributed profusely in developing this indigenous system were Maharsi Charaka (1000 – 800 BC), Sushruta (800 – 700 BC), Atreya (6th Century BC), Bangasena (500 – 100 BC), Nagarjuna (50 – 250 CE), Vagbhatta (6th Century), Madhabakar (7th Century), Patanjali (8th Century), Chakradatta, Sarangadhar etc. They no doubt had extensive knowledge on the plant life and their medicinal properties. Maharshi Parasara was one such Vedic Scholar who had codified his knowledge in the classical text "*Vrikshayurveda*", considered as one of the earliest authentic texts on plant science.

Biogrophy and Contribution of Parasara

Maharshi Parasara was a Rigvedic seer (1500 – 1000 BC), who was the father of Maharshi Ved Vyasa. His birth place is said to be at Panhala Fort in Kolhapur district of Maharashtra. He was the author of many ancient Indian texts and accredited as the author of verses in the "*Rigveda*", the *Bishnu Purana* (a religious text), "*Parasara Smruti*" (a code of laws), "*Krishi Parasara*" (a treatise on agriculture and Weed Science) and "*Vrikshayurveda*" (science of life of plants).

Vrikshayurveda:

The text gives detailed characteristics of vegetable drugs including the distribution, habitat, suitable soils for growth, season of collection, duration of efficiency and methods of storage of those medicinal plants. Parasara has clearly explained the structure of a plant cell in this Sanskrit text and even explained the phenomenon of photosynthesis in the 4th chapter (*Vriksha Sarira Dharma Sashtram*) of the same book. "*Vikshayurveda*" is considered to be an ancient botany primer for students of traditional medicine.

For such great contribution, Maharshi Parasara is known as the founding father of ancient Botany of India.

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DEVELOPMENT OF HEALTH CARE SYSTEM IN INDIA

Dr. (Mrs.) Kalyanee Dash

What is Health Care? :

According to World Health Organisation (WHO), health is a state of complete physical, mental and social well being of a person and not merely the absence of disease or infirmity. History suggests that health and healthcare system has developed since time immemorial. Primitive physicians of Egypt had very good knowledge about human body, different diseases and their treatment.

According to world famous medical historian Henry Siegerist – "Every culture had developed a system of medicine and the medical history is one aspect of history of culture". India had initiated its health care system which involved the physical ailment of the patient. But it also involved the environment and cosmological balance, imbalances and disturbances. During that time human illness and diseases were involved with physical, mental, spiritual and supernatural essence of the man. Ancient medicines were dealing with plants, minerals, environment, climate and body composition of the man. At that time priests, herbalists and magicians were diagnosing and curing the illness of the patients.

India is a country of rich heritage and culture. Many ancient civilizations have been developed here, since it has varied geographical, climatic conditions and environments.

Provision of Healthcare for human population:

When there was development of human civilization and the Indus Valley culture was so developed that it assimilated the Aryan Culture. In ancient days, Indian system of medicine was not about illness and treatment. Where there was man, there was need of medicine. Since India has been the cradle for ancient civilisation and early organized human colonisation, knowledge and use of medicines as it is today, is the total knowledge accumulated over centuries, developed with the evolution of man.

In ancient days traditional health care involved the physician and his patient. The physician was knowing all aspects of his patient's life and lifestyle before the diagnosis and treatment of his/her illness. Hippocratic oath taken by the physicians, was written in Greece in 5th Century BC. It puts a sense of dedication, sacrifice and treatment sense in the heart of physicians.

Development of Indian Medicines:

In our country, the basic medicine system were Ayurveda and Siddha. Dhanvantari is considered as the Hindu god of Ayurveda. Atreya, Charka, Sushruta and Vaghbhatt were the celebrated authorities of Ayurvedic medicine. Atreya was the first Indian physician and teacher who lived in ancient university of Takshashila. "Vatta", "Pitta" and "Kapha" are now also considered three important "Dosha"s in Ayurveda. India has developed and updated its ancient systems of medicines.

At present, AIIMS endorses Ayurveda for Rheumatoid Arthritis. On April 4th, 2015 in a significant scientific validation for traditional therapies, certain Ayurvedic formulations were tested for Rheumatoid Arthritis. Our trade practices with other countries and the invasion of our country by foreigners brought many changes in our health care systems and medicines. There was open exchange of knowledge and cross cultural interactions which brought more development in our health care system. India boasts of two truely unique indigenous systems of medicines i.e. Ayurveda and Siddha. Ayurveda (complete knowledge for long life) was used to treat ailing people, Charaka and Sushruta were respectively the oldest physicians and surgeons of our country. Charaka was giving traditional herbal preparations as medicine and Sushruta was a surgeon. *Charaka Samhita* and *Sushruta Samhita* were famous medicine and surgery books. The health care which we observe today, is the result of accumulated knowledge gathered over hundreds of years.

The earliest known surgery (an amputation) was done about 4900 BC in Bultiers – Bulan Courte of France. India was famous for its medicinal knowledge in the past. We had prescription of herbs for different illnesses.

Traditional Chinese Medicines:

Chinese medicines developed as a concept of Yin and Yang, acupuncture and acupressure. It has even been used in modern medicine. These medicines are traditional, which are built on a foundation of more than 2500 years of Chinese medical practice. It includes different herbal medicines, acupuncture, massage, exercise and dietary therapy. But recently it is influenced by modern medicine.

The Traditional Chinese Medicine (TCM) International Service Complex is located in Huaihua city, in Mid-South China. It has a medical school, TCM Book Store, TCM Hospital, Acupuncture Centre and TCM Herbal Pharmacy.

Development of Hospitals:

The hospital is an important social organisation which offers considerable advantages to both the patient and the society. According to World Health Organisation (WHO), the hospital is an integral part of social and medical organisation, the function of which is to provide for the population complete health care, both curative and preventive and whose outpatient services reach out to the family and its home environments. The hospital is also centre of the training of health workers.

Evolution of hospital is traced in ancient Mesopotamia towards the end of 2nd millennium. During that period the belief was that medicines were magical and mythological beliefs and the diseases were caused by supernatural forces. The foundation of modern medicine can be traced back to ancient Greeks. Priests and Doctors were part of ruling class with great political influences and the hospital

was also a meeting place of people. In pre-historic days a different kind of medicine was practised in Egypt, Greece, Rome, Mesopotamia, India, Tibet, China and some other countries.

About 6000 years back, medicine was first used in ancient Mesopotamia (South-West Asia). Under the rule of Hammurabi dynasty (1728-1686 BC), the first recorded medical prescription came from Sumer in ancient Babylon. During that period, first regulation about Doctor's practice and their fees were recorded. The Mesopotamian Civilisation made important contribution to the development of medical system in India.

Hippocrates is the father of medicine. He is famous for his non-religious approach to medicine and in 480 BC, he stated the use of auscultation and performed surgical operations. He kept detailed records of his patients with their diseases from tuberculosis to ulcers. He was an epidemiologist and he described the relationship between man and his environment.

In India hospitals were existing from ancient times. During 6th century BC, during the time of Buddha, there were a number of hospitals to take care of handicapped and poor patients. By 600 BC, efficient hospitals were constructed in India. During the reign of king Ashoka, outstanding hospitals were built in India.

Books written by Arabian and European travellers (Around 600 AD) reveal that the study of medicine in India was at its height during that time. The efficiency of native Indian Vaidyas became poor due to lack of encouragement. The history of hospitals has stretched over 2500 years. In ancient cultures, religion and medicines were linked. Invasion of foreigners in the 10th Century AD, brought their own physicians (Hakims). With the arrival of European missionaries, the use of Allopathic system of medicine began in the 16th Century. It was during the British rule that the construction of modern hospitals developed in our country. Organised training regarding medical studies started in the 19th century.

Hospital development became more progressive in Europe during middle ages. Pope Innocent III asked rich christians to build hospitals in every town. The oldest hospital still existing are "Hotel-Dieu" in Lyons and Paris – France.

According to Maha Vamsa, king Pandukabhaya of Anuradhapur Kingdom of Sri Lanka (437 BC – 367 BC) had built lying-in-homes and hospitals (Sivikasotthi-sala) in different parts of the country. This is the earliest evidence we have regarding the hospitals specifically dedicated to the care of sick in the world. Mihintala Hospital at Mihintala, Sri Lanka founded by King Sena the second (853-887 AD), the ruins of which can be seen in its restored layout at the entrance to the site, is one of the oldest hospitals in the world. Florence Nighingale developed the modern nursing profession during the Crimean War.

In north India, the heads of Vaishya (merchant) families established some houses in big towns for dispensing charity and medicine. All poor, destitute, orphans, crippled

and diseased persons were going there and getting all kinds of help and doctors were taking care of their diseases. They were getting good food and medicines and were getting well soon. According to *Charaka Samhita* a hospital was built between 100 BC – 150 CE. According to Fahian, India was the first part of the world to develop an organised cosmopolitan system of institutionally based medical provision. In USA, the first modern hospital was "Pennsylvania Hospital" founded in Philadelphia in 1751.

During the reign of king Ashoka, Indian hospitals started to look like modern hospitals. They followed the principles of sanitation. Caesarean Sections were performed with close attention to save both the mother and the child. Physicians were appointed for every 10 villages to serve the health care needs of the populations and regional hospitals for the infirm and destitute were built. Health care is one of the most complex activities in which people get engaged. Indian medicine began to decline from foreign invasions in the 10th century. During Akabar's period Unani Medicine System spread all through greater part of India. During this period, there were good number of government hospitals as well as private hospitals run by many physicians. The hospitals are basically service organisations. The modern system of medicine in India was introduced in the 17th century with the arrival of Christian missionaries in South India. In the 17th century, British Empire established first hospital in Chennai in 1664.Organised medical training was started with the first medical college in Calcutta in 1835, two in Delhi in 1835 and 1836, in Mumbai in 1845 and Chennai in 1850. The oldest medical college of Asia was established in Calcutta on 28th January, 1835. All India Institute of Medical Science (AIIMS) was established in 1956, which is the leading hospital in India, in the 21st century. Top hospitals in India are – AIIMS, Apollo hospitals, Fortis Hospital, NIMHANS, CMC, PGIMER, Tata Memorial Hospital, Sankara Netralaya, Bombay Hospital etc. The Health policy of our country is governed by the Ministry of Health which was established in 1947. National Health Policy was endorsed by Parliament in 1983, which aimed at universal Health Care Coverage by 2000.

Conclusion:

In our country the health care services are distributed to our population by a complex network of public and private providers. It includes single doctors, specialist doctors and multi-speciality group of doctors in more advanced hospitals. The health policy of our Government is to provide preventive and curative health care to all and to restrict infant mortality cases. Due to our safe health care system, the old and young are more healthy. The infant mortality rate is controlled. The longevity of people has increased over the years.

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SUSHRUTA: THE WORLD'S FIRST PLASTIC SURGEON

Dr. Taranisen Panda

Sushruta, the great sage surgeon, philosopher and teacher, the most prominent of all ancient Indian physicians is considered to be the father of Indian surgery as well as the first plastic surgeon in the world (Prakash 1978). The text attributed to him is '*Sushruta Tantra*'. It was revised by Nagarjuna as *Sushruta Samhita*. Sushruta was probably the first surgeon in the world to classify and describe, in detail, the surgical instruments, their method of manufacture, quality control, maintenance and their specific usage in the diagnosis and treatment of diseases. He described and used 101 blunt instruments and 20 sharp instruments, which "should have an edge so fine that it should divide the hairs on the skin." He was also the first surgeon to describe endoscopes such as rectal, aural, nasal and vaginal specula. *Sushruta Samhita* contains 184 chapters and description of 1120 illnesses, 700 medicinal plants, 64 preparations from mineral sources and 57 preparations based on animal sources (Sharma 2001).

Sushruta described diabetes (Madhumeha) as a disease characterised by passage of large amount of urine, sweet in taste, hence the name "Madhumeha" — honey like urine. He goes on to say that diabetes primarily affects obese people who are sedentary and emphasised the role of physical activity in amelioration of diabetes. Though the discovery of blood circulation is attributed to William Harvey; it is interesting to note that Sushruta had the knowledge of a structure like heart and its role in circulation of "Vital fluids" through the 'channels'. Sushruta has described the entity of "Hritshoola" in his famous treatise "*Sushruta Samihta*". His vivid account of angina ("Hritshoola" 'meaning heart pain) is marvellous, though he did not use the exact term as angina (Dwivedi and Chaturvedi 2006). It embodies all the essential components of present day definition, i.e. site, nature, aggravating and relieving factors and referral. According to him angina is chest pain which is precordial, temporary, exertional, emotional, burning like and relieved by rest. He also linked this kind of pain to obesity (Medoroga). Besides these, he has also described the symptoms of "Vatarakta" which are similar to that of hypertension. It is remarkable that Sushruta described these conditions some 150 years before Greek physician Hippocrates. He came to such a near perfect conclusion without resorting to any kind of biochemical or imaging procedures which were obviously non-existent at that point of time.

Sushruta discussed various urological ailments with conjectures about their pathogenesis followed by detailed management. Several chapters deal with urinary tract infection in both genders. He mentioned a number of urethral probes, dilators and irrigating syringes for installation of medications. His detailed management of urethral stricture is quite striking - "In a case of Niruddhaprakasha (stricture of the urethra), a tube open at both ends made of iron, wood or shellac should be lubricated with clarified butter and gently introduced into the urethra. Thicker and thicker tubes should be duly introduced every 3rdday. The urethra passage should be made to dilate in this manner and emollient food should be given to the patient. As an alternative, an incision should be made into the lower part of the penis avoiding the sevani (raphe) and it should be treated as an incidental ulcer". The causes and prevalence of urethral stricture have changed little with time. It is amazing that the principles of its management with dilatation and urethroplasty that Sushruta proposed three millenia ago still remain valid today (Das 1983).

Sushruta's greatest contribution was in the fields of Rhinoplasty (plastic surgery) and ophthalmic surgery (removal of cataracts). Sushruta lays down the basic principles of plastic surgery by advocating a proper physiotherapy before the operation and describes various methods or different types of defects, viz., (1) release of the skin for covering small defects, (2) rotation of the flaps to make up for the partial loss and (3) pedicle

Fig.: Rhinoplasty Surgery of Nose

flaps for covering complete loss of skin from an area. He has mentioned various methods including sliding graft, rotation graft and pedicle graft. Nasal repair or rhinoplasty has been described in greater detail, which to this day has stood the test of time and is mentioned as the Indian method of rhinoplasty in the books of plastic surgery. Thus, all the principles of plastic surgery, viz., accuracy, precision, economy, haemostasis and perfection find an important place in Sushruta's writings on this subject. Surprisingly, the steps followed by Sushruta are strikingly similar to those followed by modern surgeons while doing plastic surgery.

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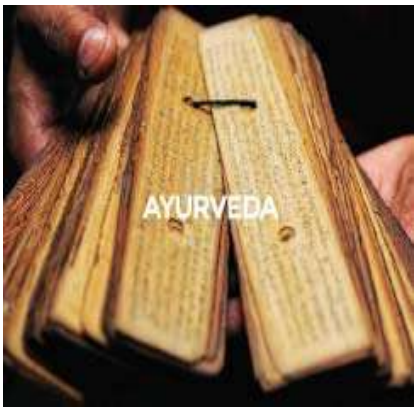
AYURVEDA
The Ancient Bharatiya Bidya

Er. Ramesh Chandra Sahoo



Veda is the religious epic of Hindu Dharma. It is called gyan or knowledge. It is also called teacher-less teaching. It enters the human intelligence domain through deep meditation. Spontaneous suktas or slokas reverberates in the minds of the meditator. It then comes out as verses in Sanskrit. Meditators are called Rishis or seers of olden days. They were teachers or Gurus to the society in large measures. To name a few, Maharsi Kapila, Charaka, Sushruta, Kanada, Patanjali, Aryabhatta, Bhaskaracharya and Vyasadeb. Their period of operation and teachings have been described in the article of Joga Vigyan in December 2016 issue of 'Science Horizon'. Vedas have further upa-bedas or branches. Those are AYURVEDA, DHANURVEDA, GANDHARV VEDA, ARTHAVEDA. The purpose of this article is to highlight the first one i.e. Ayurved, works of Maharsi Charak & Sushruta. They are called the father of Bharatiya Ayurbigyan or health science.

Born in sixth century BC Acharya Charak was one of the principal contributors to the ancient art and science, Ayurveda. It is a system of medicine and health practices developed in ancient India. Acharya Charak has been crowned as the Father of Medicine. His renowned work, the "*Charak Samhita*", is considered as an encyclopedia of Ayurveda.

The Golden Age of surgery in ancient India rests largely on the shoulders of Sushruta, who lived sometime also in 6th century BC. Both the Rishis contributed to Ayurveda (Bharatiya health science), which have surpassed annhilating effect of time on this science. This has coolly tolerated the competition from Allopathic treatment of health and disease over a period of time. Some large corporate houses have advanced it further through research and vigorous marketing techniques. To name a few, those are Dabur, Vaidyanath, Patanjali. As on today a cognizable portion of Bharatiya population depends mainly on Ayurveda.

The writer of the article has some experience on ayurvedic treatment not as a patient but as an eye witness. Through these incidents readers may establish faith on Ayurveda,

Incident one – This episode has been taken from a book '*Vaidya Satakam'* written by a Vaidya from Puri and published by Kanika Ayurveda Foundation, Bhubaneswar. One of the episode is on how an MBBS graduate is motivated to take up Ayurvedic course and

later confined his treatment to Ayurved only as a Vaidya (ayurvedic doctor) leaving allopathic treatment and his MBBS degree. This incident relates to sixties of the last century when the Vaidya was young with an MBBS degree and an allopathic Doctor's job. He was posted in Ganjam district under the Civil surgeon of Berhampur . To treat a patient in some tribal area the team along with the Civil surgeon and this young doctor once visited the village. By the time they reached the patient, a man of 52 years, he appeared to be dead to the doctors team. After a thorough check up they declared him dead and prepared to leave. At this time patient's mother intervened. She told that an old Vaidya popular for treatment in the area, must be called. If he declares the patient to be dead, then she would accept it and allow funeral rights. Vaidya was called and he came immediately with his bag for treatment. He checked the patient and gave him some Ayurvedic treatment along with curd water and coconut water, with the instruction that if within fifteen minutes the patient would not show an indication of living like sweating on forehead , then he could be taken as dead. If he would show signs of living, his further treatment would continue. Out of curiosity the team of MBBS doctors waited to see the progress. Within fifteen minutes the patient showed signs of living. After further treatment by the Vaidya the patient progressed for recovery. The then young Vaidya is now living in Puri at the age of 83 years, but has retired from extending treatment.

Incident Two - It is on the treatment of paralysis attack. The patient is one relation of the writer. He had a heart attack at the age of 71 years. He was almost confined to bed unable to move. Staying in his home at Cuttack close to SCB Medical college he took the help of treatment there. His elder brother being an MBBS doctor, and being very well known to the then Medical Superintendent of SCB, helped him to take up allopathic treatment. But the disease remained stagnant at one stage and kept him confined to bed. At this time he came across the above discussed Vaidya of Puri. The Vaidya was then visiting Cuttack once a week to treat patients. The patient was accepted for treatment and was asked to come to Puri to his fulltime clinic for deep study and tests. After two visits to Puri, he was asked to take treatment further from his camp clinic at Cuttack. Within six months of treatment, the patient was able to stand on his own. Within a period of one year, the patient was fully cured of paralysis. He is now living in his home at Cuttack at the age of 86 years and doing his daily activities. Incidentally, he has visited Bengaluru and other far off places to his located there. Since the patient was a close relation, this writer of this article, was keeping a close watch on the developments.

Incident three - Seeing the effect of Ayurved, the writer's family of five have developed confidence on it. They are opting to Ayurved now for any small attacks of cold cough and fever by maintaining a stock of Ayurvedic medicines. The chances of visiting for

allopathic treatment have been greatly reduced. The youngest member of the family a boy of fifteen years now was having repeated attack of cold and fever when he was within five years of age. His parents were taking him to various child specialists in the locality for repeated treatment. Then he remained under the treatment of the above discussed Vaidya of Puri for about a year. He has been cured of the repeated attacks of cold and fever. Now he is able to tolerate the hardships of going to his school at a distance of 20 Kms from the house daily in sizzling cold at dawn and inclement weather. While going he recites the Vaidic sloka -

ॐ सर्वे भवन्तु सुखिनःसर्वे सन्तु निरामयाः ।
सर्वे भद्राणि पश्यन्तुमा कश्चिद्दुःखभाग्भवेत् ।
ॐ शान्तिः शान्तिः शान्तिः

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"Science is built up with facts, as a house is with stones. But a collection of facts is no more a science than a heap of stones is a home".

Henri Poincare

"To see a world in a grain of sand,
And heaven in wild flower.
Hold infinity in the palm of your hand,
And eternity in an hour".

William Blake

"They who know the truth are not equal to those who love it, and they who love it are not equal to those who find pleasure in it".

Chinese proverb

THE ANCIENT INDIAN MEDICINE

Dr. Dwijesh Kumar Panda

The ancient Indian medicine is mainly Ayurvedic medicine and surgery which originated around 6,000 BC. Ayurveda means knowledge of life and longevity. Its concepts existed since the times of Indus Valley Civilization. The medical texts evolved from the Vedas. It was believed that the medical knowledge transmitted from the God Brahma to sages and then to human physicians. Sushruta, the vedic surgeon wrote that Dhanvantari, a Hindu god of Ayurveda, incarnated himself as a king of Varanasi and taught medicine to a group of physicians including himself. Ayurveda is a system of medicine developed in ancient times that is widely practiced in modern treatment. The two principal texts on Ayurveda, the *Charak Samhita* and *Susruta Samhita* originated from the 6th century BC. They were updated by the Buddhist scholar Nagarjuna in the 2nd century AD. The *Charak Samhita* is among the most important ancient medical treatises. Sushruta was the first plastic surgeon who lived nearly 150 years before Hippocrates, a famous Greek physician. The origin of plastic surgery was 4000 years old in India, back to the Indus Valley Civilization.

The Ayurvedic treatment was based on complex herbal compounds, minerals and metal substances. Surgical techniques such as

rhinoplasty, kidney stone extraction, sutures, cataract, and the extraction of foreign objects were performed by the surgeon, Sushruta. The ancient medicine had about eight components which were found in the Sanskrit epic, the Mahabharat of the 4th century B.C. Those are:

- Kayachikitsa – general medicine
- Treatment of children
- Surgical techniques
- Treatment of ears, eyes, nose and mouth
- Bhutavidya – Pacification of spirits
- Toxicology
- Rejuvenation – tonics for increasing life span, intellect and strength
- Aphrodisiacs – Increase of volume and viability of semen and sexual pleasure

There are different channels in the body which transport fluids. They can be opened up by massage and formentation. This practice is followed to-day by modern medicine. The holistic approach of body and mind is a fundamental aspect of Vedic treatment. Activity, sleep and meditation are important for good health. Regular bathing, cleaning of teeth, skin care and eye washing are usual practice of hygiene. Alcoholic beverages were used to increase pitta and reduce vatta and kapha. Sugar, fruit and cereals fermented with vinegar were intended for purgation, improving digestion, and free movements of joints. Purified opium was used to balance the vata and kapha and increase pitta. It was prescribed for diarrhea suppresses the urgings of nature and acts that with Muslim conquests. Its narcotic property for use as analgesic (pain remover) known since ancient times is used to-day in modern medicine. The traumatic bleeding is stopped by ligation of blood vessels, cauterization by heat and use of preparations to facilitate clotting and to constrict blood vessels. Cataract surgery was done by Sushruta. It is a procedure performed with *jabamukhisalaka*, a curved needle to push the matured white lens of the eye out of the field of vision. The eye would later be soaked with warm butter and then bandaged.

Sushruta was a plastic surgeon and famous for earlobe reconstruction. His treatise's insight, accuracy and details of the surgical descriptions are most impressive. It describes over 120 surgical instruments, 300 surgical procedures and classified human surgery. Sushruta stated "Surgery has the superior advantage of producing instantaneous effects by means of surgical instruments and appliances. It is the highest in value of all the medical tantras. He writes that "wine should be used before operation to produce insensibility of pain". He warns that improper intervention with surgical maneuver due to ignorance of the progress of the disease, greed of money or lack of judgement lead only to complications. According to Sushruta "Anyone, who wishes to acquire a thorough knowledge of anatomy, must procure a dead body and carefully observe and examine all its parts". Anatomy (Greek anatomç, "dissection") is the branch of biology concerned with the study of the structure of organisms and their parts.

The other treatments included lithotomy, tonsillectomy, and surgery of anal fistulas, treating fractures, amputations, cesarean sections and stitching of wounds. The use of herbs and surgical instruments became widespread. British physicians travelled to India to observe rhinoplasty being performed using native methods. Instruments described in the *Sushruta Samhita* were further modified in Europe. Josephe Constantine Carpe studied plastic surgery methods in India for 20 years and, in 1885, was able to perform the first major rhinoplasty surgery in the western world, using the "Indian" method of nose reconstruction.

The *Sushruta Samhita* provided the foundation of surgery, while *Charak Samhita* was primarily a foundation of medicine. The World Health Organization recommends integrating traditional medicine services into health care service delivery to promote universal coverage. As per 2008 Beijing declaration, practices and practitioners should integrate traditional medicine into overall health service delivery. Traditional medicine including Ayurveda has a long history of use in disease prevention and treatment. Some traditional Indian herbal medicinal products contain harmful levels of toxic heavy metals such as lead, arsenic and mercury. These are thought of as active ingredients by advocates of Ayurveda. The ancient Ayurvedic texts say that purification processes detoxify the heavy metals in it. A 2015 study of US found elevated levels of heavy metals. The food and drug administration of the US prevented the Ayurvedic products from entering the country.

Charaka Samhita is the oldest and the most authentic treatise on Ayurveda and is the ancient medical science of India. Apart from giving information on medical science ; it also gives valuable information on geographical, social, and economic conditions of India. Charak, the ancient physician prescribed some principles for the doctors and students of medicine.

The ideal medical student

He should be of a mild disposition, noble by nature, never mean in his acts, free from

Fig.1 : Cataract surgery of eye

Fig.2 : Sushruta doing earlobe reconstruction

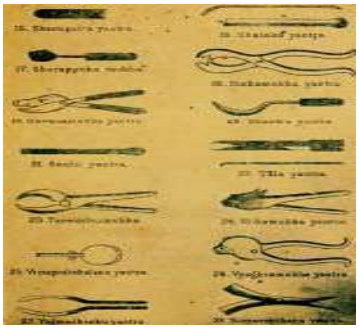

Fig.3 : Surgical Instruments

pride, strong memory, liberal mind, devoted to truth, likes solitude, of thoughtful disposition, free from anger, of excellent character, compassionate, fond of study, devoted to both theory and practice, who seeks the good of all creatures.

—Charak Samhita 3.VIII.6 (Abridged)

The aim of life science

Life is of four kinds:Sukha (happy), Duhkha(unhappy), Hita (good) and Ahita (bad). Sukham-Ayuh is a life unaffected by bodily or psychic diseases, is endowed with vigor, capabilities, energy, vitality, activity, knowledge, successes and enjoyments. The opposite of this is the Asukham-Ayuh. Hitam-Ayuh is the life of a person who is always willing to do good to all living beings, truthful, non-stealing, calm, self-restrained, taking steps after examining the situation, virtuous, achieves Dharma-Artha-Kama, without conflict with others, worshipping whatever is worthy, devoted to knowledge-understanding-serenity of mind, and to charity and peace. The opposite of this is the Ahitam-Ayuh.The aim of Ayurveda is to teach what is conducive to these four kinds of life.

—Charaka Samhita Chapters 1.1, 1.30

Diet and health

Innumerable diseases, bodily and mental, have for their root Tamas (stupefaction, darkness). Through fault of the understanding, one indulges in the five injurious objects, suppresses the urgings of nature and accomplishes acts that are highly rash. The man of Ignorance then becomes united with conditions for disease. The man of Knowledge, however, purified by knowledge avoids those conditions. One should never take any food, acting only from a desire for it or guided by ignorance. Only food that is beneficial should be eaten, after proper examination. Verily, the body is the result of food.

—Charaka Samhita, 1.XXVIII.41-48

The Indian doctors take oath before joining their profession. That is Hippocratic Oath. The Hippocratic Oath is an oath historically taken by physicians. It is one of the most widely known of Greek medical texts. In its original form, it requires a new physician to swear, by a number of healing Gods, to uphold specific ethical standards. The Oath is the earliest expression of medical ethics in the Western world, establishing several principles of medical ethics. The oath prescribed by "Charak" is a great national ethics which should be introduced by the Government of India.

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DESCRIPTION OF ANIMAL SCIENCE IN ANCIENT INDIA : AN OVERVIEW

G.B.N. Chainy

This article is a subtle attempt to describe perception of animal science in ancient Indian scripts. The article restricts its limit to description of various aspects of animal science including human anatomy. It does not describe plants. The article encompasses descriptions of perception of life and attempts by scholars of ancient India to explain life. Since, this writer is not a Sanskrit scholar, any omission of facts on the description of animals in ancient scripts may be excused. Such omissions of facts in the present article are not intentional but due to lack of knowledge in Sanskrit literature. The writer takes all responsibility for such omissions.

Ancient Indian philosophy believed that all cosmic creations were made up of five great elements of *prakruti* (nature). These elements were defined as *pancha-bhoot*. They were *bhumi* (earth), *jala* (water), *vayu* (air), *agni* (fire) and *aakash*(ether or space). Basic elements such as carbon, oxygen, hydrogen, nitrogen and others which are essential component of a cell, the unit of life, were not known to them. However, they thought that life might have evolved from components present in pancha-bhoot (five elements) of Nature . The ancient sages of India were equally inquisitive to know what is life as any intelluctual person of contemporary civilization.

Ancient Indian sages (philosophers) developed the concept of life (*Prana*). Several ancient Hindu scripts such as *Veda*, *Upnashida* and *Gita* have defined *prana* in various philosophical ways. In Sanskrit, *Prana* word is a derivative of two words: *Pra* (pratham or first) and *ana* (which moves). In a simple term, it is the vital force of life of living ogansisms. They were aware that there is a force in organic body which distinguished it from that of non-living matters. Till date it is difficult even by modern biologists to define "what is life". They had the concept that to sustain prana it is necessary to have pure substances or active agents from properly digested nourishing food. Though they did not have tools to separate or identify them, they categorized them as a common word as *Ojas*. They suggested that *Ojas* were necessary for *Tejas* (energy) of living organisms.

Ancient Indian philosophers were aware of the idea that physiology of body is essential for continuation of life. And they had realized that respiration is necessary for the continuation of life. Hence, the air necessary for the maintenance of life was identified as *pranavayu*. Ancient sages had noticed that systematic regulation of breathing (both inhalation and exhalation) of *pranavayu* is the key to healthy and long life. Regulation of inhaling and exhaling of *pranavayu* is known as *pranayam*, an important component of yoga. And when life ceases, the body is consigned to *pancha-bhoot*. Thus ancient sages of India gave the first concept of recycling of materials between living objects and Nature and

suggested a strong relationship between living organisms and nature.

Ancient Indian philosophers and sages had also contributed to the understanding of the anatomy of animal body. Several organs were named, albeit sometimes without having ideas on their proper physiological or molecular functioning. This might be due to lack of various scientific tools at that time. Sushruta mentioned the presence of 300 bones in human body. Modern medical science says that body of human is composed of 270 bones at the time of birth. This number decreased to 206 in adulthood due to fusion of several bones. Ancient scripts mention that human body is made up of five important components. They are *asthi* (bone), *majja* (bone marrow), *mansa* (flesh), *rakta* (blood) and *birja* (semen). Various internal organs of body such as *mastishka* (brain), *hrudaya* (heart), *vrkku* (kidney), *Kloma* (lungs), *yakruta* (liver), *jarayu* (uterus) and other external organs were described in Atharvaveda. The ancient Indian philosophers were aware that brain is associated with memory and essential for body to discharge various work. *Vedas* also explained four states of our inner conscience or manifestation of mind. They are *manas* (mind), *chitta* (memory), *budhi* (intellect) and *ahankar* (ego). The ancient literature mentioned stomach as *jathar*. They knew that food materials were digested by stomach and essential elements obtained after digestion were absorbed by the body for the maintenance of life. They were aware of the mechanism of digestion and must had realized complexity of the process. They named the process of digestion as *pachan kriy* and believed that some components of stomach facilitate digestion of food. They were aware that unwanted products of digestion and toxic substances of body produced during metabolism were excreted as *mala* (stool) and *mutra* (urine).

Atharvaveda also describes *sira*, *dhamani* and *nadi* as internal channels to carry life forces. They were not aware of oxygenated or deoxygenated blood circulation. Hence words *dhamani*, *sira* and *nadis* were used as synonyms. *Nadi* is described in ancient Sanskrit literature as biological structure through which vital energy(*pranik shakti*) of the human body flows. Yoga sutras describe three important *Nadis*. They are *Ida*, *Pingala* and *Sushumna*. However, physical existence of above three mentioned important nadis along with several others (which ranges as thousands) in human body as compared to modern medical science is not mentioned in ancient literature to the best of knowledge of the author. Perhaps, lack of finer techniques and appropriate instrumnets at that period might have posed restriction to study anatomy and physiology of human nervous system. Needless to say ancient scholars were aware of the fact that information from one part of the body moves to other parts particularly to brain by some structure.

Sushruta samhita has a description of skin graft for reconstructive surgery of nose and ear. Even in 2500 BCE, skin graft from oneperson to reconstruct his nose or ear (autograft) was successful. The *Sushruta*

samhita does not have any account of skin graft in a person at other organs.

Ancient Indian science also contributed to reproduction and development of human beings. *Garva uponashid*a and *Agni* purana described in detail development of human. Both ancient scripts had described development of the baby in the uterus (*jarayu*) of mother. They also thought how semen is synthesized in male reproductive organs. *Garva Upanishad* mentioned that semen is prepared in body in a stepwise manner from bone marrow. Bone marrow is formed from bones and bones are from fat. Fat is derived from flesh and flesh from blood and blood from food. Ancient Indian science believed that embryo formation in uterus is a manifestation of blood and semen. This is not true from the view of modern science. However, they described periodical development of various parts of foetus in detail. They had also tried to explain the philosophical reasons for the sex of foetus and cause for undeveloped or crippled child.

Taxonomy was known to ancient Indian scholars. Ancient Indian scholars tried to classify living organisms on the basis of their environment and habitat. Animals were classified as *jalachara* (aquatic), *navachara* (aerial) and *sthalachara* (terristorial). In ancient Vedic literature, living organisms were classified on the basis of their birth. They classified animals into *andaza* (from egg), *jarayuja* (from uterus), *udbhija* (from sprouts) and *svedaja* (from sweat such as insects, lice, flies and bugs etc). Also in ancient sanskrit literaure, animals were classified on the basis of number of legs they possesed such as dwipada (two legged) or chatuspada (four legged).

Thus, it seems that science related to animals were also described in ancient Indian scripts. With their limited facilities, the ancient sages tried their best to unfold mysteries of life. They attempted to describe anatomy and physiology of human body with their limited scope. They had also tried to classify animal world on the basis of their anatomy and source of birth.

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ANCIENT SUN-DIALS OF ODISHA

Nikunja Bihari Sahu

A Sun-dial is a simple instrument to give an idea of time from the shadow of a pointer (called the Style) cast by the Sun on a graduated dial. It did not require any battery or electricity for operation and it continues to work as long as the Sun is there in the sky. The sundials vary in size and can be as large as the largest sundial of the world, the Samrat Yantra (Height : 90 ft , built by Sawai Jai Singh-II, the King of Jaipur in 1734 AD) which is capable of measuring time up to 2 seconds accurately . Although colossal sundials like Samrat Yantra are not seen in Odisha, small sundials, mostly made up of metal or stone, are found to be existing at places like Bhubaneswar, Cuttack, Konark, Kendrapara, Baramba, Khandapara, Madhupurgarh etc. These were mostly constructed during the early twentieth century of the colonial British period. The devices were generally located in public places like Kachery to enable people to keep track of time. The possibility of sun-dials existing at other places of the state cannot be ruled out. The sundials clearly enjoyed a period of glory for quite some time which eventually dwindled to oblivion after the introduction of mechanical clocks by the Europeans.

In most devices, each hour is divided into 4 divisions and each division into 3 smaller subdivisions. Thus the dials were sensitive enough to indicate a minimum time interval of 5 minutes which is equivalent to one small division on the dial. It is important to understand that while a clock indicates the Indian Standard Time (IST), a Sundial, on the other hand, records the Local Time.

The Sun temple as an Emblem of Sundial:

The magnificent Sun temple of Konark, built in 13th century AD, was designed into a huge chariot with its richly sculptured wheels acting as sundials. Each decorated wheel consists of 8 thicker spokes that indicates 8 'Praharas' of a day: one Prahara being equal to 3 hours of time. There is a thinner spoke in between the two thicker spokes which represents 1.5 hours of time. The wheels are placed along the East – West plane of the place and when the Sun moves in the sky over these wheels, the hub of the wheel casts shadow on the spokes indicating time. While 12 wheels have been placed along the Northern side of the temple, the remaining 12 wheels have been placed along the Southern side of the temple. During the Southward journey of the Sun off the Equator towards the Southern Solstice, time is indicated on the 12 set of wheels located on the Southern side of the temple. Similarly, during the Northward journey of the Sun off the Equator towards the Northern Solstice, time is indicated on the 12 set of wheels located on the Northern side of the temple. Finer measure of time is also possible on the wheels. There are 60 beads placed along the periphery of the wheel between each two thicker spokes, each bead representing 180/60 i.e. 3 minutes of time.

Sun-dial of Mukteswar Temple, Bhubaneswar :

Made up of stone, the sun-dial in the premises of the Mukteswar temple, Bhubaneswar belongs to horizontal category (The Dial is kept parallel to the horizontal) and is still in working condition. However, visitors generally ignore the sight assuming it as a stone heap.

This has a large circular dial. But due to many high buildings and trees located on the southern side of the sundial, sunlight is often obstructed leaving the device non-operational for some part of the day. Accounts of its designer and the construction period are not known.

Sun-dial of Ravenshaw University, Cuttack :

The sundial was designed by Mr. R.C. Choudhury of the Chemistry Department of Ravenshaw College, Cuttack in the year 1902. Made up of brass, the device belongs to horizontal category and is in working condition now.

Sun-dial of Konark :

While it originally stood in a desolate place in the premises of the Inspection Bungalow of Konark near the Sun temple, now it has been shifted to a new location inside the Museum premises. This has a rectangular dial. Made up of stone, the dial belongs to horizontal category. It was designed by Rai Prasanna Kumar Pal Sahib, Asst. Engineer and constructed in 1906. The device is still in working condition.

Sun-dial of Konark

Sun-dial of Kendrapara :

This is a huge sundial made up of bricks and stones and stands in the Kachery campus of Kendrapara. It belongs to horizontal category. Apathy by the locals and lack of conservation measures by the Government have taken a heavy toll of the device leaving it in a state of ruins. Vertical cracks have developed in the sundial and rainwater seeps through it. Vegetations have mushroomed near the instrument and the locals mostly use the dial for purpose of defecation. Now, the local authorities have painted the dial with tricolor which has spoiled its antique value. Although accounts of its designer and the construction

Sun-dial of Kendrapara

period are not clearly known, it is said that the instrument was commissioned to commemorate the Golden Jubilee of the reign of Queen Victoria in 1887.

Sun-dial of Khandapara :

This is an Equatorial sun-dial made up of brass and stands in the Kachery campus of Khandapara. However, its Style is damaged leaving only the Dial , and hence , the sundial is in a state of defunct. It was designed by Shri Gadadhar Sinha Samanta, the son of Samanta Chandrasekhar, the illustrious astronomer of Odisha.

Sun-dial of Khandapara

Sun-dial of Baramba

Sundial of Baramba:

This is an Equatorial sundial made up of brass that stands in the Tahsil office campus of Baramba. The Dial is beautifully designed into a crescent moon shape. However, the Style is damaged and dislocated from the dial leaving it in a state of defunct. Accounts of its designer and the construction period are not known.

Sundial of Madhupurgarh :

A small horizontal sun-dial is found to exist in the premises of Madhupur High school, Kalana of Jajpur district. This was built by Shri Narayan Chandra Dhir Narendra, the then king of Madhupurgarh in the beginning of the twentieth century. The Style is made up of iron.

Conservation :

Although a Sun-dial is easy to construct, its installation, alignment and graduation is quite difficult to achieve and needs precise measurements. Firstly, the pointer has to be aligned towards the North and kept elevated from the ground by the local latitude angle so that it points to the Pole Star and becomes parallel to the Earth's axis. Secondly, in an Equatorial dial, the Dial has to be aligned in a plane perpendicular to the Pointer. Thirdly, while in an Equatorial dial hour-lines are uniformly spaced, in a Horizontal type, hour-lines are not uniformly spaced and are given by a trigonometric formula. Hence designing of a Sun-dial requires knowledge of astronomy, trigonometry, geometry and computing. The fact that our state has a number of Sundials testifies the mathematical prowess of their designers, and hence, these devices are invaluable assets of our heritage. Hence, these ancient masterpieces of time need upkeep and maintenance for its preservation.

The damaged components should be replaced and calibration of the dial redone. Operational instructions on the devices should be provided for the benefit of common man and a table for Equation of Time should be incorporated to convert the observed time (Local Time) from the sundial to the Indian Standard time (IST) for meaningful use by the visitors. Encroachment from the vicinity should be cleared to allow sunlight to fall continuously for uninterrupted operation of the device throughout the day. Finally, adequate publicitly should be given to attract scholars for study and research.

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QUIZ : ANCIENT INDIAN SCIENCE

1. Who is the first mathematician to develop trigonometric series?
   a) Mahavir b) Madhav
   c) Jyesthadev d) Bhaskar II
2. Who is the author of chemistry book '*Rasa-ratnakar*'?
   a) Bagabhatta b) Charak
   c) Nagarjun d) Bhab Mishra
3. Who, (a contemperory of Demoiritis) developed the concept of atom?
   a) Pingala b) Kanada
   c) Apastamba d) Aryabhatta
4. *Tantra-sangrah*, a book on mathematics and astronomy is written by a scholar of Kerala. Name him.
   a) Madhav
   b) Jyesthadev
   c) Nilakantha Somayaji
   d) Narayan
5. Who is the author of *Siddhanta-darpan*?
   a) Varahamihir
   b) Aryabhatta II
   c) Samanta Chandrasekhar
   d) Jnanaraja
6. Who is the eldest among Sulva-sutra authors?
   a) Baudhayan b) Apastamba
   c) Manava d) Katayan
7. Who is called the 'Father of Plastic Surgery'?
   a) Charak b) Sushruta
   c) Bagabhatta d) Dhanvantari
8. An Odia astronomer has written the book '*Bhasvati-karan'* in 1099. Name him.
   a) Divyananda b) Satananda
   c) Brahmadev d) Keshava

9. Evidence of earliest astronomy in India is found in *Vedanga-jyotisha* dated to 1400-1200 BC; Who is it's author?
   a) Parashar b) Vyasadev
   c) Lagadh d) Kapil

10. Name the author of *Leelavati*.
   a) Varahamihir
   b) Sridhar
   c) Bhaskar I
   d) Bhaskar II

11. Name the Indian astronomer who first said that "Earth is rotating on its axis".
   a) Aryabhatta b) Brahmagupta
   c) Bhaskar II d) Varahamihir

12. The Odia astronomer Samanta Chandrasekhar is compared with an European astronomer for their similar views on the Universe. Name him.
   a) Nicolas Copernicus
   b) Johannes Kepler
   c) Tycho Brahe
   d) Galileo

13. Who is the first mathematician to find out the area of a cyclic quadrilateral?
   a) Aryabhatta b) Brahmagupta
   c) Bhaksar I d) Mahavir

14. The first description about ellipse is found in a Jain book written about 500 BC. Name it.
   a) *Surya Prajnapati*
   b) *Anuyoga Dwara*
   c) *Ganita Anuyoga*
   d) *Bhagabati Sutra*

15. Name the famous Yoga Scientist of India, who has written the book '*Yogasutra*'?
   a) Kapil b) Jibak
   c) Atreya d) Patanjali

16. Name the famous 6th century Indian agricultural scientist.
   a) Rebana
   b) Varahamihir
   c) Khana
   d) Bhagabhatta

17. Which mathematician in the court of Sawai Jai Singh has translated Euclid's 'Elements' into Sanskrit as 'Rekha Ganit'?
   a) Kamalakar
   b) Mahendra Suri
   c) Vijaya Nandi
   d) Jagannatha Samrat

18. '*Surya Siddhanta*' is one of the well known book on astronomy. Who is its author?
   a) Aryabhatta
   b) Varahamihir
   c) Lalla
   d) Not known

19. Jyesthadeva, a mathematician of Kerala has written a book on mathematics and astronomy. Name the book.
   a) *Tantra Sangraha*
   b) *Yukti bhasa*
   c) *Sad-ratna-mala*
   d) *Karan Paddhati*

20. Who has built the famous rustfree Iron pillar located at Qutb Complex in Delhi?
   a) Qutb-uddin Aibak
   b) Firoz Shah Tughlak
   c) Chandragupta II
   d) Samudragupta

ANSWER

01. (b)	02. (c)	03. (b)	04. (c)	05. (c)
06. (a)	07. (b)	08. (b)	09. (c)	10. (d)
11. (a)	12. (c)	13. (b)	14. (a)	15. (d)
16. (a)	17. (d)	18. (d)	19. (b)	20. (c)

■

Editorial Board

SOME IMPORTANT TREATISES ON SCIENCE IN ANCIENT INDIA

Author	Year	Place	Work
Sulba-sutra authors Baudhayan, Manava, Apastamba and Katayan	800-200 BC		Sulva-sutra
Charak	600 BC	-	Charak-samhita
Sushruta	600 BC	-	Sushruta samhita
Lagadha	5th Century BC	-	Vedanga-jyotisha
Pingala	200 BC	-	Chhanda-shastra
Bagabhatta	420-508	SindhuPradesh	Astanga-sangraha Astanga-hridaya-samhita
Aryabhatta	476-550	Patna	Aryabhattiya (499) Aryabhatta sidhanta
Varahamihira	499-587	Ujjain	Pancha-Siddhantika (575)
Brahmagupta	598-670	Bhillamala, Rajasthan	Brahma-sphuta-siddhanta (628) Khanda-khadyaka (665)
Bhaskar-I	600-680	Valabhi, Gujarat	Maha-bhaskariya (629) Laghu-bhaskriya
Lalla	720-790	Dassapura, Malwa	Sishya-dhi-vriddida (748)
Anonnymous	800	-	Surya-siddhanta
Nagarjun	800	Gujarat	Rasa-ratnakar
Mahavira	800-870	Mysore	Ganita-sara-sangraha

Author	Year	Place	Work
Sridhara	870-930	Karnataka	Pati Ganita
			Tri-satika
Vateshvara	b.880	Vatanagar,	Vateshvara-siddhanta (904)
		Gujarat	
Manjula	b.,880	PrakashPatna	Laghu-manas (932)
Aryabhatta II	950-1030		Maha-siddhanta
Shripati	1019-1066	Rohinikhand,	Sidhhanta-shekhara
		Ujjain	Dhi-kotida-karana (1039)
			Ganita -tilaka
Brahmadeva	1050-1110	Mathura	Karana-prakasha (1092)
Satananda	1060-1110	Puri, Odisha	Bhasvati-karana (1099)
Bhaskar II	1114-1185	Vijjalavida,	Siddhanta-Shiromani (1150)
		Bijapur	Karana-Kutuhala (1183)
Vararuchi	13-14th century	Kerala	Vakya-karana (1282)
Narayan Pandita	1340-1400	North India	Ganita-kaumudi (1356)
			Bija-ganita vatamsa
Madhava	1350-1425	Kerala	Benvaroha
Parameshvara	1370-1460	Kerala	Drig-ganita (1430)
Jnanaraja	15th Century	Maharashtra	Siddhanta-sundara (1503)
Nilakantha	1444-1544	Kundapura,	Tantra-sangraha (1501)
Somayaji		Kerala	Jyotir-mimasa
Keshava	1410-1510	Nandgaon,	Graha-kautuka (1496)
		Maharashtra	

Author	Year	Place	Work
Chitrabhanu	1475-1550	Kerala	Karanamrita (1530)
Shankar Variyar	1500-1560	Kerala	Karana-sara
Jyesthadeva	1500-1575	Kerala	Yukti -bhasa
Ganesha Daivajna	b.1507	Nandgaon, Maharashtra	Graha-laghava (1520) Tithi-chintamani (1525)
Achyutta Pisharati	1550-1621	Tirur, Kerala	Sphuta-nirnaya-tantra Karanottama
Nityananda	1600-1680	Kurukshetra	Siddhanta-sindhu (1628) Siddhanta-raja (1639)
Munishvara	b.1603	Varanasi	Siddhanta-sarvabhauma (1646)
Kamalakar	1616-1700	Varanasi	Siddhanta-tatva-viveka (1658)
Putumana Somayaji	1660-1740	Shivapura, Kerala	Karan-paddhati
Shankar Varma	1800-1839	Kerala	Sad-ratna-mala
Samanta Chandrasekhar	1835-1904	Khandapada, Odisha	Siddhanta-darpan (1869)

Note :- The number in bracket after the work is the year of its composition.

Compiled by the Editor.

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3. The authors are requested to write clearly on one side of A/4 size paper. The relevant pictures in 4cm X 6 cm size are welcome. Photo copies of manuscripts are not accepted for consideration.
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5. The article shall be profusely illustrated with pictures.
6. At the end of the article the author should give the references and suggestions for further reading.
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11. All units in the articles should be given in the metric system.
12. The title of the article should be brief and attractive. Moreover, subtitles may be given in long articles. The writings should be coherent and cohesive.
13. There should not be repetition of specific words. While ensuring the contemporary spirit of the writing, it should reflect some valuable lesson for the society. It is also necessary to avoid mistakes in spelling, language use and factual details.
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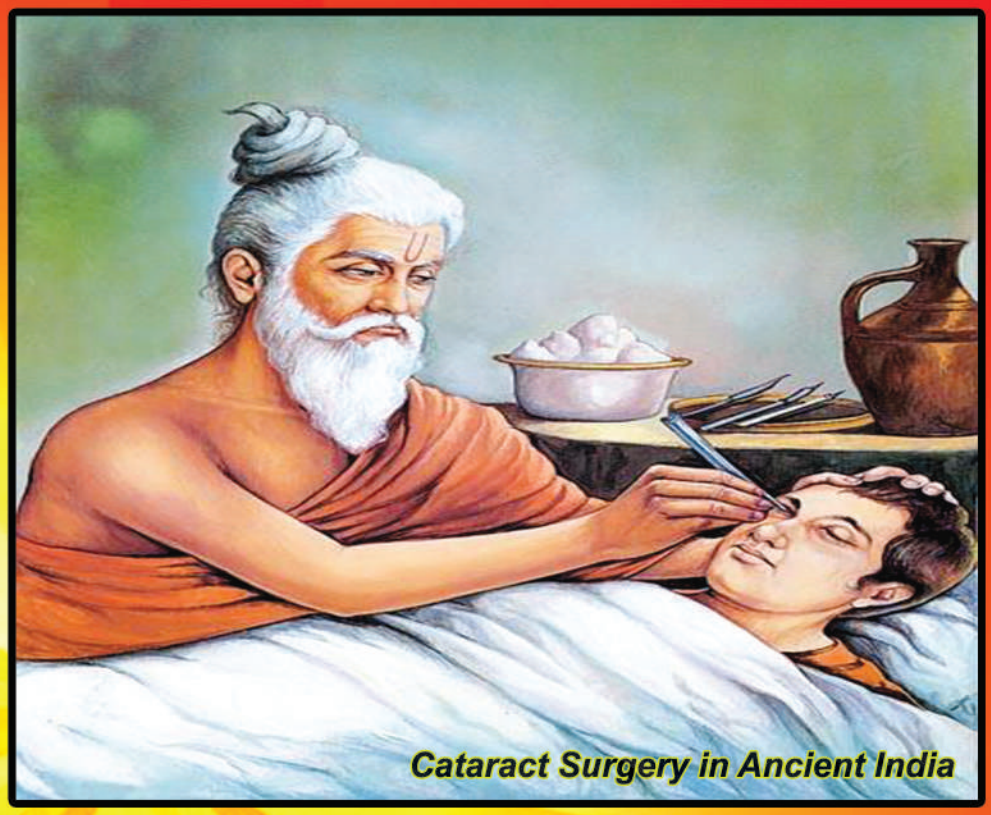

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