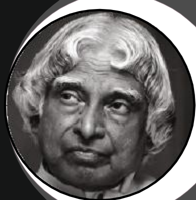
INDIAN CONTRIBUTIONS TO SCIENCE



Science India/International Forum

Indian Contributions To Science

Contents

Syllabus:

- (Class VI- VIII): Chapters 1-7 & 9-12
- (Class IX- XI): All Chapters (Chapters 1-19)

Preface

This piece of work on the India's contribution to the knowledge of science has been specifically prepared for VVM-SPC Contest. It portrays the achievements of India in science and technology since the ancient times.

The evolution of India as a unique society can be attributed to the ancient concept of *vasudaiva kutumbakam*, meaning the whole world is one family. This unity had aroused feelings of tolerance towards freedom of expression and knowledge. Eminent persons like Varahamihira, Aryabhatta, Vagbhatta, Susruta contributed towards the proliferation of knowledge of highest value and had put India at the forefront of all scientific developments and advancement. In fact, owing to the immense royal patronage provided for science, advancement of its knowledge and application of science in daily lives became a common factor in Indian society. When the whole of western society was in darkness, India rose high and shone as the 'golden sparrow' of the globe. The discovery of various scientific facts and the development of scientific concepts and technologies gave rise to a new age that could keep India in the forefront of the knowledge hub for centuries.

The most important and indestructible wealth is knowledge' and an individual with a quest to acquire knowledge is believed to be truly on the path of enlightenment and liberation. VVM-SPC intends to groom students of today, like you, to lead India as tomorrow's scientists, technocrats and innovators. Therefore, it is important for students to know our rich and glorious past. Each one of you should imbibe in you the vision of our ancient scientists and sages who could achieve highly with available resources. They were people of great vision, value, wisdom, purity and compassion. Students would feel inspired from the generosity with which the benefit of such scientific knowledge was shared for social and national progress. Hence, it is extremely important that India retains its position as the spearhead of the global scientific fraternity. The spark has already been ignited by our great scientists like Ramanujan, C.V. Raman, Vikram Sarabhai, APJ Abdul Kalam and various organizations like ISRO, CSIR, DRDO, and so on.

There is abundant talent in India and it needs to be utilized effectively and efficiently. I strongly feel that it is the duty of every parent and teacher to encourage students to think innovatively. The eagerness and spirit of scientific temperament should be developed in students. The task is accomplishable if you all strive for it. The goal is certainly not far away.

i

VVM- SASTRA PRATIBHA- 2025-26

GCC'S LARGEST SCIENCE TALENT SEARCH EXAM

Vidhyarthi Vigyan Manthan-Sastra Pratibha Contest (VVM) is a national science talent search program for New India organized by SIF , in collaboration with NCERT – Ministry of Education and National Council of Science Museums (NCSM) - an autonomous organisation of the Ministry of Culture, Government of India. VVM-SPC is a National program for educating and popularizing science among school students of VI to XI standards. VVM aims to identify and nurture the bright minds among the student community, who are keen on subjects related to science.

OBJECTIVES OF VVM SPC:

- To create interest among students in pure science.
- To educate school children about India's contributions from traditional to modern to the world of science and technology.
- To provide hands-on-training to students through workshops and other events.
- To conduct an annual talent search exam at the national level to identity students who have a scientific bent of mind.
- To provide the winning students with mentors to enrich science learning experience to carry forward their science education at higher levels.
- To organize exposure visits for the winners to various R & D institutions in the country.
- To identify successful students at the state and national levels and felicitate them with prizes and certificates.

The successful students will also be mentored appropriately, which will help them to progress further with higher education in science.

The present study material is only indicative of the range of topics that will be covered in the test. However one should understand that the material along with the books named Life Story of Dr. S. N. Bose, covers only 40% of the VVM syllabus in exam. Therefore, the organizers appeal to all students to explore further reading materials in order to prepare well for the test.

Evaluation of student will be based on their individual performance at entry level. The examination will be conducted in English.

The organizers wish you all the very best…….!!!

Acknowledgements

We gratefully acknowledges the contribution of the individuals and organizations involved in the development of this Book- "INDIAN CONTRIBUTIONS TO SCIENCE".

This is infact solely is the initiative of SIF to introduce literature prepared with material from ancient to modern period specially highlighting the contribution of India in the field of Science & Technology as a reading material for VVM-SPC talent search examination.

We are grateful to CBSE- Ex Advisors- Shri Vineet Joshi (Ex Chairman), Dr Sadhana Parashar, Ex Director (Academics & Training), Convener Prof Jagbir Singh- All the members of Material Production Team of K.T.P.I, co-ordinator, supporting members (CBSE)and Editors Prof. Kapil Kapoor and Prof. Michel Danino.

We sincerely acknowledges the contributions of the Academic Committee members VVM who participated in the review of the manuscript.

The team of VVM is highly thankful to its National Convener for his support throughout the re-making of the book. The contribution of office and administrative staff, computer staff of VVM is also gratefully acknowledged.

The efforts of the publication Department in bringing out this publication are also appreciated.

1

India's Contribution to Science and Technology (From Ancient to Modern)

Advancements in science and technology have been the major reason for the development of human civilization. India has been contributing to the fields of science and technology since ancient times. Even today, what we term as 'traditional knowledge' is actually based on scientific reasoning.

Pre-Independence

The history of scientific discoveries and development in India dates back to the Vedic era. It is believed that ancient Indian scholars had developed geometric theorems before Pythagoras had made them popular. The concept of squares, rectangles, circles, triangles, fractions, and the ability to express number 10 to the 12th power, algebraic formulae, and astronomy have all had their origins in Vedic literature; some are stated to have been known as early as 1500 BCE. The decimal system was already in use during the Harappan Civilization. This is evident in their use of weights and measures.

From the complex layout of Harappan towns to the existence of the Iron Pillar in Delhi, it is evident that India's indigenous technologies had been very sophisticated. They included the design and planning of water supply, traffic flow, natural air conditioning, complex stone work and construction engineering. The Indus Valley Civilization was the world's first to build planned towns with underground drainage, civil sanitation, hydraulic engineering and air-cooling architecture. While other ancient civilizations of the world were small towns with one central complex, the Indus Valley Civilization had the distinction of being spread across a region about half the size of Europe. Weights and linguistic symbols were standardized across this vast geography, for a period of over 1000 years, from around 3000 BCE to 1500 BCE.

Water Management

Water has been the life blood of most major civilizations. Criss-crossed by many great rivers, India is no exception to the rule. Indians had been developing water management techniques even before the Harappan time. Wells, ponds, lakes, dams and canals have been constructed with advanced technologies throughout the historic timeline of Indian civilization. Water has been used for storage, drinking and purposes of irrigation. It is estimated that even today, there are more than a million man-made ponds and lakes in India.

Iron and Steel

Iron and steel have literally been the pillars of modern civilization. Ancient India was pioneer in developing the technology of producing rust-free iron. This metal from India was famous in contemporary Europe for sword making. The famous Iron Pillar of Delhi is a testimony to that technology which is almost rust free even today.

Farming Technique and Fertilizers

Indian farming technology was mostly indigenously developed and was ahead of its time. It included soil testing techniques, crop rotation methods, irrigation plans, application of eco friendly pesticides and fertilizers, storage methods for crops, etc.

Physics

The concept of atom can be traced to the Vedic times. The material world was divided into five elements, namely, earth (*Prithvi*), fire (*Agni*), air (*Vayu*), water (*Jal*) and ether or space (*Akasha*). *Paramanu* (beyond atom) was considered to be the smallest particle, which cannot be divided further. Nuclear energy is produced today splitting the same.

Medicine and Surgery

Ayurveda (*Ayur* means life, Veda means knowledge) is probably the oldest structured system of medical science in the world. Proper knowledge about various ailments, diseases, symptoms, diagnosis and cure is the basis of Ayurveda. Many scholars like Charaka and Susruta have made invaluable contribution to Ayurveda by inscribing in written form, as found in ancient manuscripts.

Shipping and Shipbuilding

Shipbuilding was one of India's major export industries till the British dismantled it and formally banned it. Medieval Arab sailors purchased boats from India. Even the Portuguese, instead of buying from Europe, also obtained their boats from India. Some of the world's largest and most sophisticated ships were built in India and China. The compass and other navigation tools were already in use in India, much before Europe. Using their expertise in the science of maritime travel, Indians participated in the earliest known ocean-based trading system.

Post-Independence

India has witnessed considerable growth in the field of science and technology post Independence. Significant achievements have been made in the areas of nuclear and space science, electronics and defense. India has the third largest scientific and technical manpower in the world. In the field of Missile Launching Technology, India is among the top five nations of the world. Science and technology was brought into the mainstream of economic planning, with the establishment of the Department of Science and Technology (DST) in May 1971. DST, today, promotes new areas in science and technology and plays the role of a nodal department for organizing, coordinating and promoting science and technology in the country.

Our country's resources are used to get maximum output in the field of agriculture and industry. Indian scientists are making path-breaking research in the fields of agriculture, medicine, biotechnology, cold regions research, communications, environment, industry, mining, nuclear power, space and transportation. Now, India has the expertise in the fields of astronomy and astrophysics, liquid crystals, condensed matter physics, molecular biology, virology, and crystallography, software technology, nuclear power and defense research and development.

Atomic Energy

The main objective of India's nuclear energy programme is to use it to generate power, and apply the technology for further progress in agriculture, medicine, industry and research. India is, today, recognized as one of the most advanced countries in nuclear technology. Accelerators and nuclear power reactors are now designed and built indigenously.

Space

Indian Space Research Organization (ISRO) is the sixth largest space research organization in the world. It has numerous milestones to its credit since its establishment in 1969. India's first satellite Aryabhatta was built by ISRO in 1975. It was followed by many more. In 2008, Chandrayaan-1 became India's first mission to the moon. The Indian Space Research Organization (ISRO), under the Department of Space (DOS), is responsible for research, development and operation in the space through satellite communications, remote sensing for resource survey, environmental monitoring, meteorological services, and so on. India is the only Third World country to develop its own remote-sensing satellite.

Electronics and Information Technology

The Department of Electronics plays promotional role for the development and use of electronics for socio-economic development. Application of electronics in areas such as agriculture, health and service sectors has also been receiving special attention. For upgrading the quality of indigenously manufactured products, a series of tests and development centres and regional laboratories have been set up. These centres for electronic design and technology help small and medium electronics units. Information Technology (IT) is one of the most important industry in the Indian economy. The IT industry of India has registered huge growth in recent years. India's IT industry grew from 150 million US dollars in 1990/91 to a whopping 500 billion US dollars in2006/07. In the last ten years, the IT industry in India has grown at an average annual rate of 30%.

Oceanography

India has a coastline of more than 7,600 km and 1,250 islands. The Department of Ocean Development was established in 1981 to ensure optimum utilization of living resources, exploitation of non-living resources such as hydrocarbons and minerals and production of ocean energy. Two research vessels, *FORV Sagar Kanya* and *FORV Sagar Sampada*, are assessing and evaluating the resource potential.

Surveys and exploration efforts have been directed to assess sea bed topography, and concentration and quality of mineral nodules. India has sent 13 scientific research expeditions to Antarctica since 1981, and has established a permanently manned base, Dakshin Gangotri. A second permanent station, an entirely indigenous effort, was completed by the eighth expedition. The objective was to study the ozone layer and other important constituents like optical aurora, geomagnetic pulsation and related phenomena. The National Institute of Ocean Technology has been set up for the development of ocean-related technologies.

Biotechnology

India has been the frontrunner among the developing countries in promoting multidisciplinary activities in this area, recognizing the practically unlimited possibility of their applications in increasing agricultural and industrial production, and in improving human and animal life. The National Biotechnology Board was formed in 1982. The Department of Biotechnology was created in 1986. The areas which have been receiving attention are cattle herd improvement through embryo transfer technology, in vitro propagation of disease- resistant plant varieties for obtaining higher yields and development of vaccines for various diseases.

Council of Scientific and Industrial Research

The Council of Scientific and Industrial Research (CSIR) was established in 1942, and is today the premier institution for scientific and industrial research. It has a network of 40 laboratories, two cooperative industrial research institutions and more than 100 extensions and field centres. It plays a leading role in the fulfilment of the technological missions supported by the government.

***

Follow Guide to Pronunciation (Chapter 2 to 6)

In this course, we have used diacritical marks for words in Sanskrit and other Indian languages, that is to say, accents, dots and macrons. This is necessary in order to get their pronunciation right.

Should you find those marks disconcerting at first, just keep in mind these few simple and easy principles:

- A macron (¯) over a vowel makes it long; for instance *rāga* is pronounced *raaga.*
- The letter *c* stands for 'ch'- as in 'Caraka', pronounced 'Charaka'.
- sR (as in 'SusRruta') and *ş* (as in nak*ş*atra) may be pronounced more or less as 'sh' in 'shall'. Thus SSulbasuTtra is pronounced shulbasootra.
- The letter rU(as in smrUti) may be roughly pronounced as ri, but keeping the' i' as brief as possible.
- Other dotted consonants (d, ţ and nU mainly) are 'hard', that is, pronounced by hitting the tongue on the palate. Thus 'AWryabhata' is pronounced 'aaryabhatta' with a hard sounding 'tt'.

  Undotted consonants are soft, with the tongue on the teeth. For instance, in ganita, ni is hard, but ta is soft.

Students who wish to know the precise correspondence between diacritics and the Devanagari alphabet may refer to the following two tables, for vowels and consonants:

Short vowel	Roman with diacritics	Long vowel	Roman with diacritics
अ	*a*	आ	*ā*
इ	*i*	ई	*ī*
उ	*u*	ऊ	*ū*
ऋ	*ṛ*	ॠ	*ṝ*
ऌ	*ḷ*	ॡ	*ḹ*
ए	*e*	ऐ	*ai*
ओ	*o*	औ	*au*

Guttural	क *ka*	ख *kha*	ग *ga*	घ *gha*	ङ *ṅa*	ह *ha*
Palatal	च *ca*	छ *cha*	ज *ja*	झ *jha*	ञ *ña*	य *ya*
Cerebral	ट *ṭa*	ठ *ṭha*	ड *ḍa*	ढ *ḍha*	ण *ṇa*	र *ra*
Dental	त *ta*	थ *tha*	द *da*	ध *dha*	न *na*	ल *la*
Labial	प *pa*	फ *pha*	ब *ba*	भ *bha*	म *ma*	व *va*
Sibilants	श *śa*	ष *ṣa*	स *sa*			

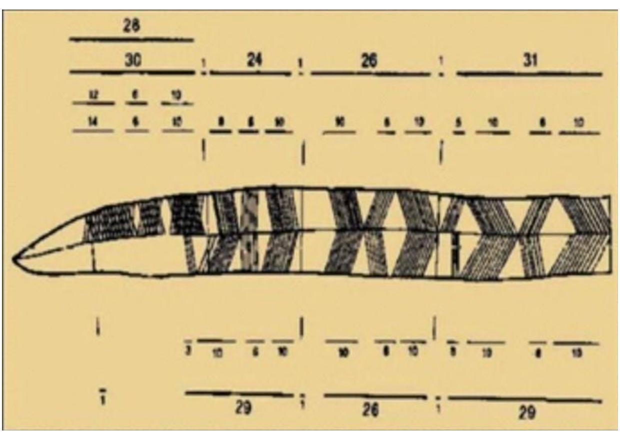
In every ancient culture, astronomy was born before mathematics: there is, in fact, no need of maths to look at the sky, observe the periodicity of the moon's phases, of a few identifiable planets, the northward or southward journey of the sunrise on the eastern horizon through the year, or to trace imaginary lines between the stars.

2

Astronomy in India

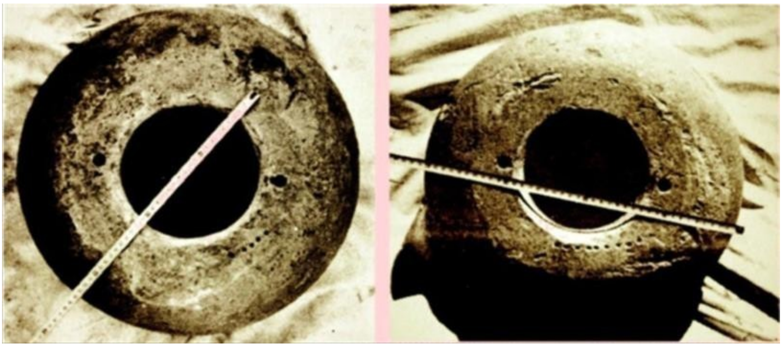
The Beginnings of Indian Astronomy

And that is indeed how the story of astronomy always begins. In India, those beginnings are not adequately documented. The first 'astronomical' objects, found in the Andamans, belong to the palaeolithic era, some 12,000 years ago; they are calendar sticks noting the waxing and waning * of the moon by incising daily notches on a wooden stick.



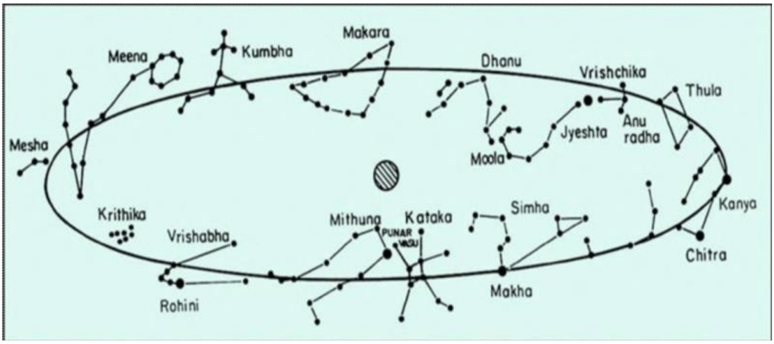
One of the calendar sticks found in the Andaman islands, apparently recording lunar phases across several months

*The apparent increase (waxing) and decrease (waning) of the moon's disc from new moon to full moon and back, in the course of a lunar month.



Some of the rings stone found at Mohenjo-daro, with rows of small drilled holes that appears to point to the sunset across the year. (Courtesy: Erkka Maula)

Patterns of rock art found in Kashmir, such as a double sun or concentric circles, have convinced some scholars that they were depictions of a supernova and meteor showers respectively, perhaps witnessed some 7,000 years ago. Ring-stones found at Mohenjo-daro, the largest city of the Indus civilization (2600-1900 BCE), which exhibit rows of small drilled holes, have been interpreted as calendrical devices keeping track of the sunrise at different times of the year. The perfect east–west alignment of streets in the same city has been attributed to the sighting of the star cluster Pleiades (*Kṛttikā*). While the above statements remain speculative, it is well recognized that ancient people everywhere felt a need to relate to the universe by tuning in to the rhythms of celestial objects.



The 27 nakṣatras, with the earth in the centre. (Courtesy: M.S. Sriram)

Because of the need to keep time for the proper conduct of rituals, calendrical astronomy grew more sophisticated in the late Vedic period, with the VedaTga Jyotiṣa of Lagadha as its representative text (and, if we may call it so, the first extant Indian scientific text). On the basis of its own astronomical data, it has been dated between the 12th and the 14th centuries BCE by most scholars. The length of the sidereal day (i.e. the time taken by the earth to complete one revolution with respect to any given star) it uses is 23 h 56 min 4.6 s, while the correct value is 23 h 56 min 4.091 s; the tiny difference is an indication of the precision reached in that early age. The VedaTga Jyotiṣa also discusses solstices (ayanaTnta) and equinoxes (viṣuva) and uses two intercalary lunar months (adhikamaTsa) to catch up with the solar calendar.* In some ways, this text remains the foundation for India's traditional luni-solar calendars.

*The solar year is about 365.24 solar days, while the lunar year is, at most, 360 days. After a few years, the difference between the two will grow so much that a month needs to be added to the lunar year to restore a broad coincidence between the two systems. This is the intercalary month.

The Early Historical Period

The second period extended from the 3rd century BCE to the 1st century CE and was marked by astronomical computations based on the risings and settings of planets, their revolutions, etc. Jain astronomy also developed in this period, based on a peculiar model of two sets of 27 nak ṣatras, two suns and two moons; it nevertheless resulted in precise calendrical calculations.

This is also the period when huge scales of time were conceived of such as a ‘day of BrahmaT’ (or kalpa) of 4.32 billion years, which curiously comes close to the age of the earth (4.5 billion years). Of course, there are much longer time scales to be found in Jain texts and in the PuraT ṇas.

While some scholars have discerned Babylonian and Greek influences at play during this and the next periods, the issue remains open. Nevertheless, such influences seem clear enough in the introduction of the seven-day week a few centuries BCE (late Vedic India divided the month only into two lunar fortnights or pak ṣa, one light and one dark), and of the zodiac of 12 signs (raTsi), first recorded in the YavanajaTtaka (c. 269 CE).

The Siddhāntic Era

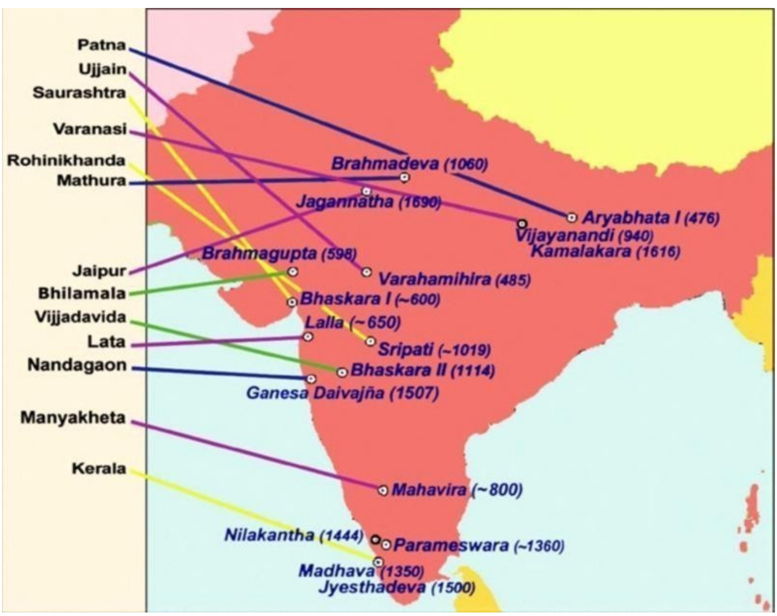
There are many gaps in our knowledge after the above period and before the start of what has been called the golden age of Indian mathematics and astronomy. Beginning in the 5th century CE, this is the SiddhaTntic era, when texts called siddhaTntas were composed — a Sanskrit word meaning ‘principle’ or ‘conclusion’, but which applies here to a collection of conclusions or a treatise. Their chief characteristics were the use of trigonometric methods and epicyclic* models for the computations of planetary positions.

---

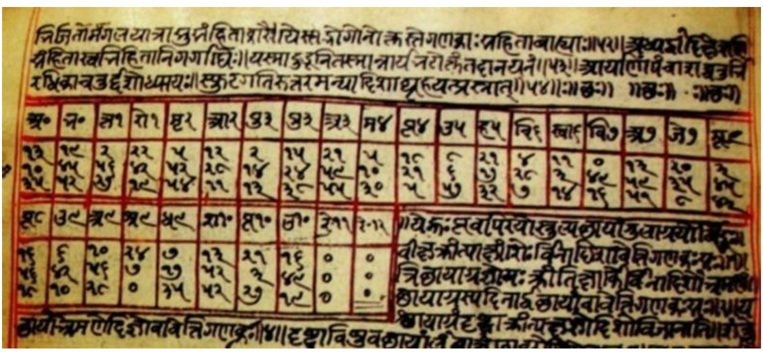
*Because they were using a geocentric system, early Greek and Indian astronomers could not explain the planets’ occasional retrograde motion (as seen from the earth); they assumed that the planets moved along smaller orbits, called epicycles, whose centres revolved around the earth along larger circles (the planets’ mean orbits).

AWryabhṭa I (born 476 CE), working near what is today Patna, ushered in this era with his AWryabha ṭīUUUTya, which dealt concisely but systematically with developments in mathematics and astronomy. Among other things, it discussed units of time and features of celestial sphere, described the earth as a rotating sphere hanging in space, and produced a table of the planets' mean positions. AWryabhạa also gave a correct explanation for both lunar and solar eclipses, and stated that the diameter of the earth is 1,050 yojanas (defining the yojana as 8,000 average human heights or about 13.6 km); this is close to the actual dimension, though 12% too large. (His diameters for the planets and the sun are however much too small.)

Many brilliant astronomers followed, dealing with issues of coordinate systems, time measurement and division, mean and



A map showing some of India's astronomers / mathematicians. Their dates of birth as well as their place of birth or work are often approximate. Note that many more names, from Baudhāyana (~ 600 BCE) to Śrīdhara (~ 800) or Āryabhaṭa II (~ 950), simply cannot be placed on the map, as the texts are silent on their locations. (Courtesy: Michel Danino, compiled from various sources) true positions of celestial bodies, and eclipses. VaraThamihira, AWryabhṭa’s contemporary, composed in 505 CE a collection of five astronomical texts prevalent during his time; one of the five texts, the SuTrya SiddhaTnta, was revised later and became a fundamental text of Indian astronomy; two others expounded the principles of Greek astronomy. VaraThamihira extensively discussed the revolutions of planets, eclipses, and the zodiac, often with an astrological background. BhaTskara I (b. 600 CE), the earliest known exponent of AWryabhaṭa I, provided a very useful elucidation of AWryabhṭa’s astronomy, besides improved calculation methods.



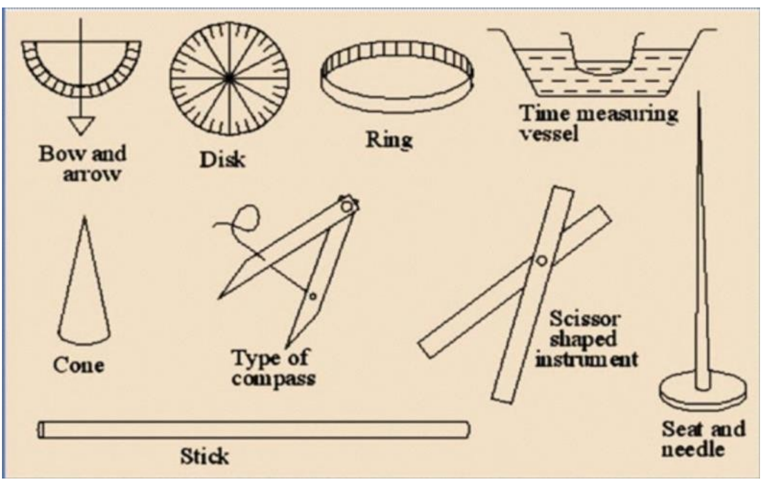
A manuscript of a passage of Brahmagupta’s Brahmasphuta Siddhānta. (Courtesy: Bombay University Library)

A few years later, Brahmagupta (born 598 CE), who lived near Mount Abu, mistakenly rejected AWryabhṭa view of the earth as rotating sphere, but contributed much to calculations of the mean and true longitudes of planets, conjunctions and problems of lunar and solar eclipses, applying to all these his considerable mathematical skills. *

---

*The celestial longitude of a celestial body (planet or star) is the arc of the ecliptic measured eastward from the vernal equinox (Aries) to the point where the ecliptic is intersected by the great circle passing through the body. (The ecliptic is the plane of the earth’s orbit.) ‘Mean longitude’ refers to an average value, i.e. the body’s average position, while ‘true longitude’ refers to its actual position at a given time.

Indian astronomers could not have achieved so much without a strong tradition of observation, and the 22nd chapter of Brahmagupta's *magnum opus*, the *Brahmasphuta Siddhānta*, dealt with a variety of astronomical instruments, most of which could be easily made by any good craftsman: among them, a water clock (*ghaṭī yantra*) consisting of a bowl with a small hole at the bottom, which would sink in exactly 24 minutes (a *ghaṭī*) if placed over water; a gnomon (a short stick kept vertically for the study of the motion of its shadow); a graduated disk or half-disk; and a scissor-like pair acting as a compass. Those instruments and the computational techniques applied to them were both adopted by later scholars, beginning by Lalla of the 8th century.



Some of the instrum ents described by Lalla for astronomical o bservations. (Courtesy: S hekher Narveker)

Brahmagupta also authored a manual of astronomical calculations which remained popular for centuries, as testified by Al-Biruni, the Persian savant who came to India in the 11th century as part of Mahmud of Ghazni's entourage. Al-Biruni was deeply interested in Indian astronomical techniques, wrote about them at length, and translated texts by VaraThamihira and Brahmagupta into Arabic or Persian.

BhaTskara II (b. 1114), better known as BhaTskaraTchaTrya, brought important innovations to both astronomical and mathematical techniques, discussing in particular the mean and true positions of planets, the triple problem of time, direction and place, the risings and settings and conjunctions of the planets, eccentric and epicyclic theories for their motions of planets, and a large number of astronomical instruments. Over all, BhaTskaraTchaTrya greatly improved upon the formulas and methods adopted by earlier Indian astronomers.

Inscription of 1128 CE recording King Ratnadeva's donation of a village to astronomer Padmanābha for predicting a total lunar eclipse. Over 350 such inscriptions, from 440 to 1859, have been traced out.
(Courtesy: B.V. Subbarayappa)

During those centuries, astronomy's interface with the general public was mostly through calendars and *pañcāṅgas* (almanacs), and the prediction of eclipses, which had great religious and social significance. Indeed, an astronomer's fame was guaranteed if he could accurately predict the occurrence, nature and duration of eclipses, and numerous inscriptions record a king's reward to such an astronomer. Another interface was architecture, and many temples show clear astronomical alignments with events such as the sunrise at solstices and equinoxes.

The Kerala School

The widespread belief that there was virtually no progress in Indian astronomy and mathematics after BhaTskara II is based on a general ignorance of the intense developments that took place in the southern state of Kerala. The so-called 'Kerala School of astronomy and mathematics' flourished there from the 14th to the 17th century, when networks of knowledge transmission in north India were severely disrupted in the wake of repeated invasions.

ParamesRvara (c. 1362-1455), an author of some thirty works, was one of the foremost astronomers of this School, and the founder of the dṛk system, which improved computations of eclipses and the positions of the planets and proved to be very popular. He emphasized the need to regularly correct formulas to bring them closer to actual observations, and was said to have studied eclipses and their parameters over a period of years.
He was followed by NīUUUṇṭha SomayaTjīUU(1444-1545), who, in his landmark Tantrasaṅgraha, carried out a major revision of the older Indian planetary model for the inferior planets, Budha (Mercury) and SSukra (Venus), and described them, along

with Maṅgala or Kuja (Mars), Bṛhaspati or Guru (Jupiter) and SSani (Saturn), as moving in eccentric orbits around the sun. This achievement of the Kerala school of astronomy is truly remarkable in the light of the fact that NīĪaka ṇṭha preceded Copernicus (1473-1543), the propounder of the heliocentric theory in Europe. It seems unlikely, however, that Indian heliocentrism directly influenced European advances in the field.

Other Post-Siddhāntic Developments

About the same time, a complex interface with Islamic astronomy took place, which, among other benefits, brought instruments such as the astrolabe to India. The famous and massive yantramantra or Jantar Mantar observatories built in the early 18th century by the Maharaja of Jaipur, Sawai Jai Singh (1688-1743), represent a convergence between Indian, Arabic and European astronomy.

In a general way, Indian astronomers were more interested in efficient methods of computation than in theoretical models. Some of the techniques used to calculate planetary positions and

Two views of New Delhi's Jantar Mantar. (Courtesy: Michel Danino)

eclipses yielded remarkably precise results and impressed by their speed European astronomers such as Le Gentil, a French savant who stayed in Puducherry for two years to observe a solar transit of Venus in June 1769.

Although traditional tables and even calculation methods survived well into the nineteenth century (witness the case of the Odiya astronomer, SaTmantaCandrasRekharaSimha, who was completely insulated from European astronomy and authored in 1869 a voluminous SiddhaTnta), the introduction of modern astronomy brought to a close India's own developments in this science. But India, in many ways, had contributed to the growth of the new science, as some of the techniques developed by Indian astronomers and mathematicians had been relayed to Europe centuries earlier through the Arabs. Indeed, Indian astronomy interacted not only with Islamic (or Zīj) and European astronomies, but also with Chinese astronomy, in complex interplays that invariably enriched both players.

3

Chemistry in India: A Survey

Chemistry, as we understand it today, is a relatively young discipline; it took shape in 18th -century Europe, after a few centuries of alchemical tradition, which was partly borrowed from the Arabs. (Alchemy was a semi-esoteric practice whose ultimate goal was to turn base metals into gold and discover an 'elixir of life' that would grant immortality.) Other cultures — especially the Chinese and the Indian — had alchemical traditions of their own, which included much knowledge of chemical processes and techniques.

Early Chemical Techniques

In India, we can trace such techniques all the way to the Indus civilization (3rd millennium BCE) and its antecedents. The Harappans' metallurgical skills have been described in the

A bleached bead from Harappa (courtesy: J.M. Kenoyer).

module on **Metallurgy in India**. Pottery called for a control of processes such as heating, fusion and evaporation. Bead-making involved complex treatments of minerals, including bleaching a bead with a solution of calcium carbonate, then heating it in a kiln, so as to leave permanent white designs on it.

Harappans also experimented with various mortars and cements made of burnt limestone and gypsum, among other components. Finely crushed quartz, once fired, produced faience, a synthetic material; it was then coated with silica (perhaps fused with soda) to which copper oxide was added to give it a shiny turquoise glaze. Faience was then shaped into various ornaments or figurines. The addition of iron oxide gave a greenish blue tint to glazed pottery, while manganese oxide resulted in a maroon colour.

Such techniques survived the end of the Indus civilization and found their way to the later Ganges civilization (1st millennium BCE), often with innovations — glass manufacture, for instance: numerous glass beads and other artefacts have been unearthed from Taxila in the Northwest to Nalanda in the East and Arikamedu in the South.

A Harappan Bangle made of faience

Pigments were another area for skilled chemical practices, and were required for painting (witness the famous Ajanta murals) as well as dyeing of cotton and other textiles. Interestingly, sources of pigments were not limited to organic materials (such as extracts of specific flowers or fruits) but included mineral sources, from carbon (lamp black) to arsenic sulphide (yellow ochre) or copper acetate (verdigris, greenish-blue in colour).

Atomism in Vaiśeṣika

Although it did not translate into actual chemistry, the Indian notion of atomism deserves a brief mention. Atomism, or the concept that matter is ultimately made of indivisible building blocks, appeared in India a few centuries BCE as part of philosophical speculations, in particular in the VaisReṣika, one of the six philosophical systems of ancient India. The author of the VaisReṣika SuTtras came to be known as KaṇaTda (literally 'eater of particles') and may have lived any time after 500 BCE. In this system, all substance was seen as an aggregated form of smaller units called atoms (aṇu or paramaṇTu), which were eternal, indestructible, spherical, supra -sensible and in motion at the primordial state; they could form pairs or triplets, among other combinations, and unseen forces caused interactions between them. The VaisReṣika system identified nine types of substance (dravya): (1 to 5) the five elements (earth or prithvi, water or ap, fire or tejas, wind or vaTyu, ether or aTkaTs(R)), (6) time (kaTla), (7) space or direction (dik), (8) the mind (manas), and (9) the spirit or knower (aTtman). Besides, substance had twenty-four different qualities (guṇas), including fluidity, viscosity, elasticity and gravity. While fluidity was related to water, earth and fire, viscosity was unique to water, and gravity to earth. Distinctive characteristics of sound, heat and light were also discussed, which often came close to later discoveries of physics, although, lacking a mathematical apparatus, they did not evolve into scientific theories.

Chemistry in Early Literature

We find plentiful evidence of knowledge of chemical practices in some of India's early literature.

Kauṭilya's ArthasRaTstra is a well-known text of governance and administration authored probably in the 3rd or 4th century BCE, during the Mauryan era. It has much data on prevailing chemical practices, in particular a long section on mines and minerals (including metal ores of gold, silver, copper, lead, tin and iron). It also discusses the various characteristics of precious stones (pearl, ruby, beryl, etc.), details of fermented juices (from sugarcane, jaggery, honey, jambu, jackfruit, mango, etc.), and oil extraction.

The fundamental two texts of Ayurveda are the Caraka SaṃhitaT and the SusRruta SaṃhitaT, both dated a few centuries CE. Not only do they turn to a wide range of chemicals for medical use — metals, minerals, salts, juices — but they also discuss the preparation of various alkalis (kṣaTra), which is regarded as one of the 'ten arts' (kalaT). Alkalis are described as mild, caustic or average and are prepared from specific plants: after the plants have been burnt together with some limestone, their ashes are then stirred in water, filtered, and the resulting solution is concentrated by boiling, to which burnt limestone and conch shells are added. Such alkalis were used to treat surgical instruments as well as thin sheets of metals like iron, gold or silver intended for the preparation of drugs. These texts also speak of organic acids extracted from plants such as citrus or tamarind (an awareness of mineral acids came much later).

VaraThamihira's Bṛhat SaṃhitaT, an encyclopaedia of sorts composed in the 6th century CE, has a chapter on the preparation of numeous perfumes out of sixteen fundamental substances mixed in different proportions. Indeed, perfumery and cosmetics formed a major branch of chemical practices in classical and medieval India.

The Bṛhat SaṃhitaT also includes various recipes, for instance for the preparation of a glutinous material to be applied on the roofs and walls of houses and temples; it was prepared entirely from extracts from various plants, fruits, seeds and barks which, after being boiled and concentrated, were then treated with various resins. It would be interesting to test and scientifically assess such recipes.

Among them, interestingly, we find, 'Knowledge of gold and silver coins, jewelsand gems; chemistry and mineralogy; coloured jewels, gems and beads; knowledge of mines and quarries,' which testifies to the attention paid to such fields.

The Classical Age

Alchemy in India emerged around the mid-first millennium CE, during the Gupta empire. Its origins remain hard to trace, and scholars have proposed that it received inputs from China, where the discipline is well attested as early as in the 2nd century CE. Whatever its beginnings, Indian alchemy soon took a stamp of its own. It was variously called rasasRaTstra, rasavidyaT or dhaTtuvaTda; the word rasa has many meanings, such as essence, taste, sap, juice or semen, but in this context refers to mercury, seen as one of the most important elements. This is in tune with the Tantra philosophy, and indeed, in alchemical practices, preparations and processes, mercury was regarded as divine and assumed to be potent enough to confer not only longevity but also occult powers, including invisibility and levitation.

There is a vast alchemical literature, authored by savants such as NaTgaTrjuna, Govinda BhaTgavat, VaTgbhata, Somadeva, YasRodhara, among many others. The rasasRaTstra texts discuss many chemical substances and their interactions. They were categorized as follows (with some variations):

- **mahārasas or eight major substances**: mica, tourmaline, copper pyrite, iron pyrite, bitumen, copper sulphate, zinc carbonate, and mercury (sometimes lapis lazuli and magnetite or lodestone are included);
- **uparasas or eight minor substances**: sulphur, red ochre, iron sulphate, alum, orpiment (arsenic trisulphide), realgar (arsenic sulphide), collyrium (compounds of antimony), and tintstone or cassiterite (tin dioxide).
- **navaratnas or nine gems**, including pearl, topaz, emerald, ruby, sapphire and diamond;
- **dhātus or seven metals**: gold, silver, copper, iron, lead, tin, zinc; a few alloys (such as brass, bronze and combinations of five metals) were also included; **poisons (viṣa or garala) and plants**; among the latter, over 200 are named in the texts (their identification is not always certain); plants were required, in particular, to treat or 'digest' metals and minerals.

In the quest for the elixir of life, mercurial preparations were supposed to bestow long life and youthful vigour; mercury was sometimes called amṛtadhaTtu or 'immortal metal'. In practice, some Ayurvedic and Siddha medicines were derived from various metals and minerals, but only after those had undergone complex purificatory processes so as to remove their toxic effects (or 'kill' them, as the texts say) and make them fit for internal use. For instance, although mercury compounds are regarded as poisonous, cinnabar (mercuric sulphide, HgS) went through eighteen complex processes (saṃskaTras), including rubbing with various medicinally efficacious plant juices and extracts, incorporation of sulphur, mica, alkaline substances, etc. The resulting mercury compound was then declared fit for consumption and believed to lead to the body's rejuvenation. Similar processes existed in Tamil alchemy and the Siddha system of medicine, which developed, in addition, special techniques in connection with naturally occurring salts, especially three of them (muppu), consisting of rock salts and various carbonates.

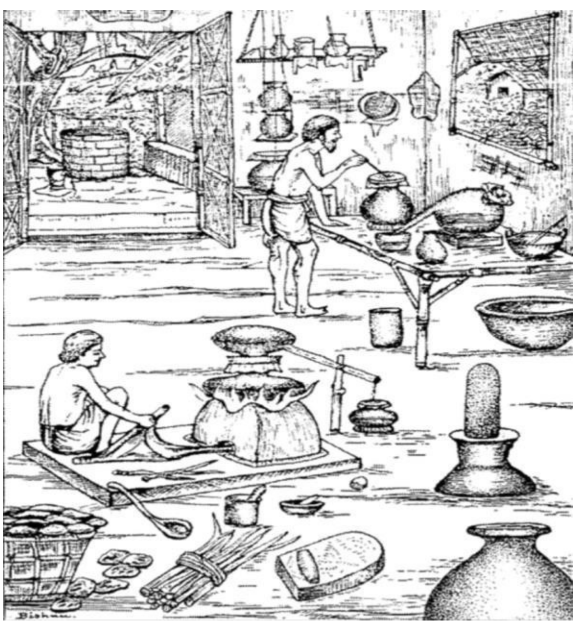
Native cinnabar or mercuric sulphide

Transmuting base metals, such as lead, tin or copper, into gold was another pursuit of alchemy, and involved five operations: smearing, throwing, pouring, fumigating and impact. Here again, mercury, sometimes called svar ṇakaTraka or 'maker of gold', often played a major role. The processes described in the texts are quite elaborate, extending to many days; their precise details cannot often be followed, however, as there are uncertainties about some plants, minerals, or their treatments. But transmutation was not regarded as a purely mechanical process: honesty, self-control, sincerity of purpose, devotion to God, obedience to the guru and faith in rasavidyaT were regarded as essential for the rasavaTdin to achieve success. Actual practices were kept secret, as the goal would fail to be reached if they were divulged to the uninitiated. devotion to God, obedience to the guru and faith in rasavidyaT were regarded as essential for the rasavaTdin to achieve success. Actual practices were kept secret, as the goal would fail to be reached if they were divulged to the uninitiated.

Claims of actual production of gold out of base metals extend to recent times, such as a 1941 demonstration recorded on a marble slab at New Delhi's Lakshminarayan temple; naturally, such claims must be viewed with the greatest scepticism. More likely, the colour of the metal was so altered that it appeared golden; indeed, some texts refer to gold-looking alloys of silver, copper and mercury. In the alchemical tradition, the transmutation of metals may also be taken as a metaphor for the body's own transmutation through the elixir of life, which was the ultimate objective of Indian alchemists. In any case, the quest for this elixir or the transmutation of base metals did lead to actual and valuable chemical techniques, in the medical field in particular, and eventually contributed to the Ayurvedic and Siddha pharmacopoeias.

Laboratory and Apparatus

The texts carefully spell out the layout of the laboratory, with four doors, an esoteric symbol (rasaliṅga) in the east, furnaces in the southeast, instruments in the northwest, etc. Besides mortars (of stone or iron) and pestles, bellows (to heat the furnaces), sieves, pans, tongs, scissors and earthen or

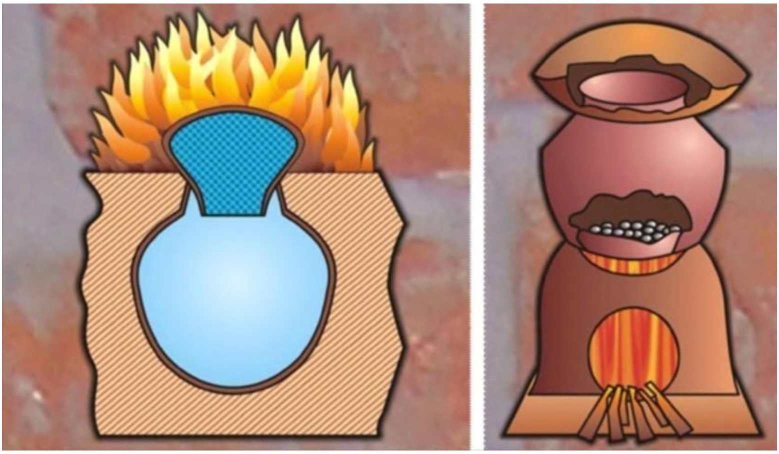


An artist's view of an alchemical laboratory or rasasala glass vessels, the apparatus included specialized instruments ingeniously developed for heating, steaming, distilling, triturating or extracting substances. Let us mention just a few of them:

- **the mūsa yantra or crucible**, usually made of white clay or of the earth of an anthill mixed with rice husk, iron dust, chalk, etc.; such crucibles would have various shapes and sizes, depending on their application;
- **the koṣṭhi yantra,** for the extraction of 'essences' of metals, consisting of two rimmed vessels, with fire urged from above and a side blower; besides the metals, the vessels would be filled with charcoal;
- **the svedanī yantra**, a big earthen vessel used for steaming;
- **the dolā yantra**, in which a pot is half-filled with a liquid and a suspended substance absorbs the liquid's vapours;

A representation of the koṭhi yantra (left) and the dolā yantra (right) (Courtesy: National Science Centre, New Delhi)

- **the pātana yantra,** for sublimation or distillation; it could be upward, downward or sideways; the second was the aTdhana yantra, in which a paste of mercury was coated at the bottom of the upper vessel, allowing vapours to descend into the lower vessel and combine with substances kept there;
- **the dhūpa yantra,** used for fumigation of gold leaves or silver foils with fumes of sulphur or other substances



A representation of the ādhana yantra (left) and the dhūpa yantra (right) (Courtesy: National Science Centre, New Delhi)

Altogether, India's chemical traditions were rich and varied, and fused elaborate techniques with a spiritual component. Although they may not have directly contributed to the birth of modern chemistry, they did result in considerable practical applications, especially in fields like metallurgy, gemmology and medicine.

4

The Historical Evolution of Medicinal Tradition in Ancient India

Specialization into eight branches

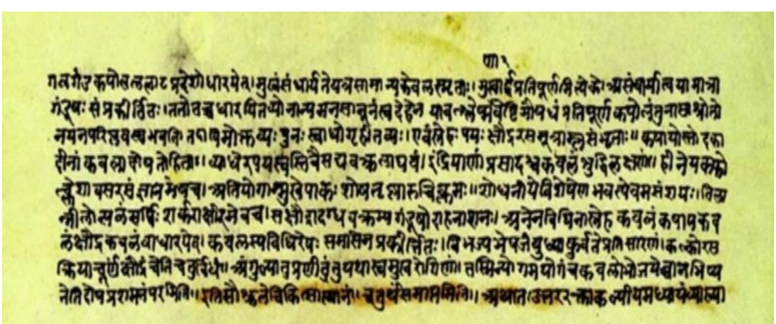
The history of medicine in India spans a period of several thousand years, definitely dating back to a few centuries before the Common Era. There is evidence that the earliest textbooks of Ayurveda like Caraka SaṃhitaT (General Medicine), SusRruta SaṃhitaT (Surgery), and KaTsRyapa SaṃhitaT (Paediatrics) were edited and revised several times over a thousand years. They attained their current form in the first few centuries of the Common Era. It is an amazing fact that so early, Sanskrit texts were composed dealing exclusively with specialties like Paediatrics, Surgery, Ophthalmology, ENT and so on. In these texts, Ayurveda is already seen in a developed form specialized into eight branches: General Medicine, Surgery, Ophthalmology-ENT-Dentistry, Paediatrics, Psychiatry, Toxicology, Rejuvenative Medicine and Reproductive Medicine. Around the 6th or 7th centuries CE, the renowned physician VaTgbhaṭa compiled the specialized knowledge of the eight branches of Ayurveda into one compendium; the larger version is known as AṣṭaṅTga Saṃgraha and the shorter version is called AṣṭaṅTga Hṛdaya.

The tradition of surgery

The tradition of surgery in Ayurveda has a long history. Researchers at the University of Missouri-Columbia discovered that physicians in ancient India had developed technology to

A mesolithic (15,000 – 6,000 BCE) rock painting from Bhimbetka, Madhya Pradesh seems to depict surgery being performed on a subject's head or eye.

drill teeth and remove decay 8,000 to 9,000 years ago. Study of fossils from Mehrgarh, now in Pakistan, revealed tiny holes drilled into teeth on the biting surface of male molars. Evidence has also been unearthed from Harappa and Lothal revealing an ancient surgical practice on a Bronze Age skull dating back to nearly 4,300 years ago. Trepanation, a common means of surgery practised in prehistoric societies starting with the Stone Age, involved drilling or cutting through the skull vault, often to treat head injury or to remove bone splinters or blood clots caused by a blow to the head.

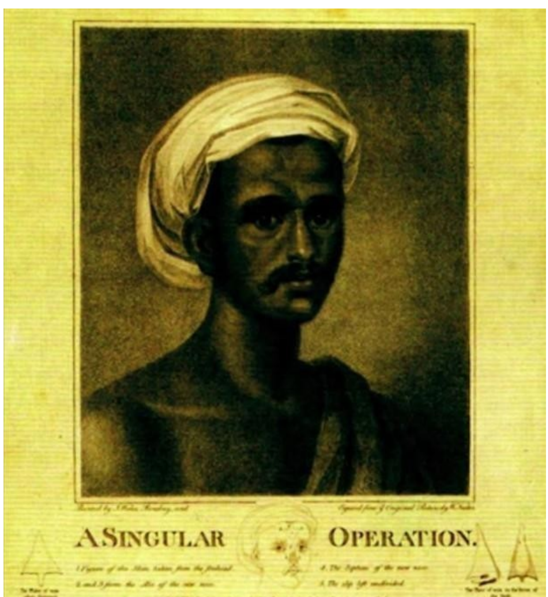


A folio from a manuscript of the Suśruta Saṃhitā, an Ayurvedic textbook on various surgical procedures and surgical instruments. (Courtesy: Wellcome Library, London)

The saga of Indian surgery continued to flourish and reached its acme in the time of SusRruta, who is believed to have lived in the 2nd century BCE. SusRruta is now revered as the father of surgery and advocated a thorough study of anatomy by dissecting the dead body. He introduced the method of sterilizing surgical instruments to prevent sepsis after surgical procedures. The compendium of SusRruta describes hundreds of sharp and blunt surgical instruments and many of them resemble instruments used by surgeons today. SusRruta is recognized for having developed innovative surgical procedures like reconstruction of the nose or rhinoplasty through plastic surgery, use of a specific species of ants as dissolvable sutures to close the intestines, surgical removal of cataract, and surgical management of urinary calculi.

Medical and surgical implements of 19th century origin from India.
(Courtesy: Science Museum, London)

This painting shows Suśruta's disciples learning surgery by working on vegetables



This painting by James Wales, commissioned in 1794 by two British surgeons, was published along with the first known description of plastic surgery in the West. (Courtesy: Wellcome Institute, London)

The Indian rhinoplasty technique was (re)discovered by Western medicine in the 18th century, when the East India Company surgeons Thomas Cruso and James Findlay witnessed Indian rhinoplasty procedures at the British Residency in Poona. The surgeons published photographs of the procedure and its nasal reconstruction outcomes in the October 1794 issue of the Gentleman's Magazine of London.

An oculist treating a patient with specialized instruments.(Painting of 1825, courtesy The British Library, London)

Medical genetics in Ayurveda

In the Caraka SaṃhitaT one comes across the earliest reference to the genetic basis of diseases. Caraka points out that the reproductive element is composed of seeds (bīUUUTja) which are further divided into parts (bīUUUTjabhaTga) and subparts (bīUUUTjabhaTgaTvayava). Each part or subpart of a seed represents a particular organ of the body and damage to the part can damage the organ.

Inoculation for smallpox

In the 18th century, British officials and travellers observed and documented the practice of inoculation for smallpox, which was in vogue in India centuries before vaccination was discovered by Edward Jenner. In an account written for London's College of Physicians, J.Z. Holwell, who studied and himself practised the Indian method of inoculation, testified to its great effectiveness in preventing the occurrence of smallpox.

Microbiology and parasitology

There are references to microbial life in textbooks of medicine like Caraka SaṃhitaT dating back to several centuries before the Common Era. Lower life forms were classified into pathogenic and non-pathogenic. The pathogenic organisms include microbes that cannot be seen with the naked eye. Technical nomenclature was developed for different types of microbes and their shapes and sizes have also been described. How those physicians were able to provide such descriptions, or even conceive of microbes, centuries before microscopes were invented remains a mystery.

Communicable diseases and epidemics

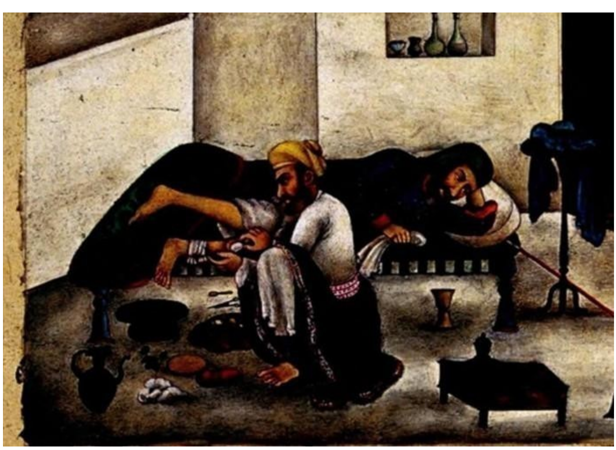
SusRruta SaṃhitaT describes communicable diseases and explains that disease can be transmitted from one person to the other by close contact, through air, sharing of clothes, sleeping together and so on. Fumigation is mentioned as a measure to prevent infectious diseases from spreading. Caraka Sa ṃhitaT devotes an entire chapter to epidemiology and prescribes methods to prevent epidemics as well as manage the outbreak of epidemics. During the period of King AsRoka, an efficient public healthcare system was established.

An evolving pharmacopoeia

The practice of medicine in Ayurveda is based on the principle that there is no substance in the world that does not potentially have medicinal property. The evolution of Ayurvedic pharmacopoeia represents a continuous and unfinished quest for discovering new medicines from natural resources. About 1,500 medicinal plants have been described and formulated into thousands of medicines in the tradition of Ayurveda. Hundreds of animals and animal products have also been mentioned in the texts. Around the 6th century in the Common Era, the branch of medicine specializing in the use of minerals and metals known as RasasRaTstra developed and established itself, especially in the North of India. The older tradition of herbal medicines continued to be practised in India's southern states. In Tamil Nadu, the system of Siddha medicine (traditionally regarded as having been founded by eighteen 'Siddhars' or realized beings, but in practice similar to Ayurveda) added to its pharmacopoeia drugs metallic and mineral components.

Pluralistic approach to healthcare

Ayurveda nurtured a pluralistic approach to healthcare in India. From ancient times, healthcare in India developed in



This painting shows an Ayurvedic surgeon attending to a wound with his surgical instruments. (Courtesy: Wellcome Library, London) the two streams of the folk and classical expressions. India has a rich tradition of folk medicine, which was organized into a paramedical force of health practitioners, bonesetters, poison healers and birth attendants who delivered primary healthcare for the people. Many of these traditions have survived into modern times. Today India is perhaps the only country in the world that officially recognizes a pluralistic healthcare system patronizing medical systems like Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homoeopathy.

Cross-cultural interactions

Ayurveda benefited from cross-cultural interactions and spread out of India into neighbouring countries like China, Sri Lanka, Tibet, Thailand and Indonesia. Buddhism played a major role in the spread of Ayurveda outside India. When Alexander the Great invaded India in 325 BCE, he was so impressed by the snakebite healers and Ayurvedic physicians that he invited them to Greece. There is historical evidence indicating interactions between the physicians of Greek medicine and Ayurveda. Important textbooks of Ayurveda like Caraka SaṃhitaT, SusRruta SaṃhitaT and AṣṭaTṅga Hṛdaya were translated into Tibetan, Persian and Arabic languages in the Middle Ages.

Travellers from China and the Middle East narrated in their accounts the advanced state of medical practice in India.

A dynamic literary tradition

The history of Ayurveda reveals the evolution of a vibrant and dynamic medical tradition with compendia, medical lexicons, pharmacopoeias, handbooks, manuals of treatment and so on being composed at important chronological and geographical landmarks. For example, in the 8th century CE, a treatise devoted exclusively to diagnostics was composed by MaTdhava known as MaTdhava NidaTna. In the 11th century, a new treatise was composed on dietetics by VisRvanaTtha Sena called PathyaTpathyavinisRcaya. In the 13th century the SSaTrngadhara SaṃhitaT was composed on the subject of pharmacy and pharmaceuticals, providing the first description of the physiology of respiration. When pulse diagnosis was introduced in Ayurveda, independent treatises were composed on the subject. This tradition of constant updating and documentation of medical knowledge continued without a break right up to the colonial period. In the 19th century, Ayurveda suffered a setback when unfavourable policies and regulations were enforced by the colonial rulers. However, with the publication of the main Ayurvedic texts, a revival set in around the turn of the 20th century, with a few leading Indian scholars coming out in defence of the discipline.

Global resurgence of Ayurveda

In the post-independence period, Ayurveda's resurgence continued, and in recent years it has been gaining prominence as a whole system approach to healthcare under the banner of Complementary and Alternative Medicine. Although it is not the West, Ayurveda is taught and practised in many countries like Germany, Italy, United Kingdom, Austria, Netherlands and so on. There are many schools of Ayurveda in the United States.

Contemporary status Ayurveda

Continues to manage a wide range of conditions effectively like chronic degenerative diseases and life style disorders and is being sought after by people around the globe. As the world is moving towards an integrative approach to healthcare, Ayurveda continues to inspire visions of healing that is holistic, pluralistic and integrative at the same time through a tradition that has exhibited remarkable continuity, resilience and adaptiveness to the vicissitudes of time.

5

Plant and Animal Science in Ancient India

Ayurveda also represent Life Sciences like Botany, Zoology, Veterinary Science and agriculture along with medicine. Plant science was known as Vrksayurveda and Animal science as Mrgayurveda. Asvayurveda and Gajayurveda represent Veterinary Medicine for horses and elephants respectively. Agriculture was known as Krsisastra.

Plant Science in Ancient India

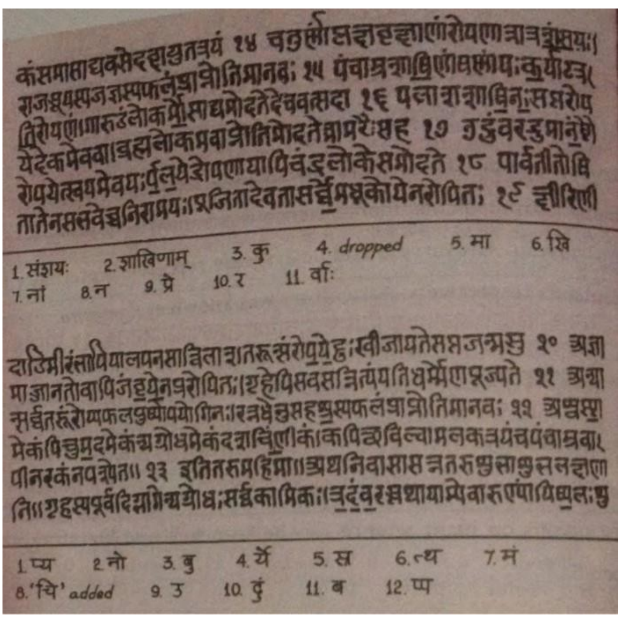
Antiquity and continuity

Knowledge of plants and agricultural practices are documented in ancient Indian literature. Discussions on plant science can be seen in Vedic literature, the epics and various compendia.

Sources

Arthasastra of Kautilya contains very interesting passages relating to the harvesting and management of crops and crop diseases and very many aspects of agroforestry. Brhat Samhita of Varahamihira composed in the 6th Century CE has an entire chapter devoted to Vrksayurveda. Agni Purana also includes a chapter on the topic. Cakrapanidatta, a commentator of the celebrated Ayurvedic text, Caraka Samhita, puts forth the theory that plants have feelings and cognitive abilities. There are also independent works on the subject like Surapala's Vrksayurveda and Upavana Vinoda of Sarngadhara. The legacy of Vrksayurveda has also been preserved through folk traditions in oral form. The farming and tribal communities constitutes the largest repository of the working knowledge of plant science in India.

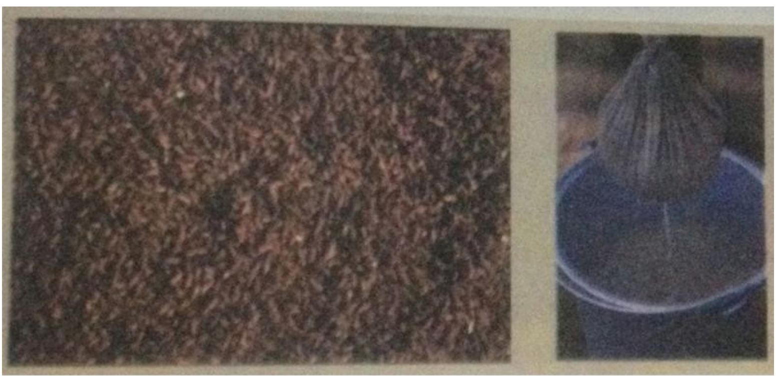
Surapala applied the dosa theory to plants to provide a number of recipes for plant protection and treatment, depending on the particular dosa imbalance affecting the plant. Many of the ingredients he lists have been shown to possess antimicrobial properties. Among them are milk (elephant milk at times!), ghee, honey, licorice, cow urine and dung, various liquid manures, mustard, pastes made of various barks and roots, asafetida, turmeric, sesame oil, salt and ash; the flesh, fat or marrow from various animals (mammals and fish) was also recommended in specific cases.



Folios from the manuscript of Vrksayurveda of Surapala, a text on plant science composed in the 10th century. (Courtesy: Asian Agri-History Foundation, Secunderabad)

Scope

Ayurvedic literature refers to plants and their classification into forest trees, other trees, shrubby plants and herbs. Shrubby plants are either climbers or shrubs as such and herbs are flowering and non- flowering. Flowering and an non-flowering trees are also distinguished. Vrksayurveda includes topics like collection, selection and storage of seeds, germination and sowing, various techniques of plant propogation and grafting, nursing and irrigation, testing and classification of soil, selection of soils suitable for various plants, types of plants, manuring,



Preparation of extract from neem kernels to treat crops against pests and diseases. (Courtesy: Centre for Indian Knowledge Systems, Chennai)

Preparation of extract from garlic, ginger and chilli to treat crops against pests and diseases. (Courtesy: Centre for Indian Knowledge Systems, Chennai) pest and disease management, nomenclature and taxonomy, description and classification of plants to get varied purposes, favorable and unfavorable meteorological conditions. Use of plants as indicators of weather, water, and minerals as well as botanical marvels.

Validation

The Indian Council of Agricultural Research (ICAR) has documented 4,879 indigenous practices in the field of traditional plant science. A set of 111 indigenous technical practices were selected and subjected to experimental testing and validation in efforts that were conducted by several ICAR institutes and state agricultural departments and universities across the country. These pertain to various topics such as pest control, crop protection, farm implements, weather forecasting etc., and it was shown that slightly more than 80% of these practices were valid and about 6% were partly valid. Vrksayurveda promises many new areas for fresh research initiatives like the study of meteorological conditions (tithi, naksatra) that are suitable for various agricultural operations in the cultivation of crops, increasing plant growth and yield, testing and classification of soil and use of plants as indicators for water, minerals and weather.

Animal Science in Ancient India

Antiquity and continuity

The branch of veterinary medicine was well developed in ancient India and was devoted to the well being of domesticated animals like cows, horses and elephants. Earliest references can be seen in vedic literature.

Sources

Hayayurveda of Salihotra is an ancient textbook of veterinary medicine that classifies horse and describes

(Left) A veterinary surgeon performing surgery on the eye of a horse.
(Right) A veterinary surgeon performing bloodletting on a horse.
(Courtesy: Wellcome Library, London)

treatments for horses apart from providing accounts of anatomy. Salihotra composed many treatises on horses, which were translated into Arabic, Persian and Tibetan. A treatise on Gajayurveda devoted to elephants was composed by Palakapya which deals with treatment of diseases afflicting elephants. The Mrgapaksisastra by Hamsadeva composed in the 13th century CE gives fascinating descriptions of animals and birds.

Scope

The diversity of animal life has been well captured in the ancient literature of India. The canons of Caraka and Susruta classify animals on the basis of their habitat and predatory behaviour. Animals are classified on the basis of habitat into terrestrial, underground, aquatic, aerial and marshy types. Animals are prey snatchers (prasaha), peckers (viskira) or attackers (pratuda). In different text, animals have been classified on the basis of varied criteria. The texts also speak of life emerging from moisture and heat as well as from head vegetation. One classification distinguishes animals by number of feet and another by the presence or absence of hoofs. The Matsyapurana classifies animals on the basis of their activity into diurnal, nocturnal or both. A number of animals have been described in the context of food and dietetics. The medicinal and nutritional properties of meat from a variety of animal sources have been documented in the classical text of Ayurveda. The food web and food chain have been described highlighting the principle that one form of life is food for another (jivo jivasya jivanam).

People of ancient India lived in close proximity with nature and were ken observers of animal life. It has been mentioned in some text that the first clues regarding medicinal properties of plants can be discovered from animal behaviour. Thus ancient Indian literature has one of the earliest documented evidence of the practice of zoo-pharmacognosy, that is, the discovery of medicinal uses of plant by observing how animals eat specific plants when they suffer from a disease, have worm or have been bitten by a snake.

The texts of Ayurveda also talk about confirming the toxicity of substances by administering test doses to animals, perhaps the earliest account of animal experiments in toxicology.

Current status

Gajayurveda is still practiced by traditional experts in states like Kerala. Veterinary herbal medicines are manufactured and marketed by pharmaceutical firm in India.

Biodiversity and folk traditions

The richness of the biodiversity and the climatic and geographic variations were highlighted in ancient writings. Different geographical regions were described along with the cycle of six seasons setting the stage for variations in biodiversity. It is mentioned in Ayurvedic texts that there is a variation of biodiversity in term of flora and fauna as well as human life and habits over a span of 12 yojanas or 96 miles. Ancient Indians estimated that there are nearly 8.4 million yonis or species of life on earth. This comes strikingly close to the recent estimate of modern scientists at 8.7 million species. Susruta proclaims that one must hunt for the earth is bountiful everywhere. There are about 4,600 ethnic communities in India who have lived in close proximity with nature and nurtured a folk system of medicine. It is estimated that there are one million specialized carries of folk medicine, outnumbering the paramedics on the payroll of the government.

6

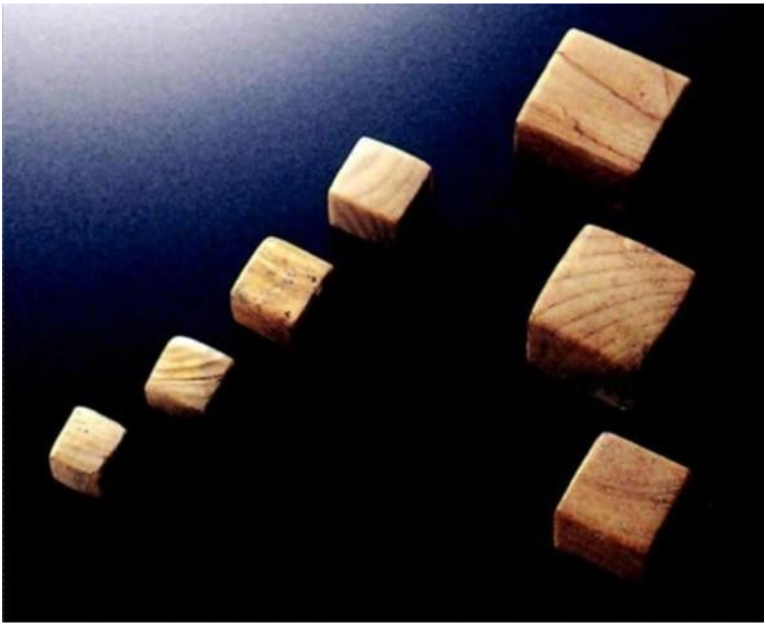
Mathematics in India

As early Indian astronomers tried to quantify the paths of the sun, the moon, the planets and the stars on the celestial sphere with ever more accuracy, or to predict the occurrence of eclipses, they were naturally led to develop mathematical tools. Astronomy and mathematics were thus initially regarded as inseparable, the latter being the maid-servant of the former. Indeed, about 1400 BCE, the *Vedāṅga Jyotiṣa,* the first extant Indian text of astronomy, states in two different versions:

Like the crest on the head of a peacock, like the gem on the hood of a cobra, *jyotiṣa* (astronomy) / *gaṇita* (mathematics) is the crown of the *Vedāṅga śāstras* [texts on various branches of knowledge]. In fact, *jyoti ṣa* initially referred to astronomy and mathematics combined; only later did it come to mean astronomy alone (and much later did it include astrology).

First Steps

India's first urban development, the Indus or Harappan civilization (2600-1900 BCE), involved a high degree of town planning. A mere glance at the plan of Mohenjo-daro's acropolis (or upper city), Dholavira (in the Rann of Kachchh) or Kalibangan (Rajasthan), reveals fortifications and streets generally aligned to the cardinal directions and exhibiting right angles. Specific proportions in the dimensions of major structures have also been pointed out. All this implies a sound knowledge of basic geometric principles and an ability to measure angles, which the discovery of a few cylindrical compasses made of shell, with slits cut every 45°, has confirmed. Besides, for trading purposes

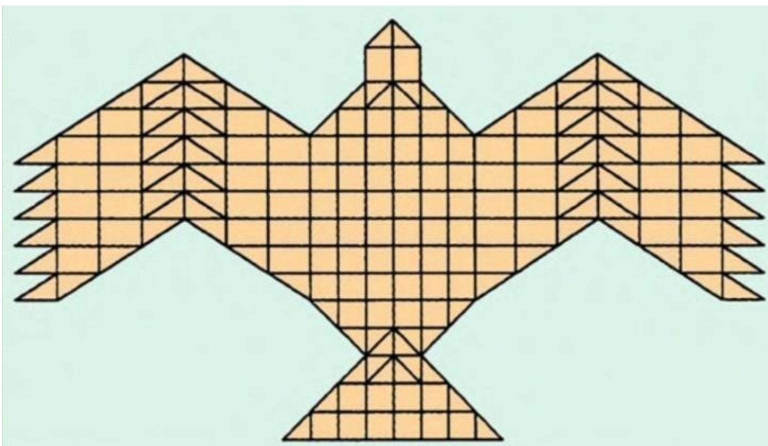


A few Harappan weights made of chert, from Dholavira, Gujarat (Courtesy: ASI)

the Harappans developed a standardized system of weights in which, initially, each weight was double the preceding one, then, 10, 100 or 1,000 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 multiples. However, there is no agreement among scholars regarding the numeral system used by Harappans.

Early Historical Period

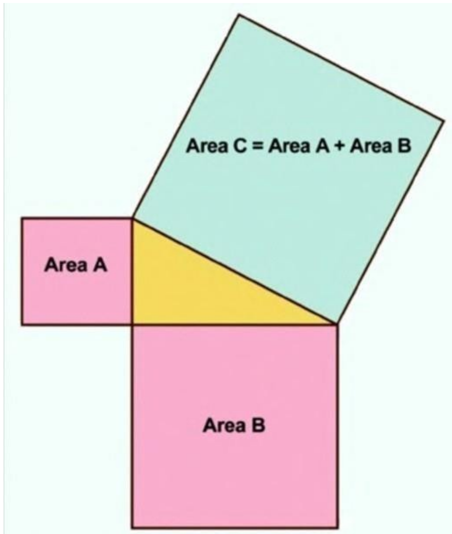
The first Indian texts dealing explicitly with mathematics are the *Śulbasūtras*, dated between the 8 th and 6th centuries BCE. They were written in Sanskrit in the highly concise *sūtra* style and were, in effect, manuals for the construction of fire altars (called *citis* or *vedis*) intended for specific rituals and made of bricks. The altars often had five layers of 200 bricks each, the lowest layer symbolizing the earth, and the highest, heaven; they were thus symbolic representations of the universe.



The first layer of one kind of śyenaciti or falcon altar described in the Śulbasūtras, made of 200 bricks of six shapes or sizes, all of them adding up to a specified total area.

Because their total area needed to be carefully defined and constructed from bricks of specified shapes and size, complex geometrical calculations followed. The *Śulbasūtras*, for instance, are the earliest texts of geometry offering a general statement, in geometric form, of the so-called Pythagoras theorem (which was in fact formulated by Euclid around 300 BCE).

They spelt out 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 classic problems of the squaring of a circle or the circling of a square (which, because of π's transcendental nature, cannot have exact geometrical solutions, only approximate ones). All



The geometrical expression of the Pythagoras theorem found in the Śulbasūtras.

these procedures were purely geometrical, but led to interesting corollaries; for instance, √2 was given a rational approximation which is correct to the fifth decimal

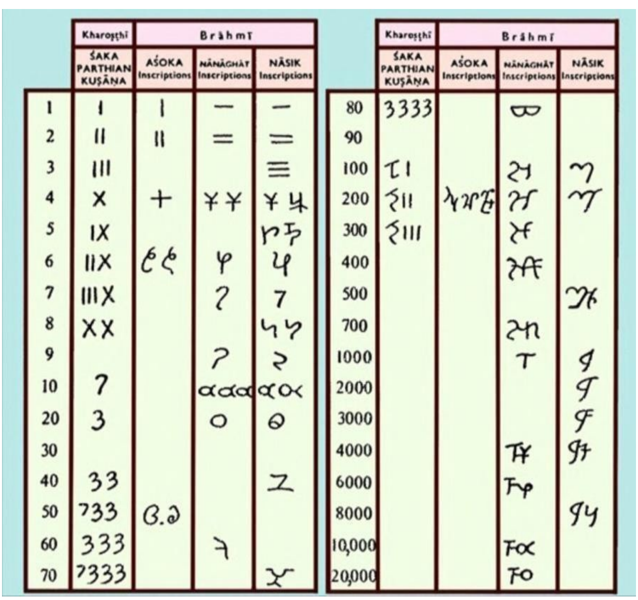
$$\sqrt{2} \approx 1 + \frac{1}{3} + \frac{1}{(3)(4)} - \frac{1}{(3)(4)(34)}$$

The *Śulbasūtras* also introduced a system of linear units, most of them based on dimensions of the human body; they were later slightly modified and became the traditional units used across India. The chief units were:

14 *aṇus* (grain of common millet) = 1 *a ṅgula* (a digit)
12 *aṅgulas* = 1 *prādeśa* (the span of a hand, later *vitasti*)
15 *aṅgulas* = 1 *pada* (or big foot)
24 *aṅgulas* = 1 *aratni* (or cubit, later also *hasta*)
30 *aṅgulas* = 1 *prakrama* (or step)
120 *aṅgulas* = 1 *puruṣa* (or the height of a man with his arm extended over his head)

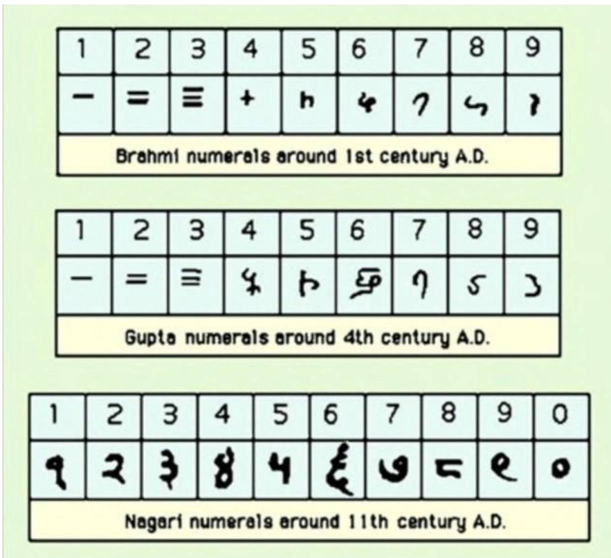
A few centuries later, Pi ṅgala's *Chandasūtras*, a text on Sanskrit prosody, made use of a binary system to classify the metres of Vedic hymns, whose syllables may be either light (*laghu*) or heavy (*guru*); rules of calculation were worked out to relate all possible combinations of light and heavy syllables, expressed in binary notation, to numbers in one-to-one relationships, which of course worked both ways. In the course of those calculations, Piṅgala referred to the symbol for *śūnya* or zero.

About the same time, Jaina texts indulged in cosmological speculations involving colossal numbers, and dealt with geometry, combinations and permutations, fractions, square and cube powers; they were the first in India to come up with the notion of an unknown (*yāvat-tāvat*), and introduced a value of π equal to √10, which remained popular in India for quite a few centuries.



Numerals as they appeared in early inscriptions, from the 3rd century BCE to the 1st century CE. Note that they do not yet follow a decimal positional system; for instance, in the first column, 40 is written as '20, 20', 60 as '20, 20, 20'. (Adapted from INSA)

With the appearance of the BraThmTUscript a few centuries BCE, we come across India's first numerals, on Ashoka's edicts in particular, but as yet without any decimal positional value. These numerals will evolve in shape; eventually borrowed by Arabs scholars, they will be transmitted, with further alterations, to Europe and become our modern 'Arabic' numerals.

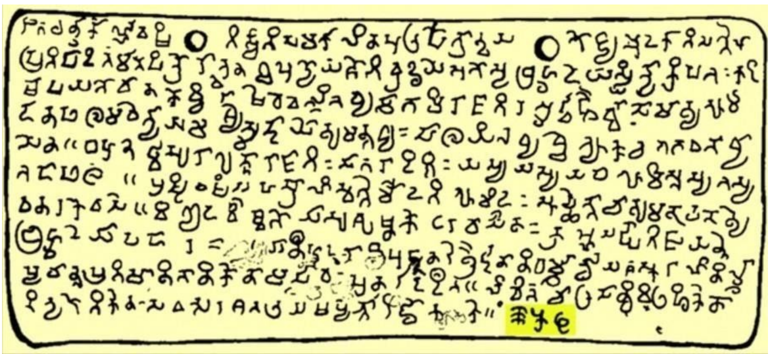


Evolution of Indian numerals, as evidenced by inscriptions. The first script, Brāhmī, was used by Aśoka in his Edicts; the last is an antecedent of the Devanagari script. (Adapted from J.J. O'Connor & E.F. Robertson)

The Classical Period

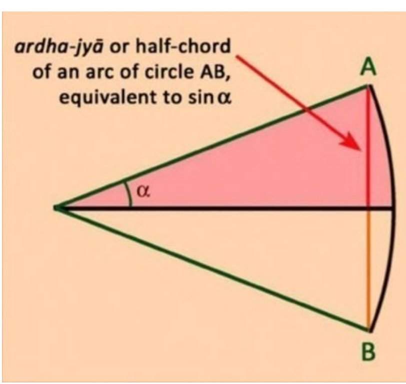
Together with astronomy, Indian mathematics saw its golden age during India's classical period, beginning more or less with the Gupta age, i.e. from about 400 CE.

Shortly before that period, the full-fledged place-value system of numeral notation — our 'modern' way of noting numbers, unlike non-positional systems such as those depicted above or Roman numbers — had been worked out, integrating zero with the nine numerals. It is a pity that we shall never know who conceived of it. Amongst the earliest known references to it is a first-century CE work by the Buddhist philosopher Vasumitra, and it is worked out more explicitly in the Jain cosmological work *Lokavibhāga,* written in 458 CE. Soon it was adopted across India, and later taken to Europe by the Arabs. This was a major landmark in the world history of science, since it permitted rapid developments in mathematics.



One of the first attested inscriptions (from Sankheda, Gujarat) recording a date written with the place-value system of numeral notation. The date (highlighted) reads 346 of a local era, which corresponds to 594 CE. (Adapted from Georges Ifrah)

About 499 CE, living near what is today Patna, AWryabhaṭa I (born 476 CE) authored the *Āryabhaṭīya*, the first extant *siddhānta* (or treatise) attempting a systematic review of the knowledge of mathematics and astronomy prevailing in his days. The text is so concise (just 121 verses) as to be often obscure, but between the 6th and the 16th century, no fewer than twelve major commentaries were authored to explicate and build upon its contents. It was eventually translated into Arabic about 800 CE



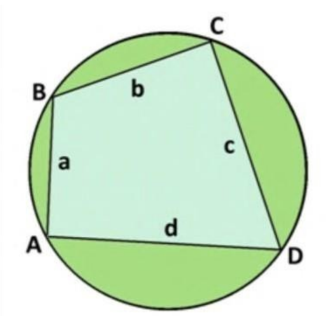
Āryabhaṭa introduced the notion of a half-chord, a substantial advance over Greek trigonometry, which considered the full chord of an arc of circle.

(under the title *Zīj al-Ārjabhar*), which in turn led to a Latin translation in the 13th century (in which AWryabhaṭa was called 'Ardubarius').

The mathematical content of *Āryabhaṭīya* ranges from a very precise table of sines and an equally precise value for π (3.1416, stated to be 'approximate') to the area of a triangle, the sums of finite arithmetic progressions, algorithms for the extraction of square and cube roots, and an elaborate algorithm called *kuṭṭaka* ('pulverizing') to solve indeterminate equations of the first degree with two unknowns: $ax + c = by$. By 'indeterminate' is meant that solutions should be integers alone, which rules out direct algebraic methods; such equations came up in astronomical problems, for example to calculate a whole number of revolutions of a planet in a given number of years.

It is worth mentioning that despite its great contributions, the *Āryabhaṭīya* is not free of errors: its formulas for the volumes of a pyramid and a sphere were erroneous, and would be later corrected by Brahmagupta and BhaTskaraTcaTrya respectively.

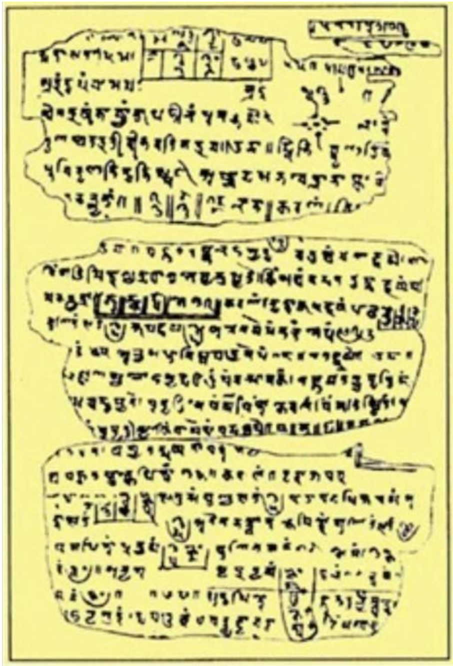
The Classical Period, post-Āryabhaṭa



Born in 598 CE, Brahmagupta was an imposing figure, with considerable achievements in mathematics. In his *Brahmasphuta Siddhānta*, he studied cyclic quadrilaterals (i.e., inscribed in a circle) and supplied the formula for their area (a formula rediscovered in 17th-century Europe): if ABCD has sides of lengths *a, b, c,* and *d*, and the semi-perimeter is $s = (a + b + c + d)/2$, then the area is given by:

$$\text{Area } ABCD = \sqrt{[(s-a)(s-b)(s-c)(s-a)]}$$

Brahmagupta boldly introduced the notion of negative numbers and ventured to define the mathematical infinite as khacheda or 'that which is divided by kha', kha being one of the many names for zero. He discovered the bhaTvanaT algorithm

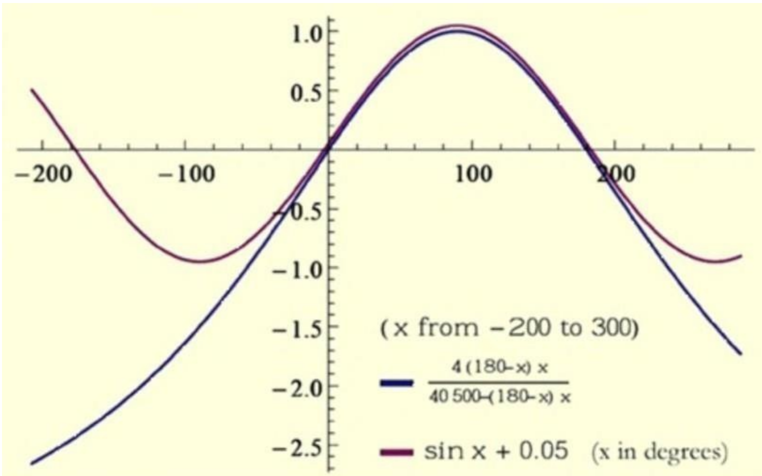


A few leaves from the Bakhshali manuscript (Courtesy: Wikipedia)

for integral solutions to second-order indeterminate equations (called varga prakriti) of the type $Nx^2 + 1 = y^2$. He was in many ways one of the founders of modern algebra, and his works were translated into Persian and later Latin.

Dated around the 7th century, the Bakhshali manuscript, named after the village (now in northern Pakistan) where it was found in 1881 in the form of 70 leaves of birch bark, gives us a rare insight into extensive mathematical calculation techniques of the times, involving in particular fractions, progressions, measures of time, weight and money.

Other brilliant mathematicians of the siddhaTntic era included BhaTskara I, a contemporary of Brahmagupta, who did pioneering work in trigonometry (proposing a remarkably accurate rational approximation for the sine function), SSrTdhara and MahaTvraUU. The last, a Jain scholar who lived in the 9th century in the court of a Rashtrakuta king (in today's Karnataka), authored the first work of mathematics that was not as part of a text on astronomy. In it, MahaTvraUU dealt with finite series, expansions of fractions, permutations and combinations (working out, for the first time, some of the standard formulas in the field), linear equations with two unknowns, quadratic equations, and a remarkably close approximation for the circumference of an ellipse, among other important results.



Graph showing the high accuracy of BhaTskara I's rational approximation for the sine function from 0° to 180° (in blue). The sine function (in read) had to be shifted upward by 0.05 to make the two curves distinguishable. (Courtesy: IFIH)

BhaTskara II, often known as BhaTskaraTcaTrya, lived in the 12th century. His *Siddhāntaśiromani* (literally, the 'crest jewel of the *siddhāntas*') broke new ground as regards cubic and biquadratic equations. He built upon Brahmagupta's work on indeterminate equations to produce a still more effective algorithm, the *chakravāla* (or 'cyclic method'); with it he showed, for instance, that the smallest integral solutions to $61x^2 + 1 = y^2$ are x = 226153980, y = 1766319049 (interestingly, five centuries later, the French mathematician Fermat offered the same equation as a challenge to some of his contemporaries). BhaTskaraTcaTrya also grasped the notion of integration as a limit of finite sums: by slicing a sphere into ever smaller rings, for instance, he was able to calculate its area and volume. He came close to the modern notion of derivative by discussing the notion of instant speed (taTtkaTlika gati) and understood that the derivative of the sine function is proportional to the cosine.

The first part of BhaTskaraTcaTrya's SiddhaTntasRiromani is a collection of mathematical problems called LīUUUTIa, named after an unknown lady to whom BhaTskara puts problems in an often poetical language. LīUUUTlāTīUUH became so popular with students of mathematics across India that four centuries later, Akbar had it translated into Persian by a court poet.

The Kerala School of Mathematics

Along with astronomy, mathematics underwent a revival in the Kerala School, which flourished there from the 14th to the 17th century. Its pioneer, MaTdhava (c. 1340–1425), laid some of the foundations of calculus by working out power series expansions for the sine and cosine functions (the so- called Newton series), and by spelling out this fundamental expansion of π:

$$\frac{\pi}{4} = 1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \cdots + \frac{(-1)^n}{2n+1} + \cdots$$

This is known as the Gregory–Leibniz series, but ought one day to be named after MaTdhava. He went on to propose a more rapidly convergent series for π:

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

which enabled him to calculate π to 11 correct decimals.

NīUUUṇṭha SomayaTji (c. 1444–1545) and Jyeṣṭhadeva (c. 1500–1600) built on such results and considerably enriched what might be called the Indian foundations of calculus. The latter, for instance, worked out the binomial expansion:

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

Features of Indian mathematics

As elsewhere, mathematics in India arose from practical needs: constructing fire altars according to precise specifications, tracking the motion of planets, predicting eclipses, etc. But India's approach remained essentially pragmatic: rather than developing an axiomatic method such as that of the Greek (famously introduced by Euclid for geometry), it focused on obtaining formulas and algorithms that yielded precise and reliable results.

Nevertheless, Indian mathematicians did often provide logically rigorous justifications for their results, especially in the longer texts. Indeed, BhaTskaraTcaTrya states that presenting proofs (upapattis) is part of the teaching tradition, and Jyeṣṭhadeva devotes considerable space to them in his Yukti BhaṣTaT. The shorter texts, on the other hand, often dispensed with the development of proofs. In the same spirit, the celebrated S. Ramanujan produced many important theorems but did not take time to supply proofs for them, leaving this for others to do!

Whether those specificities limited the further growth of Indian mathematics is open to debate. Other factors have been discussed by historians of science, such as historical disruptions of centres and networks of learning (especially in north India), limited royal patronage, or the absence of a conquering impulse (which, in Europe, did fuel the growth of science and technology). Be that as it may, India's contribution in the field was enormous by any standard. Through the Arabs, many Indian inputs, from the decimal place-value system of numeral notation to some of the foundations of algebra and analysis, travelled on to Europe and provided crucial ingredients to the development of modern mathematics.

7

Metallurgy in India

Technology is today defined as applied science, but early humans developed technologies — such as stone-working, agriculture, animal husbandry, pottery, metallurgy, textile manufacture, bead-making, wood-carving, cart-making, boat-making and sailing — with hardly any science to back them up. If we define technology as a human way of altering the surrounding world, we find that the first stone tools in the Indian subcontinent go back more than two million years! Jumping across ages, the 'neolithic revolution' of some 10,000 years ago saw the development in agriculture in parts of the Indus and the Ganges valleys, which in turn triggered the need for pots, water management, metal tools, transport, etc.

Agriculture apart, metallurgy brought about important changes in human society, as it gave rise to a whole new range of weapons, tools and implements. Some of these had been made in stone earlier, it is true, but the result was coarser as well as heavier. Metal, precious or not, is also a prime material for ornaments, and thus enriches cultural life.

Metallurgy may be defined as the extraction, purification, alloying and application of metals. Today, some eighty-six metals are known, but most of them were discovered in the last two centuries. The 'seven metals of antiquity', as they are sometimes called, were, more or less in order of discovery: gold, copper, silver, lead, tin, iron and mercury. For over 7,000 years, India has had a high tradition of metallurgical skills; let us see some of its landmarks.

Metallurgy before and during the Harappan Civilization

The first evidence of metal in the Indian subcontinent comes from Mehrgarh in Baluchistan, where a small copper bead was dated to about 6000 BCE; it is however thought to have been native copper, not the smelted metal extracted from ore. The growth of copper metallurgy had to wait for another 1,500 years; that was the time when village communities were developing trade networks and technologies which would allow them, centuries later, to create the Harappan cities.

Archaeological excavations have shown that Harappan metal smiths obtained copper ore (either directly or through local communities) from the Aravalli hills, Baluchistan or beyond. They soon discovered that adding tin to copper produced bronze, a metal harder than copper yet easier to cast, and also more resistant to corrosion. Whether deliberately added or already present in the ore, various 'impurities' (such as nickel, arsenic or lead) enabled the Harappans to harden bronze further, to the point where bronze chisels could be used to dress stones! The alloying ranges have been found to be 1%–12% in tin, 1%–7% in arsenic, 1%–9% in nickel and 1%–32% in lead. Shaping copper or bronze involved techniques of fabrication such as forging, sinking, raising, cold work, annealing, riveting, lapping and joining.

Among the metal artefacts produced by the Harappans, let us mention spearheads, arrowheads, axes, chisels, sickles, blades (for knives as well as razors), needles, hooks, and vessels such as jars, pots and pans, besides objects of toiletry such as bronze mirrors; those were slightly oval, with their face raised, and one side was highly polished. The Harappan craftsmen also invented the true saw, with teeth and the adjoining part of the blade set alternatively from side to side, a type of saw unknown elsewhere until Roman times.

Besides, many bronze figurines or humans (the well-known 'Dancing Girl', for instance) and animals (rams, deer, bulls...) have been unearthed from Harappan sites. Those figurines were cast by the lost-wax process: the initial model was made of wax, then thickly coated with clay; once fired (which caused the wax to melt away or be 'lost'), the clay hardened into a mould, into which molten bronze was later poured.

Harappans also used gold and silver (as well as their joint alloy, electrum) to produce a wide variety of ornaments such as pendants, bangles, beads, rings or necklace parts, which were usually found hidden away in hoards such as ceramic or bronze pots. While gold was probably panned from the Indus waters, silver was perhaps extracted from galena, or native lead sulphide.

After the Harappans

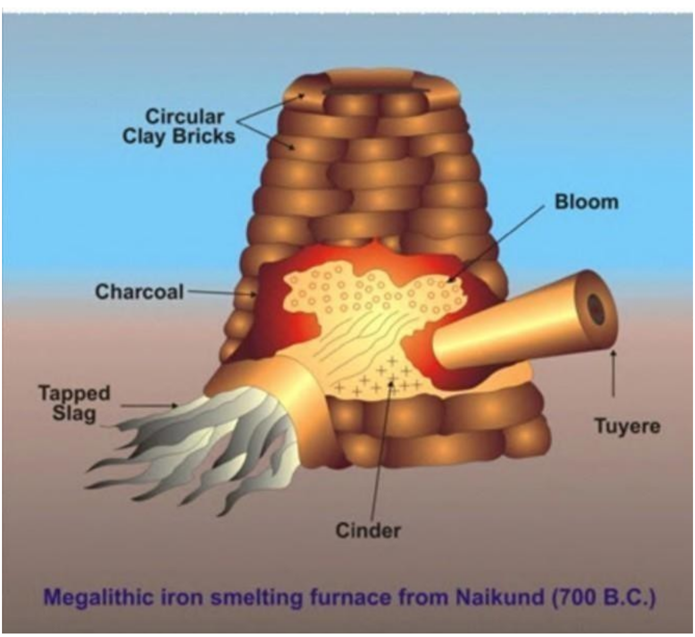
During and after the Harappan civilization, a 'Copper Hoard' culture of still unclear authorship produced massive quantities of copper tools in central and northern India. Later, in the classical age, copper-bronze smiths supplied countless pieces of art. Let us mention the huge bronze statue of the Buddha made between 500 and 700 CE in Sultanganj (Bhagalpur district, Bihar, now at the Birmingham Museum); at 2.3 m high, 1 m wide, and weighing over 500 kg, it was made by the same lost-wax technique that Harappans used three millenniums earlier.

So were thousands of statues made later (and up to this day) in Tamil Nadu, such as the beautiful Nataraja statues of the Chola period, among other famous bronzes. Of course, all kinds of bronze objects of daily use have continued to be produced; for instance, highly polished bronze mirrors are still made in Kerala today, just as they were in Harappan times.

Iron Metallurgy

While the Indus civilization belonged to the Bronze Age, its successor, the Ganges civilization, which emerged in the first millennium BCE, belonged to the Iron Age. But recent excavations in central parts of the Ganges valley and in the eastern Vindhya hills have shown that iron was produced there possibly as early as in 1800 BCE. Its use appears to have become widespread from about 1000 BCE, and we find in late Vedic texts mentions of a 'dark metal' (kr ṣnaTyas), while earliest texts only spoke of ayas, which, it is now accepted, referred to copper or bronze.

Whether other parts of India learned iron technology from the Gangetic region or came up with it independently is not easy to figure out. What seems clear, however, is that the beginnings of copper-bronze and iron technologies in India correspond broadly with those in Asia Minor (modern Turkey) and the Caucasus, but were an independent development, not an import.



A typical iron-smelting furnace in the first millennium BCE.
(Courtesy: National Science Centre, New Delhi)

Wootz Steel

Instead, India was a major innovator in the field, producing two highly advanced types of iron.

The first, wootz steel, produced in south India from about 300 BCE, was iron carburized under controlled conditions. Exported from the Deccan all the way to Syria, it was shaped there into 'Damascus swords' renowned for their sharpness and toughness. But it is likely that the term 'Damascus' derived not from Syria's capital city, but from the 'damask' or wavy pattern characteristic of the surface of those swords. In any case, this Indian steel was called 'the wonder material of the Orient'. A Roman historian, Quintius Curtius, recorded that among the gifts which Alexander the Great received from Porus of Taxila (in 326 BCE), there was some two-and-a-half tons of wootz steel — it was evidently more highly prized than gold or jewels! Later, the Arabs fashioned it into swords and other weapons, and during the Crusades, Europeans were overawed by the superior Damascus swords. It remained a favoured metal for weapons through the Moghul era, when wootz swords, knives

A typical sword made of wootz steel (about 18th century); the hilt is of iron and coated with a thick layer of gold. (Courtesy: R. Balasubramaniam) and armours were artistically embellished with carvings and inlays of brass, silver and gold. In the armouries of Golconda and Hyderabad's Nizams, Tipu Sultan, Ranjit Singh, the Rajputs and the Marathas, wootz weapons had pride of place.

Wootz steel is primarily iron containing a high proportion of carbon (1.0 – 1.9%). Thus the term wootz (an English rendering of 'ukku', a Kannada word for steel) applies to a high-carbon alloy produced by crucible process. The basic process consisted in first preparing sponge (or porous) iron; it was then hammered while hot to expel slag, broken up, then sealed with wood chips or charcoal in closed crucibles (clay containers) that were heated, causing the iron to absorb appreciable amounts of carbon; the crucibles were then cooled, with solidified ingot of wootz steel remaining.

Right from the 17th century, several European travellers documented India's iron-and steel-making furnaces (Francis Buchanan's accounts of south India are an important source of information as regards wootz). From the 18th century, savants in England (Pearson, Stodart and Faraday), France and Italy tried to master the secrets of wootz; the French Jean-Robert BreRant, conducting over 300 experiments by adding various metals to steel, understood the role of the high carbon proportion in wootz, and was the first European who successfully produced steel blades comparable to the Indian ones. Together, such researches contributed to the understanding of the role of carbon in steel and to new techniques in steel-making.

The Delhi Iron Pillar

The second advanced iron is the one used in the famous 1,600-year-old Delhi Iron Pillar, which, at a height of 7.67 m, consists of about six tons of wrought iron. It was initially erected 'by Chandra as a standard of Vishnu at Vishnupadagiri', according to a six-line Sanskrit inscription on its surface. 'Vishnupadagiri' has been identified with modern Udayagiri near Sanchi in Madhya Pradesh, and 'Chandra' with the Gupta emperor, Chandragupta II Vikramaditya (375–414 CE). In 1233, the pillar was brought to its current location in the courtyard of

The Delhi Iron Pillar, with a close-up of the inscription. (Courtesy: R. Balasubramaniam)

the Quwwat-ul Islam mosque in New Delhi's Qutub complex, where millions continue to come and see this 'rustless wonder'.

But why is it rustless, or, more precisely, rust-resistant? Here again, numerous experts, both Indian and Western, tried to grasp the secret of the pillar's manufacture. Only recently have its rust-resistant properties been fully explained (notably by R. Balasubramaniam). They are chiefly due to the presence of phosphorus in the iron: this element, together with iron and oxygen from the air, contributes to the formation of a thin protective passive coating on the surface, which gets reconstituted if damaged by scratching. It goes to the credit of Indian blacksmiths that through patient trial and error they were able to select the right type of iron ore and process it in the right way for such monumental pillars.

Other Iron Pillars and Beams

There are a few more such pillars in India, for instance at Dhar (Madhya Pradesh) and Kodachadri Hill (coastal Karnataka). Besides, the same technology was used to manufacture huge iron beams used in some temples of Odisha, such as Jagannath of Puri (12th century). The iron beams at Konarak's famous sun temple are of even larger dimensions. Chemical analysis of one of the beams confirmed that it was wrought iron of a phosphoric nature (99.64% Fe, 0.15% P, traces of C, traces of S and no manganese).

Zinc

Indian metallurgists were familiar several other metals, of which zinc deserves a special mention because, having a low boiling point (907°C), it tends to vaporize while its ore is smelted. Zinc, a silvery-white metal, is precious in combination with copper, resulting in brass of superior quality. Sometimes part of copper ore, pure zinc could be produced only after a sophisticated 'downward' distillation technique in which the vapour was captured and condensed in a lower container. This technique, which was also applied to mercury, is described in Sanskrit texts such as the 14th -century Rasaratnasamuccaya.

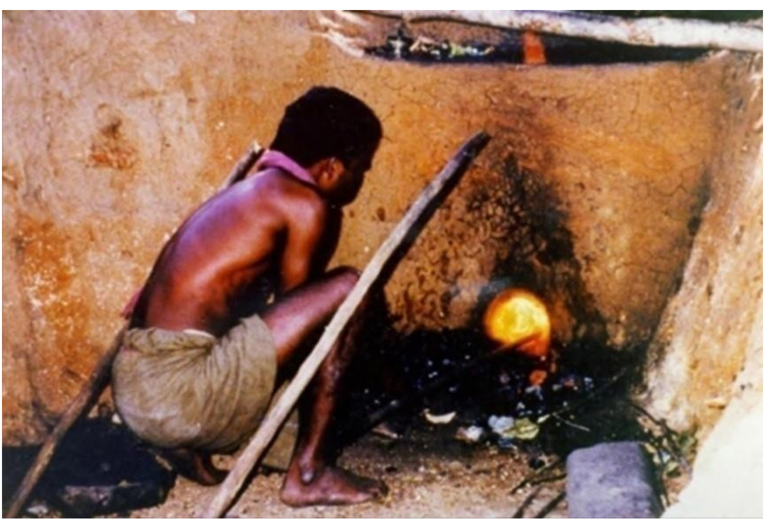
Zinc metallurgy at Zawar mines.
(Courtesy: National Science Centre, New Delhi)

There is archaeological evidence of zinc production at Rajasthan's mines at Zawar from the 6th or 5th century BCE. The technique must have been refined further over the centuries. India was, in any case, the first country to master zinc distillation, and it is estimated that between 50,000 and 100,000 tons of zinc was smelted at Zawar from the 13th to the 18th century CE! British chroniclers record continuing production there as late as in 1760; indeed, there is documentary evidence to show that an Englishman learned the technique of downward distillation there in the 17th century and took it to England — a case of technology transfer which parallels that of wootz steel.

Social Context

We should finally note that most of India's metal production was controlled by specific social groups, including so-called tribes, most of them from the lower rungs of Indian society.

For instance, the Agarias of Uttar Pradesh and Madhya Pradesh are reputed iron smiths, and there are still such



An underground furnace at Ghatgaon (Madhya Pradesh), with a tribal smelting iron ore. (Courtesy: A.V. Balasubramaniam) communities scattered across Jharkhand, Bihar, West-Bengal, Kerala and Tamil Nadu.

Together, they contributed substantially to India's wealth, since India was for a long time a major exporter of iron. In the late 1600s, shipments of tens of thousands of wootz ingots would leave the Coromandel Coast for Persia every year. India's iron and steel industry was intensive till the 18th century and declined only when the British started selling their own products in India while imposing high duties on Indian products. Industrially produced iron and steel unavoidably put a final stop to most of India's traditional production.

8

Indian Traditional Knowledge on Environmental Conservation

Introduction

In many parts of India, communities have inherited the rich tradition of love and reverence for nature through ages. Religious preaching, traditions and customs have played a big role in this regard: Indian religions have generally been the advocates of environmentalism. They campaigned for such guidelines to the commoners that ensured an intimate contact and sense of belonging in nature. It came in the form of directives to the believers to perform certain rites and rituals, so that it became a way of their life. Sometimes the messages of environmental protection and conservation are in a veiled form. Today, when the world is undergoing a serious crisis of ecological imbalance and environmental degradation, it is all the more important for us to understand such traditions.

Nature

Sun worship is of vital importance in ancient period; the sun was worshipped in the form of SuTrya, MaTrta ṇḍa, Uṣa, PuṢan, Rudra, etc. Today it has been proved that solar energy is the ultimate source of energy that regulates the energy flow through the food-chain, drives various nutrient cycles and thus controls the ecosystem all over the earth, but it was probably well understood and realized by the ancient people as well.

With remarkable foresight, Thiruvalluvar's *Kural*, an ancient text in Tamil from south India stresses the need to remain under nature's protection: 'Sparkling water, open space, hills and forests constitute a fortress.' Guru Granth Saheb states, 'Air is the guru, water is the father, and earth is the great Mother of all.'

Flora and fauna

Tress have also been given huge importance the ancient Indian tradition. Trees and plants were considered as animate beings and to harm them was regarded as a sacrilege. In the ancient texts we come across references to trees like *kalpavṛkṣa* and *pārijāta* with mythical powers. *Padma* (lotus) and trees like *vaṭavṛkṣa* (banyan), or flame of the forest (*pālāśa* in Hindi, *Butea frondosa*) were given special attention. The worship of the pipal tree (also known as Boddhi tree, *aśvattha* in Sanskrit, *Ficus religiosa*) became a folk ritual, and the pipal was called the king of trees in *Brahma Purāṇa*.

In your own locality, you must have seen women moving in a circle around a tree each morning. Did you ever try to understand the reason ? There are some scientific reasons underlying those beliefs. The papal tree continuously releases oxygen in the atmosphere, and therefore, such knowledge must have been put into a spiritual form by our ancestors.

Similarly, trees such as bael (Aegle marmelos), asRoka (Saraca asoca) sandalwood and coconut hold special significance in various religious rituals; so do duTrvaTgrass (Cynodon dactylon), tulsi or tulasīUUUT (Ocimum), the banana, lotus, marigold, china rose (hibiscus), and the flowers of milkweed (aak, Calotropis). Three major factors were responsible for the origin of the tree-cult in India: their wood, leaves, fruits, etc. were useful to humans; it was believed that trees were possessed by spirits who guided humans in their distress; and humans developed respect for trees which often provided them with an alternative for medicinal plants.

Flora and fauna and their associations with human beings were depicted in epics like the Mahabharata, the Ramayana , and in Kalidasa's Abhijnanasakuntala, etc. They provide colorful potrayal of trees, creepers, animals and birds conversing with people and sharing their joys and sorrows, which shows that people believed in harmony between man and nature.

Manusmṛti, an early Sanskrit text, gives a distinct classification of plants and states that some of them can experience pleasure and pain and have awareness. It is also marked in the scriptures that a tree could be adopted as son; many Puraṇas describe this ritual as *taruputravidhi*. The *upanayaya* (initiation) ceremony performed for the *aśvattha* tree (pipal) and the marriage ritual performed between the banyan tree and neem tree are also noteworthy. Watering the plants is considered as greatly rewarding in the *dharmaśāstra* texts.

According to Kautilya, cutting trees or its branches is an offence and he prescribed various punishments for it.

Sacred Groves

The tradition of sacred groves was also common in the ancient period and is still practised by folk and tribal communities. A sacred grove consists of a bunch of old trees, generally at the outskirts of a village, which were left untouched when the original settlers cleared the forest to establish the village. Such groves were protected with utmost care. The cutting of trees was prohibited in these areas and nobody dared to disobey the injunction,

This tradition of sacred groves could be matched with the contemporary notion of biosphere reserves.

State-wise numbers of sacred groves in India.
(Courtesy: Down to Earth)

Votive horses in a sacred grove, Madurai region

Wildlife

Wild animals and even domesticated ones were also given pride of place and respect in the ancient tradition.

These include lion, tiger, elephant, bull, horse, peacock, swan, owl, vulture, ox, mouse, etc. The association of wild animals with peoples' religious beliefs played a significant role in their preservation for so very long in India, until the colonial rule indulged in intensive hunting. The feeling

of sacredness attached to wildlife protected it and contributed to maintaining an ecological balance.

.

Manusmṛti has references to direct and indirect instructions about the conservation of plants and animals. It gives specific punishments for harming trees or animals.

Many artefacts and seals of the ancient Indus valley civilization depict animals like the bull (with or without a hump), the tiger, the elephant, the rhinoceros, the buffalo, the gharial (crocodile), but often too mythical animals such as the unicorn. Although the precise significance of this animal symbolism remains a matter of debate, Harappans clearly attached great importance to it. They also appear to have worshipped trees, as evidenced by several tablets, such as this one *(left)* in which a tree is depicted raised over a platform.

Seals from the Indus civilization depicting a bull, an elephant, and two unicorns (a mythical animal with a single horn) on either side of a papal tre. (Courtesy: ASI)

Many of the sastras prescribed the unnecessary killing of animals. Later, the Mauryan ruler Asoka also prohibited in his edicts hunting and cruelty to animals; his edict at Girnar in Gujarat (left) also ordered medical treatment for them when necessary.

TABLE I: PROTECTION OF PLANTS		
S. No.	Nature of offence	Punishment prescribed
1. (a)	Felling living tree for establishing mine, factory or constructing big bridge/ dam etc.	Offender should be condemned as a degraded person (XI. 64)
(b)	firewood.	Offender should be condemned as a degraded person (XI. 65)
2.	Cutting down fruit-laden tree or shrub or twiner or climber or flowering herb.	Offender should recite certain Rks for hundred times (XI. 143)
3.	Destroying plants-cultivated or monocarpous or wild.	To atone for the sin, the offender has to attend on a cow throughout a whole day, and undergo penance by subsisting only on milk. (XI. 145)
TABLE II: PROTECTION OF ANIMALS		
S. No.	Nature of offence	Punishment prescribed
1.	Teasing the animals.	Punishment should be commensurate with the gravity of offence (VIII. 286)
2.	Wounding, injuring leading to blood-shed, etc.	Cost of the treatment should be borne by the offender (VIII. 287)
3.	If other animals are harmed because of untrained driver of a vehicle.	Owner of the vehicle is to pay a fine of two hundred *panas* (VIII. 293)
4.	Causing harm to noble animals like cow, elephant, camel, horse, etc.	Offender is to pay a fine of five hundred *panas* (VIII. 296)

Punishments prescribed in Manusmriti for acts hostile to the environment (from Priyadarsan Sensarma, " Conservation of Biodiversity in Manu Samhita", Indian Journal of History of Science, 33(4), 1998)

Kautilya's Arthasastra also mentioned forests and animal sanctuaries, where animals were protected from poaching. A superintendent of forests was responsible for their upkeep and for the proper management of forest produce; poaching was punished with various penalties.

on earth

Bishnois and conservation

During the medieval period many religious sects became popular which vehemently advocated conservation of the natural environment. One such sect was that of the Bishnois, which became widely accepted in a climatically hostile zone of Rajasthan. The followers of the sect advocated the banning of tree-felling since they believed that trees are the basis of a harmonious and prosperous environment. The love for trees

A specimen of khejri tree (courtesy: Wikipedia) was so greatly infused in the minds and souls of the Bishnois that in Khejrali village of Rajasthan about 363 young and old men and women embraced the *khejri* trees (*Prosopis cineraria*) toprotect them from being felled by the king's men. The local ruler had ordered the cutting of *khejri* trees to use them for his lime kilns as fuel; the Bishnois hugged them and many were killed in the episode. Later, a temple was built in honour of the Bishnoi martyrs. One of the leading women of the movement was Amrita Devi Bishnoi. The repentant king later issued an edict protecting trees and animals in Bishnoi-controlled lands.

The commoners from a semi-arid zone had understood the real value of trees. *Khejri* leaves constitute an important feed for livestock in a desert region like westernRajasthan, as they have high nutritional value for camels, cattle, sheep and goat. A unique feature of this tree is that it yields much green foliage even during dry winter months when no other green fodder is available in the dry tracts. People from semi-arid parts of western Rajasthan encouraged the growth of the *khejri* tree in between the cultivable lands and pastures because its extensive root system helped stabilize the shifting sand dunes. It also fixes nitrogen through bacterial activity. Besides, villagers used*khejri* leaves as organic matter for rejuvenating non-fertile soil. Women use its flowers mixed with sugar during their pregnancy as a safeguard against miscarriage, and its bark is effective against dysentery, asthma, common cold and rheumatic arthritis.

Tradition of resistance

The nineteenth and twentieth centuries saw more examples of resistance against forest cutting. Most of those movements were largely against unjust colonial forest laws which affected the livelihood of the local people, especially tribals: the creation of government-protected forests by the colonial government was disastrous for the tribals, who were purely dependent on forest produce. The tribal communities were thus the worst hit by governmental forest departments.

9

Ayurveda for Life, Health and Well-being: A Survey

WHAT IS AYURVEDA?

Definition of Ayurveda– Ayurveda is made up of two words — ayus meaning life and veda meaning knowledge. Ayurveda is thus knowledge of life or Life Science. A classical text defines Ayurveda as the knowledge that describes the wholesome (hitam), unwholesome (ahitam), happy (sukham) and unhappy (asukham) life as well as that which informs what is wholesome and unwholesome for life and longevity.

We can see from the above definition that the goal of Ayurveda is to promote both individual and social well-being at all levels of experience. Ayurveda aims to establish the highest level of health that a human being is capable of achieving and its scope is not restricted to curing diseases. Health is a state of physiological, psychological and spiritual well-being.

Several thousands of years ago, the tradition of Ayurveda anticipated the most modern definition of health that has been trumpeted by the World Health Organization: 'Health is a state of complete physical, mental and social well-being and not merely absence of disease or infirmity.' Ayurveda also adds the spiritual dimension to health and points out that the human being is three-dimensional and needs to be healthy in body, mind and self. Health is a tool to achieve the four-fold goal of life: pursuit of spiritual and material well-being through resources obtained by righteous activity — dharma, artha, kaTma and mok ṣa.

Ayurveda emphasizes that individual well-being should not come into conflict with social well-being. A happy life is that which achieves individual well-being, whereas a wholesome life is that which is conducive to social well-being. These concepts are currently in application and we have countries projecting their personal and national well-being indices, which match exactly the Ayurvedic notion of a happy and wholesome life.

Integrative approach to healthcare

Ayurveda is perhaps the earliest form of Integrative Medicine practised by humanity. The definition of Ayurveda is in tune with modern notions of Integrative Medicine. Integrative Medicine attempts to heal the body, mind and self at the same time or treats the human being as a complete whole. Integrative Medicine combines mainstream medical therapies and complementary and alternative medical therapies for which there is some highquality scientific evidence of safety and effectiveness.

Ayurveda states that human life rests on the tripod of the body, mind and self. Ayurvedic texts also advise that there are multiple approaches to healing that are prevalent in the world and that we must examine and integrate the most effective methods to make a complete system of healing.

Balance of inner environment and personalized medicine

Ayurveda defines health as a dynamic balance of the internal environment that positively impacts the sense organs, mind and the self. Just like the sun, the moon and the wind maintain the balance of the external environment, the body maintains itself by balancing anabolic (building up) and catabolic (breaking down) activities by selfregulation. Each individual is unique and has a specific mental and physical constitution, which defines the vulnerability to disease and the scope for achieving higher levels of health. Ayurveda has also been at the forefront of advocating an approach to personalized medicine from historical times. Advances in human genetics and medical genetics have heralded the emergence of a personalized approach to medicine today that tailors medical intervention to suit individual needs.

Harmony with the external environment

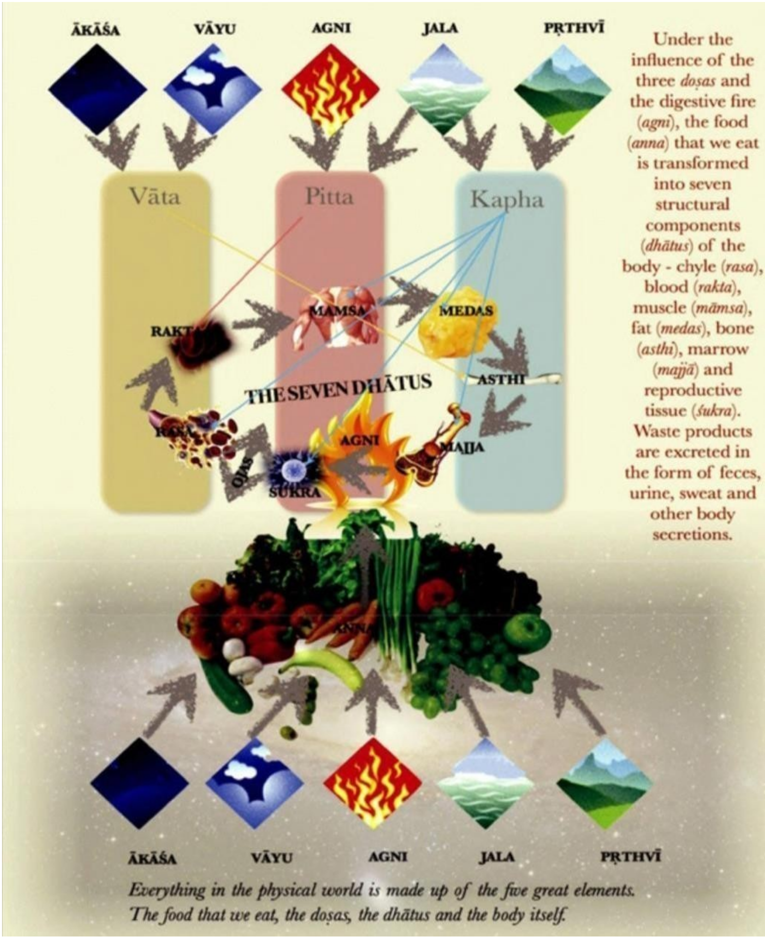
Ayurveda points out that the balance of the inner environment can be maintained only by establishing harmony with the external environment. Ayurveda proclaims that the human being is an epitome of the universe. The microcosm is a miniature representation of the macrocosm and the human being is made up of the same elements that make up nature. Thus it is that Ayurveda developed into an ecologyconscious system of healthcare. For the people of a locality, the plants growing around them are the most suited. Each individual has to carve a lifestyle that considers the geographical region as well as the changing seasons.

The principles of ayurvedic healing

Ayurveda deals with both preventive and curative medicine. Preventive medicine is centred on the theme of cultivating a lifestyle that is most suited to one's physical and mental constitution as well as the geographical and climatic conditions. It also includes detoxification and rejuvenating programmes to enhance the strength and immunity of the individual. Ayurveda prescribes guidelines for developing a daily regimen that has to be dynamically modified according to the seasons. Every individual has to work out a diet plan based on constitution, activity and the state of the digestive system. Not only should the diet be personalized to the needs of each individual, but it should also be modified according to the external environmental conditions.

The five elements in nature make up the human body

The physical universe is made up of the five great elements or pandcamahaTbhuTtas, which are symbolically represented



This diagram depicts the correspondence between the materials that make up the external world and the living body, as well as the transformation of food into the tissues of the body.

by earth (prthvīWUUT), water (ap), fire (tejas), air (vaTyu) and space (aTkaTsRa). To simplify, they denote space and the solid, liquid, thermal and gaseous states of physical matter and correspond to the five sense perceptions of sound, smell, taste, colour and touch. Everything in the visible universe including the human body is made up of the five elements in various permutations and combinations. Thus, the imbalance in the human body can be corrected by using appropriate substances from the external environment.

The five elements organize dynamically into the three doṣas in the body and govern anabolic and catabolic activities. VaTta, Pitta and Kapha are the three doṣas that serve as the functional units of the body. Kapha is a combination of the principles of earth and water and broadly represents anabolism. Pitta is a combination of the principles of water and fire; it represents transformation and catabolism. VaTta is a combination of the principles of wind and space; it represents regulation and control. Under the influence of the three do ṣas and the digestive fire (agni), the food that we eat is transformed into seven structural components (dhaTtus) of the body: chyle (rasa), blood (rakta), muscle (maTmsa),fat (medas), bone (asthi), marrow (majjaT) and reproductive tissue (sRukra). Waste products are excreted in the form of faeces, urine, sweat and other body secretions. When this transformation is completed, there is ojas or innate vitality and immunity that create higher levels of health and well-being.

Treating diseases to restore health

Disease manifests when the doṣas are out of balance leading to derangement of the dhaTtus or structural components of the body. A judicious use of plant, animal and mineral substances formulated into medicines by combination and processing supported by dietary and behavioural changes can restore health. Medicine, diet and behaviour are the three essential components of Ayurvedic treatment.

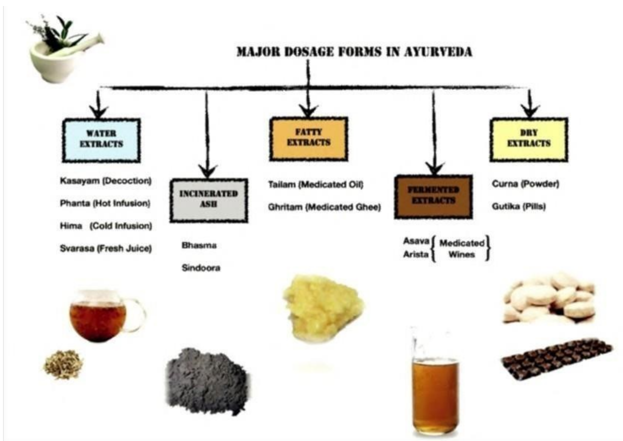


Chart listing the major dosage forms used in Ayurveda for administering medicines.

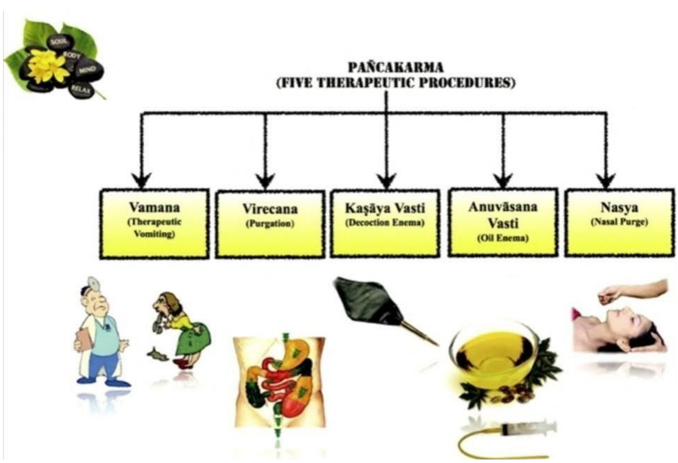


Chart listing the five therapeutic procedures known as Pañcakarma

Medicine is internal or external, regulative or purificatory and surgical or non-surgical. Internal medications are formulated into various dosage forms like decoctions (kṣaTya), medicated wines (ari ṣṭa), pills (gu ṭikaT), medicated ghee (ghṛta), medicated jam (lehya), herbal powders (cuTṃa), incinerated ash (bhasma), fresh juice (svarasa) and so on and so forth. External treatments include massage and different methods of oiling and fomentation. Regulative treatment comprises of medicine, diet and behavioural changes without cleansing the body. Purificatory treatments comprise of therapeutic emesis (induced vomiting), purgation, enema, nasal purge and bloodletting. When emesis, purgation, oil enema, decoction enema and nasal purge are given in sequence, it is known as pandcakarma or five procedures.

Ayurveda also advises to combine physical treatment with psychological and spiritual interventions like prayer, meditation, control of sense organs and the like.

10

Nobel Laureates of Indian Origin

1. SIR RONALD ROSS

Ronald Ross was born in India in 1857 in Almora district, located in present day Uttarakhand. His father was a General in the British Army in India. Ross lived in India until he was eight. Then he was sent to a boarding school in England. He later studied medicine from St. Bartholomew Hospital in London.

When Ross was a small boy, he saw many people in India fall ill with malaria. At least a million people would die of malaria due to lack of proper medication. While Ross was in India his father fell seriously ill with malaria, but fortunately recovered. This deadly disease left an impression in his mind. When Ross returned to India as part of the British-Indian medical services, he was sent to Madras where a large part of his work was treating malaria patients in the army.

Ronald Ross proved in 1897 the long-suspected link between mosquitoes and malaria. In doing so, he confirmed the hypotheses previously put forward independently by scientists Alphonse Laveran and Sir Patrick.

Till that time, it was believed that malaria was caused by breathing in bad air and living in a hot, humid and marshy environment. Ross studied malaria between 1882 and 1899. While posted in Ooty, he fell ill with malaria. After this, he was transferred to the medical school in Osmania University, Secunderabad. He discovered the presence of the malaria parasite within a specific species of mosquito of the genus Anopheles. He initially called them Dapple-wings. Ross made his crucial discovery while dissecting the stomach of a mosquito fed on the blood of a malaria victim. He found the previously observed parasite. Through further study, he established the complete life cycle of this parasite. He contributed majorly to the epidemiology of malaria and brought a method to its survey and assessment. Most importantly, he made mathematical models for further study. In 1902, Ross was awarded the Nobel Prize in Medicine for his remarkable work on malaria and was conferred Knighthood as mark of his great contribution to the world of medicine. In 1926, he became the Director of the Ross Institute and Hospital for Tropical Diseases in London, which was founded in his honour. Ross dedicatedly advocated the cause and prevention of malaria in different countries by conducting surveys and initiating schemes in many places, including West Africa, Greece, Mauritius, Sri Lanka, Cyprus and many areas affected by the First World War.

In India, Ross is remembered with great respect and love. There are roads named after him in many Indian towns and cities. The Regional Infectious Disease Hospital at Hyderabad was named after him as Sir Ronald Ross Institute of Tropical and Communicable Diseases in recognition of his services. The building where he worked and actually discovered the malaria parasite, located in Secunderabad near the old Begumpet airport, is a heritage site and the road leading up to the building is named Sir Ronald Ross Road.

A small memorial on the walls of SSKM Hospital Kolkata commemorates Ross' discovery. The memorial was unveiled by Ross himself, in the presence of Lord Lytton, on 7 January 1927.

2. SIR C.V. RAMAN

Chandrashekhara Venkata Raman was born on 7 November 1888 at Tiruchirappalli, Tamil Nadu. His father, Chandrashekhara Iyer, was a lecturer in physics, in a local college. His mother Parvathi was a homemaker. He passed his matriculation when he was 12. He joined Presidency College in Madras. He passed his Bachelors and Masters examinations in science with high distinction. He had a deep interest in physics.

While doing his Masters, Raman wrote an article on physics and sent it to various scientific journals of England. On reading this article, many eminent scientists in London noted the talent of this young Indian. Raman wanted to compete for the ICS examination. But to write that examination, one had to go to London. As he was poor and could not afford it, he took the Indian Financial Service examination conducted in India. He was selected and posted at Rangoon, Burma (now Myanmar), which was then a part of British India.

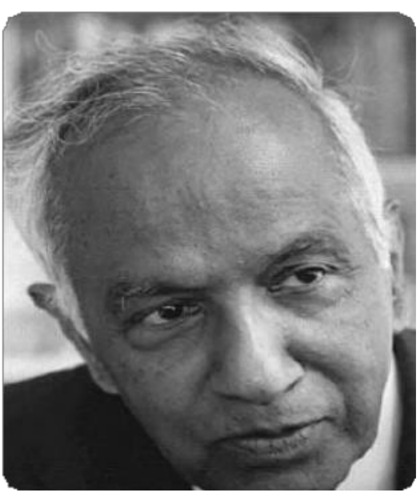
Later, while working in Kolkata, he associated himself with an Institute called Indian Association for the Cultivation of Science, which was the only research institution in those days. While working there, his research work came to the notice of the Vice Chancellor of Calcutta University. The Vice Chancellor appointed him as Professor of Physics in Calcutta University. Sir Raman was in a good position in the Financial Service. He sacrificed his profession and joined the academic career. When he was working as a professor, he got an invitation from England to attend a science conference.

As the ship was sailing through the Mediterranean Sea, Raman had a doubt as to why the sea water was blue in colour.

This doubt initiated his research on light. He found out by experiment that the sea looks blue because of the 'Scattering Effect of the Sunlight'. This discovery is called 'The Raman Effect'. A question that was puzzling many other scientists at the time was easily solved by him. His pioneering work helped him become a Member of Royal Society of London in 1924. He was awarded with Knighthood by the British Empire in 1929. This discovery also got Sir Raman the Nobel Prize for Physics for the year 1930. He became the first Indian scientist to receive the Nobel Prize. Raman discovered 'The Raman Effect' on 28 February 1928 and this day is observed as the 'National Science Day' in India. In 1933, he joined the Indian Institute of Science, Bangalore, as Director. Later he quit the post of Director and continued to work only in the Department of Physics. The University of Cambridge offered him a professor's job, which he declined stating that he is an Indian and wants to serve in his own country. Dr Homi Bhabha and Dr Vikram Sarabhai were his students. Sir C.V. Raman died on 21 November 1970.

3. SUBRAHMANYAN CHANDRASEKHAR

Subrahmanyan Chandrasekhar was born on 19 October 1910 in Lahore. His father, Chandrasekhara Subrahmanya Iyer was an officer in Indian Audits and Accounts Department.



His mother Sitalakshmi was a woman of high intellectual attainments. Sir C.V. Raman, the first Indian to get Nobel Prize in science, was his paternal uncle. Till the age of 12, Chandrasekhar was educated at home by his parents and private tutors. In 1922, at the age of 12, he attended the High School. He joined the Madras Presidency College in 1925. Chandrasekhar passed his Bachelors (hons) in physics in June 1930. In July 1930, he was awarded a Government of India scholarship for graduate studies in Cambridge, England.

Subrahmanyan Chandrasekhar completed his PhD at Cambridge in the summer of 1933. In October 1933, Chandrasekhar was elected to receive Prize Fellowship at Trinity College for the period 1933–37. In 1936, while on a short visit to Harvard University, Chandrasekhar was offered a position as a Research Associate at the University of Chicago and remained there ever since. In September 1936, Chandrashekhar married Lalitha Doraiswamy. She was his junior at the Presidency College in Madras.

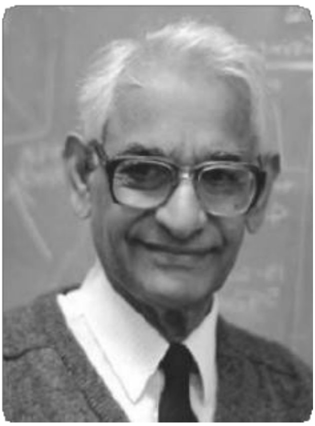
Subrahmanyan Chandrasekhar is best known for his discovery of Chandrasekhar Limit. He showed that there is a maximum mass which can be supported against gravity by pressure made up of electrons and atomic nuclei. The value of this limit is about 1.44 times a solar mass. The Chandrasekhar Limit plays a crucial role in understanding the stellar evolution. If the mass of a star exceeded this limit, the star would not become a white dwarf but it would continue to collapse under the extreme pressure of gravitational forces. The formulation of the Chandrasekhar Limit led to the discovery of neutron stars and black holes. Depending on the mass, there are three possible final stages of a star—white dwarf, neutron star and black hole.

Apart from the discovery of the Chandrasekhar Limit, major works done by Subrahmanyan Chandrasekhar includes: stellar dynamics, including the theory of Brownian motion (1938–43); the theory of radiative transfer, including the theory of stellar atmospheres and the quantum theory of the negative ion of hydrogen and the theory of planetary atmospheres, which again comprised the theory of the illumination and the polarization of the sunlit sky (1943–50); hydrodynamic and hydro magnetic stability, including the theory of the Rayleigh-BeRnard convection (1952–61); the equilibrium and the stability of ellipsoidal figures of equilibrium, partly in collaboration with Norman R. Lebovitz (1961–68); the general theory of relativity and relativistic astrophysics (1962–71); and the mathematical theory of black holes (1974–83).

Subrahmanyan Chandrasekhar was awarded (jointly with the nuclear astrophysicist W.A. Fowler) the Nobel Prize in Physics in 1983. He died on 21 August 1995.

4. HAR GOVIND KHORANA

Har Govind Khorana was born on 9 January 1922 in a small village called Raipur in Punjab (now in Pakistan) and was the youngest of five siblings. His father was a patwari, an agricultural taxation clerk in British India.



Khorana had his preliminary schooling at home. Later he joined the DAV High School in Multan. He graduated in science from Punjab University, Lahore, in 1943 and went on to acquire his Masters in science in 1945. He joined the University of Liverpool for his doctoral work and obtained his doctorate in 1948. He did postdoctoral work at Switzerland's Federal Institute of Technology, where he met Esther Sibler who became his wife. Later, he took up a job at the British Columbia Research Council in Vancouver and continued his pioneering work on proteins and nucleic acids.

Khorana joined the University of Wisconsin in 1960, and 10 years later, joined Massachusetts Institute of Technology (MIT).

Dr Khorana received the Nobel Prize in Physiology or Medicine in 1968 along with M.W. Nirenberg and R.W. Holley for the interpretation of the genetic code, its function and protein synthesis. Till his death, he was the Alfred P. Sloan Professor of Biology and Chemistry Emeritus at MIT. The Government of India honoured him with Padma Vibhushan in 1969.

He won numerous prestigious awards, including the Albert Lasker award for medical research, National Medal of Science, the Ellis Island Medal of Honour, and so on. But he remained modest throughout his life and stayed away from the glare of publicity.

In a note after winning the Nobel Prize, Dr Khorana wrote: 'Although poor, my father was dedicated to educating his children and we were practically the only literate family in the village inhabited by about 100 people.' Following his father's footsteps, Dr Khorana imparted education to thousands of students for more than half a century. He was more interested in the next project and experiments than cashing in on his fame. He was born in a poor family in a small village in Punjab, and by dint of sheer talent and tenacity rose to be one of science's immortals. Dr Har Govind Khorana died in a hospital in Concord, Massachusetts, on 9 November 2011.

5. VENKATARAMAN RAMAKRISHNAN

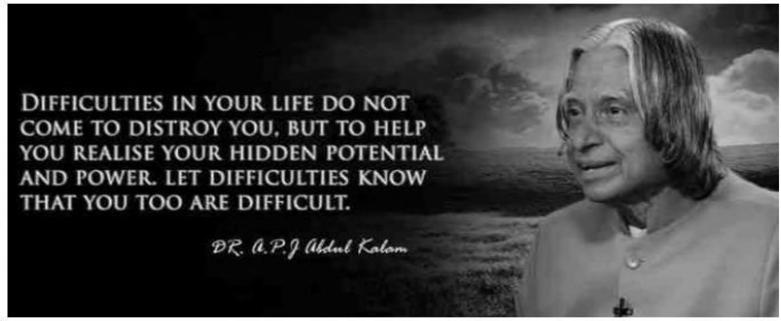
Venkataraman Ramakrishnan was born in Chidambaram, a small town in Cuddalore district in Tamil Nadu in 1952. His parents C.V. Ramakrishnan and Rajalakshmi were lecturers in biochemistry at Maharaja Sayajirao University in Baroda, Gujarat. Venky, as he is popularly known, did his schooling from the Convent of Jesus and Mary in Baroda. He migrated to America to do his higher studies in physics. He then changed his field to biology at the University of California.

He moved to Medical Research Council Laboratory of Molecular Biology, Cambridge, UK. It was there he cracked the complex functions and structures of ribosomes, which fetched him Nobel Prize for Chemistry in 2009, along with Thomas E. Steitz, USA and Ada E. Yonath, Israel. He became the fourth scientist of Indian origin to win a Nobel Prize after Sir C.V. Raman, Har Gobind Khurana and Subrahmanyan Chandrasekhar.

Venkataraman Ramakrishnan began his career as a Post-Doctoral Fellow with Peter Moore at Yale University, where he worked on ribosomes. After completing this research, he applied to nearly 50 universities in the US for a faculty position. But he was unsuccessful. As a result of this, Venkataraman continued to work on ribosomes from 1983 to 1995 in Brookhaven National Laboratory. In 1995, he got an offer from the University of Utah to work as a professor of biochemistry. He worked there for almost four years and then moved to England where he started working in Medical Research Council Laboratory of Molecular Biology. Here, he began a detailed research on ribosomes.

In 1999, along with his fellow mates, he published a 5.5 angstrom resolution structure of 30s subunit of ribosome. In the subsequent year, Venkataraman submitted a complete structure of 30s subunit of ribosome and it created a sensation in the field of structural biology.

Venkataraman earned a fellowship from the Trinity College, Cambridge and the Royal Society. He is also an honorary member of the US National Academy of Sciences. In 2007, he was awarded with the Louis-Jeantet Prize for his contribution to Medicine. In 2008, he was presented with Heatley Medal of British Biochemistry Society. For his contribution to science, he was conferred with India's second highest civilian award, the Padma Vibhushan in 2010.



***

Inspiring Lives of Scientists and Their Contributions

1. Sushruta

An ancient Indian surgeon dating back to almost 2,500 years ago, Sushruta made numerous contributions to the field of surgery. Sushruta is regarded as the Father of Surgery. In his book *Sushruta Samhita*, he described over 300 surgical procedures, 120 surgical instruments and classified human surgery categories. He lived, taught and practiced his art on the banks of the Ganges which is now called Varanasi in North India.

Some of his contributions include surgical demonstration of techniques of making incisions, probing, extraction of foreign bodies, alkali and thermal cauterization, tooth extraction, excisions, and so on. He also described removal of the prostate gland, urethra, hernia surgery, caesarian section, and so on. He classified details of six types of dislocations, 12 varieties of fractures and types of bones and their reaction to injuries. He has written about 76 signs of various eye diseases, symptoms, prognosis, medical/surgical interventions and cataract surgery. There is also description of a method of stitching the intestines by using ant-heads as stitching material. He even introduced the use of wine to minimize the pain of surgical incisions.

Sushruta provided details of almost 650 drugs of animal, plant, and mineral origin. Other chapters in *Sushruta Samhita* emphasizes on the well-being of children and expectant mothers. Sushruta had also written in detail about the symptoms of poisoning, first-aid measures and long-term treatment, as well as classification of poisons and methods of poisoning. The *Sushruta Samhita* was translated into Arabic and later into Persian. These translations helped to spread the science of Ayurveda far beyond India.

2. Bhaskara II

Bhaskara II, also known as Bhaskaracharya, was born in 1114 CE near Vijjaydavida or present-day Bijapur in the state of Karnataka. Born to a family of scholars, he learnt mathematics from his astrologer father Mahesvara. A leading mathematician of twelfth century, he wrote his first work on the systematic use of the decimal number system. He also headed the astronomical observatory at Ujjain, a leading mathematical centre of ancient India.

His main work *Siddhanta Shiromani*, which has four parts, namely, Lilavati, Bijaganita, Grahaganita and Goladhaya deals with arithmetic, algebra, mathematics of the planets and spheres, respectively. Bhaskara is particularly known for the discovery of the principles of differential calculus and its application to astronomical problems and computations. While Newton and Leibniz have been credited with differential and integral calculus, there is strong evidence to suggest that Bhaskara was a pioneer in some of the principles of differential calculus. He was perhaps the first to conceive the theorems of differential coefficient and differential calculus.

He conceived the modern mathematical finding that when a finite number is divided by zero, the result is infinity. He also accurately defined many astronomical quantities using models developed by seventh-century scholar Brahmagupta. For example, he calculated that the time that is required for the Earth to orbit the Sun is 365.2588 days. The modern accepted measurement is 365.2563 days, a difference of just 3.5 minutes. Bhaskara wrote *Karanakuthuhala*, a book on astronomical calculations, which is still referred in making precise calendars. Bhaskara II was also a noted astrologer, and it is said that he named his first work after his daughter Lilavati.

3. Aryabhatta

Aryabhatta is the earliest known mathematician and astronomer of India. The birth place of Aryabhatta, who lived between circa 476–550 CE, is still a mystery. While many believe that he was born in Pataliputra in Magadha, present-day Patna in the state of Bihar, others are of the view that he was born in Kerala and lived in Magadha at the time of the Gupta rulers.

His works include the *Aryabhatiya* (499 CE, when he was 23) and the *Arya Siddhanta*.

His most famous work, *Aryabhatiya* is a detailed text on mathematics and astronomy. The mathematical part of the *Aryabhatiya* covers arithmetic, algebra and trigonometry. It also contains continued fractions, quadratic equations, sums of power series and a table of sines. Aryabhatta is believed to have written at least three texts on astronomy and wrote some free stanzas as well. Aryabhatta was a genius and all his theories continue to surprise many mathematicians of the present age. The Greeks and the Arabs developed some of his works to suit their demands.

He wrote that if 4 is added to 100, multiplied by 8, added to 62,000 and then divided by 20,000, the answer will be equal to the circumference of a circle of diameter 20,000. This calculates to 3.1416 close to the actual value of Pi (3.14159). He was also the one who created the formula $(a + b)^2 = a^2 + b^2 + 2ab$.

His other work *Arya Siddhanta* deals with astronomical calculation and this is evident through the writings of Aryabhatta's contemporary, Varahamihira and later mathematicians and commentators, including Brahmagupta and Bhaskara I. It contains description of several astronomical instruments like gnomon (*shanku yantra*), a shadow instrument (*chhaya yantra*), possibly angle-measuring devices, semicircular and circular instrument (*dhanur yantra*/*chakra yantra*), a cylindrical stick *yasti yantra*, an umbrella-shaped device called the *chatra yantra* and water clocks of at least two types—bow-shaped and cylindrical.

Aryabhatta was aware that the earth rotates on its axis and that the earth rotates round the sun and the moon moves round the earth. He discovered the positions of the nine planets and related them to their rotation round the sun. He also knew about the eclipse of the sun, moon, day and night, earth contours and the 365 days as the exact length of the year. Aryabhatta also revealed that the circumference of the earth is 39,968km. According to modern-day scientific calculations it is 40,072 km. Solar and lunar eclipses were also scientifically explained by Aryabhatta. India's first satellite Aryabhatta was named in his honour.

4. Jagadish Chandra Bose

Jagadish Chandra Bose was born on 30 November 1858 in Mymensingh (now in Bangladesh). His father Bhagaban Chandra Bose was a deputy magistrate. Bose received early education in a vernacular village school. He was sent to Kolkata at the age of 11 to learn English and was educated at St. Xavier's

School and College. He was a brilliant student. He passed his Bachelors in physical sciences in 1879.

In 1880, Bose went to England. He studied medicine at London University for a year but gave it up because of his ill health. Within a year, he moved to Cambridge to take up a scholarship to study Natural Science at Christ's College, Cambridge. In 1885, he returned from abroad with a BSc degree and Natural Science Tripos (a special course of study at Cambridge).

After his return, he got a lecturer's job at Presidency College, Kolkata, with a salary half that of his English colleagues. He accepted the job but refused to draw his salary in protest. After three years, the college ultimately conceded his demand and Jagdish Chandra Bose was paid full salary from the date he joined the college. As a teacher, Jagadish Chandra Bose was very popular and engaged the interest of his students by making extensive use of scientific demonstrations. Many of his students at the Presidency College later became famous in their own right and those included Satyendra Nath Bose and Meghnad Saha.

In 1894, Jagadish Chandra Bose decided to devote himself to pure research. He converted a small enclosure adjoining a bathroom in the Presidency College into a laboratory. He carried out experiments involving refraction, diffraction and polarization. It would not be wrong to call him as the inventor of wireless telegraphy. In 1895, a year before Guglielmo Marconi patented this invention, he had demonstrated its functioning in public.

Jagadish Chandra Bose later switched from physics to the study of metals and then plants. He was the first to prove that plants too have feelings. He invented an instrument to record the pulse of plants.

Although Jagadish Chandra Bose did invaluable work in science, his work was recognized in the country only when the western world recognized its importance. He founded the Bose Institute at Calcutta, devoted mainly to the study of plants. Today, the Institute carries out research in other fields too. Jagadish Chandra Bose died on 23 November 1937.

Acharya Prafulla Chandra Ray

Acharya Prafulla Chandra Ray was born on 2 August 1861 in Khulna district in present-day Bangladesh. His father Harish Chandra Ray was a land proprietor. Up to the age of nine, Prafulla Chandra studied in a school in his village. In 1870, his family migrated to Calcutta and Ray and his elder brother were admitted to Hare School. When in the fourth standard, he suffered from a severe attack of dysentery and had to postpone his studies for a couple of years and returned to his ancestral home in the village. However, he utilized this time in reading literature.

A pioneer in chemical research in India, Prafulla Chandra Ray joined the Presidency College as a lecturer in chemistry in 1889 after completing higher education at the Edinburgh University. With the help of a renowned French chemist, Berthelot, he did commendable research work in Ayurveda. In 1892, he founded Bengal Chemicals and Pharmaceutical Works, India's first pharmaceutical company, which progressed phenomenally under his guidance. His book *History of Chemistry* was published in 1902. He attended several international science congresses and seminars as a representative of Indian universities. In 1920, he was elected as President of Indian Science Congress Association.

Prafulla Chandra Ray's ultimate aim was to make use of the wonders of science to uplift the masses. He wrote several articles on science, which were published in leading journals of the time. An ardent social worker, he was actively involved in relief work during famine in 1922 in North Bengal. He advocated the use of khadi and started several cottage industries. A firm believer in rationalism, he condemned the decadent social customs such as untouchability. He continued with his constructive social reform work till his death.

Birbal Sahni

The renowned paleobotanist, Birbal Sahni, was born on 14 November 1891 at Shahpur district, now in Pakistan. He was the third son of Ishwari Devi and Lala Ruchi Ram Sahni. He studied at the Government College, Lahore and Punja b University and graduated from Emmanuel College, Cambridge in 1914 . After completion of his education, Birbal Sahni came back to India and worked as professor of botany at Banaras Hindu University, Varanasi and Punjab University for about a year. In 1920, he married Savitri Suri, who took an interest in his work and was a constant companion.

He studied the fossils of the Indian subcontinent. He was the founder of Birbal Sahni Institute of Palaeobotany, Lucknow. Palaeobotany is a subject that requires the knowledge of both botany and geology. Birbal Sahni was the first botanist to study extensively about the flora of Indian Gondwana region. Sahni also explored the Raj Mahal hills in Bihar, which is a treasure house of fossils of ancient plants. Here he discovered many new genus of plants.

Birbal Sahni was not only a botanist but also a geologist. By using simple instruments and his huge knowledge of ancient plants, he estimated the age of some old rocks. He showed to the people that the salt range, now in Pakistan Punjab, is 40 to 60 million years old. He found that the Deccan Traps in Madhya Pradesh were of the tertiary period, about 62 million years old. Moreover, Sahni took a keen interest in archaeology. One of his investigations led to the discovery of coin moulds in Rohtak in 1936. He was awarded the Nelson Wright Medal of the Numismatic Society of India for his studies on the technique of casting coins in ancient India.

Being a teacher, Sahni first raised the standard of teaching at the Department of Botany. Sahni died on the night of 10 April 1949, less than a week after laying the foundation stone of his institute. The Institute of Palaeobotany was the first of its kind in the world. His wife completed the task he had left undone. The institute is today known as the Birbal Sahni Institute of Palaeobotany.

P.C. Mahalanobis

A well-known Indian statistician and scientist, Mahalanobis is greatly popular for introducing new methods of sampling. His most significant contribution in the field of statistics was the 'Mahalanobis Distance'. Besides, he had also made pioneering studies in the field of anthropometry and had founded the Indian Statistical Institute.

Originally, the family of Mahalanobis belonged to Bikrampur, Bangladesh. As a child, Mahalanobis grew up in an environment surrounded by socially active reformers and intellectuals. He had his initial education from Brahmo Boys School in

Calcutta. Further, he enrolled himself into Presidency College and got a BSc degree with specialization in physics. In 1913, Mahalanobis left for England for further studies and came in contact with S. Ramanujan, the famous mathematician from India. After completion of his studies, he returned to India and was invited by the Principal of Presidency College to take classes in physics. Soon he was introduced to the importance of statistics and realized that it was very useful in solving problems related to meteorology and anthropology. Many of his colleagues took interest in statistics and as a result in his room in the Presidency College, a small statistical laboratory grew up where scholars like Pramatha Nath Banerji, Nikhil Ranjan Sen, and Sir R.N. Mukherji actively participated in all discussions. The meetings and discussions led to the formal establishment of the Indian Statistical Institute which was formally registered on 28 April 1932. Initially, the Institute was in the Physics Department of Presidency College, but later with passing time the institute expanded.

The most important contributions of Mahalanobis are related to large-scale sample surveys. He had pioneered the concept of pilot surveys and sampling methods. He also introduced a method of measuring crop yields. In the later stage of his life, Mahalanobis became a member of the Planning Commission of India. During his tenure as a member of the Planning Commission of India, he significantly contributed to the Five Year Plans of India.

The Mahalanobis Model was implemented in the second Five Year Plan of India and it assisted in the rapid industrialization of the country. He had also corrected some of the errors of the census methodology in India. Besides statistics, Mahalanobis had a cultural bend of mind. He had worked as secretary to Rabindranath Tagore, particularly during the foreign visits of the great poet and also worked in the Visva-

Bharati University. Mahalanobis was honoured with the second highest civilian award of the country, Padma Vibhushan, for his immense contribution to the field of statistical science.

Mahalanobis died on 28 June 1972 at the age of 78. Even at such a ripe age he continued research work and discharged all his duties perfectly. In the year 2006, the Government of India declared 29 June, the birthday of Mahalanobis, as the National Statistical Day.

Meghnad Saha

Meghnad Saha was an astrophysicist, best known for his development of the Saha equation, used to describe chemical and physical conditions in stars. Meghnad Saha was born on the 6 October 1893 in a village near Dhaka in Bangladesh. His father Jagannath Saha had a grocery shop in the village. His family's financial condition was very bad. He studied in the village primary school while attending the family shop during free time. He got admitted into a middle school which was seven miles away from his village. He stayed in a doctor's house near the school and had to work in that house to meet the cost of living. He was ranked first in the Dhaka middle school test and got admitted into Dhaka Collegiate School.

Saha graduated from Presidency College with major in mathematics and got the second rank in the University of Calcutta whereas the first one was bagged by Satyendra Nath Bose, another great scientist of India. In 1915, both S.N. Bose and Meghnad ranked first in MSc examination, Meghnad in applied mathematics and Bose in pure mathematics. Meghnad decided to do research in physics and applied mathematics. While in college, he got involved with the freedom struggle and came in contact with great leaders of his time like Subhash Chandra Bose and Bagha Jatin.

Meghnad Saha made remarkable contribution to the field of astrophysics. He went abroad and stayed for two years in

London and Germany. In 1927, Meghnad Saha was elected as a Fellow of the London Royal Society. He joined the University of Allahabad in 1923 where he remained for the next 15 years. Over this period, he gained a lot of recognition for his work in astrophysics and was made president of the physics section of the Indian Science Congress Association in 1925.

In 1938, he became a professor of physics at the University of Calcutta. He took several initiatives, such as, introducing nuclear physics in the MSc physics syllabus of the University of Calcutta, starting a post post-MSc course in nuclear science, and also took steps to build a cyclotron, the first of its kind in the country.

Saha also invented an instrument to measure the weight and pressure of solar rays and helped to build several scientific institutions, such as the Department of Physics in Allahabad University and the Institute of Nuclear Physics in Calcutta. He founded the journal *Science and Culture* and was its editor until his death. He was the leading spirit in organizing several scientific societies, such as the National Academy of Science (1930), the Indian Physical Society (1934), Indian Institute of Science (1935) and the Indian Association for the Cultivation of Science (1944). A lasting memorial to him is the Saha Institute of Nuclear Physics, founded in 1943 in Kolkata.

In addition to being a great scientist, he was also an able institution builder. He founded the Indian Science News Association at Calcutta in 1935 and the Institute of Nuclear Physics in 1950. He is also credited with preparing the original plan for the Damodar Valley Project. Other than being a scientist, he was also elected as a Member of Parliament. Besides, Saha's work relating to the reformation of the Indian calendar was very significant. He was the Chairman of the Calendar Reform Committee appointed by the Government of India in 1952. It was Saha's efforts which led to the formation of the Committee. The task before the Committee was to prepare an accurate calendar based on scientific study, which could be adopted uniformly throughout India. It was a mammoth task, but he did it successfully. Saha died on 16 February 1956.

Satyendra Nath Bose

Satyendra Nath Bose came into the news in connection with the discovery of 'Higgs Boson' or popularly called the 'God Particle'. Satyendra Nath Bose was an outstanding Indian physicist. He is known for his work in Quantum Physics. He is famous for the 'Bose-Einstein Theory' and a kind of particle in atom has been named after him as Boson.

Satyendra Nath Bose was born on 1 January 1894 in Kolkata. His father Surendra Nath Bose was employed in the Engineering Department of the East India Railways. Satyendra Nath was the eldest of seven children. Satyendra did his schooling from Hindu High School in Kolkata. He was a brilliant student and did his college from the Presidency College, Kolkata with mathematics as his major. He topped the University in the Bachelors and Masters. In 1916, the University of Calcutta started MSc classes in modern mathematics and modern physics.

S.N. Bose started his career in 1916 as a lecturer in physics in the University of Calcutta. He served there from 1916 to 1921. He joined the newly established Dhaka University in 1921 as a Reader in the Department of Physics. In 1924, Satyendra Nath Bose published an article titled 'Max Planck's Law and Light Quantum Hypothesis'. This article was sent to Albert Einstein, who appreciated it so much that he himself translated it into German and sent it for publication to a famous periodical in Germany—*Zeitschrift fur Physik*. The hypothesis received great attention and was highly appreciated by scientists who named it as the 'Bose-Einstein Theory'.

In 1926, Satyendra Nath Bose became a professor of physics in Dhaka University. Though he had not completed his doctorate till then, he was appointed as professor on Einstein's recommendation. In 1929, Satyendra Nath Bose was elected as Chairman of the Physics Session of the Indian Science Congress and, in 1944, as Chairman of the Congress. In 1945, he was appointed as Khaira Professor of Physics in the University of Calcutta. He retired from Calcutta University in 1956. The University honoured him on his retirement by appointing him as Emeritus Professor. Later, he became the Vice Chancellor of the Visva-Bharati University. In 1958, he was made a Fellow of the Royal Society, London.

Satyendra Nath Bose was honoured with Padma Bhushan by the Government of India in recognition of his outstanding achievements. He died in Kolkata on 4 February 1974.

10. Salim Ali

Dr Salim Moizuddin Abdul Ali or Dr. Salim Ali is synonymous with birds. The famous ornithologist-naturalist was born on 12 November 1896 in Mumbai. He is also known as the 'Birdman of India'. He pioneered a systematic survey on birds in India. His research work has shaped the course of ornithology in India to a great extent. A great visionary, he made birds a serious pursuit when it used to be a mere fun for many. Orphaned at a very young age, Salim Ali was brought up by his maternal uncle, Amiruddin Tyabji who introduced him to nature.

As a 10-year-old, Salim once noticed a flying bird and shot it down. Tender at heart, he instantly ran and picked it up. It appeared like a house sparrow, but had a strange yellowish shade on the throat. Curious, he showed the sparrow to his uncle and wanted to know more about the bird. Unable to answer, his uncle took him to W.S. Millard, the Honorary Secretary of the Bombay Natural History Society (BNHS). Amazed at the unusual interest of the young boy, Millard took him to see many stuffed birds. When Salim finally saw a bird similar to the bird he had shot down, he got very excited. After that, the young Salim started visiting the place frequently.

Ali failed to get an ornithologist's position at the Zoological Survey of India due to lack of a proper university degree (He was a college dropout). He, however, decided to study further after he was hired as guide lecturer in 1926 at the newly opened natural history section in the Prince of Wales Museum in Mumbai. He went on study leave in 1928 to Germany, where he trained under Professor Erwin Stresemann at the Zoological Museum of Berlin University. On his return to India, in 1930, he discovered that the guide lecturer position had been eliminated due to lack of funds. Unable to find a suitable job, Salim Ali and his wife Tehmina moved to Kihim, a coastal village near Mumbai, where he began making his first observations of the Baya or the Weaver bird. The publication of his findings on the bird in 1930 brought him recognition in the field of ornithology.

Salim Ali was very influential in ensuring the survival of the Bombay Natural History Society (BNHS) and managed to save the 200-year old institution by writing to the then Prime Minister Pandit Nehru for financial help. Dr Ali's influence helped save the Bharatpur Bird Sanctuary and the Silent Valley National Park. In 1990, the Salim Ali Centre for Ornithology and Natural History (SACON) was established at Anaikatty, Coimbatore, aided by the Ministry of Environment and Forests (MoEF), Government of India. He was honoured with a Padma Vibhushan in I976. He died at the age of 90, on 20 June 1987.

Panchanan Maheshwari

Born in November 1904 in Jaipur, Rajasthan, Panchanan Maheshwari is a famous biologist. During his college days, he was inspired by Dr W. Dudgeon, an American missionary teacher. Maheshwari invented the technique of test-tube fertilization of angiosperms. Till then no one thought that flowering

plants could be fertilized in test tubes. Maheshwari's technique immediately opened up new avenues in plant embryology and found applications in economic and applied botany. Cross-breeding of many flowering plants which cannot cross-breed naturally can be done now. The technique is proving to be of immense help to plant breeders. Maheshwari's teacher once expressed that if his student progresses ahead of him, it will give him a great satisfaction. These words encouraged Panchanan to enquire what he could do for his teacher in return. Dudgeon had replied, Do for your students what I have done for you.' Meticulously following his teacher's advice, he did train a host of talented students. He pursued his postgraduate university education in botany at Allahabad University.

He went on to establish the Department of Botany in the University of Delhi as an important centre of research in embryology and tissue culture. The department was recognized by the University Grants Commission as Centre of Advanced Studies in Botany.

Maheshwari was assisted by his wife in preparation of slides in addition to her household duties. Way back in 1950, he talked on contacts between embryology, physiology and genetics. He also emphasized the need of initiation of work on artificial culture of immature embryos. These days, tissue culture has become a landmark in science. His work on test- tube fertilization and intra-ovarian pollination won worldwide acclaim. He founded an international research journal *Phytomorphology*, which he continued editing till his death in May 1966, and a popular magazine *The Botanica* in 1950. He was honoured with the Fellowship of Royal Society of London, Indian National Science Academy and several other institutions of excellence. He also wrote books for schools to improve the standard of teaching of life sciences. In 1951, he founded the International Society of Plant Morphologists.

B. P. Pal

B.P. Pal, the famous agricultural scientist, was born in Punjab on 26 May 1906. His family later moved to Burma (presently known as Myanmar), then a British colony, to work as a medical officer. Pal studied at St. Michael's School in Maymyo, Burma. Apart from being a brilliant student, Pal was fond of gardening and painting.

In 1929, Pal qualified for Masters in Botany at Rangoon University where he also won the Matthew Hunter Prize for topping all science streams at the University. He was awarded a scholarship which permitted him to pursue his postgraduate education at Cambridge. Dr Pal worked with Sir Frank Engledow on hybrid vigour in wheat at the famous Plant Breeding Institute. This provided the basis for the design of the Green Revolution, essentially based on the commercial exploitation of wheat hybrids.

In March 1933, Dr Pal was appointed Assistant Rice Research Officer in the Burmese Department of Agriculture. In October, the same year, he moved to Pusa, Bihar, to become the Second Economic Botanist at the Imperial Agricultural Research Institute, which was renamed the Indian Agricultural Research Institute (IARI) in 1947. IARI was earlier located in Pusa, Bihar, but after a severe earthquake which damaged its main building, the institute was shifted to New Delhi in 1936. Dr Pal was the first Indian Director of the IARI in New Delhi, and the institute was named Pusa in 1950. He continued to serve in that capacity until May 1965, when he became the first Director General of the Indian Council of Agricultural Research (ICAR). He held this position from May 1965 to January 1972, during which period the Green Revolution was launched with outstanding success.

Dr Pal's major contribution to the scientific aspects of the Green Revolution was in the area of wheat genetics and breeding. He observed that rust disease was largely responsible for low yields of wheat and, therefore, developed a systematic breeding method to develop varieties with resistance to rust disease. Then India was reeling under a severe food crisis and was known in the world as a country of starving people. Dr Pal was instrumental in changing India's global image and it soon became an exporter of food grains.

Dr Pal was also a rose breeder of distinction and created several varieties. He was the founder President of the Rose Society and Bougainvillea Society. He also founded the Indian Society of Genetics and Plant Breeding and edited the *Indian Journal of Genetics and Plant Breeding* for 25 years. He was elected as a Fellow of the Royal Society in 1972. He was awarded the Padmashri in 1959, the Padma Bhushan in 1968 and the Padma Vibhushan in 1987.

He died on 14 September 1989.

Homi Jehangir Bhabha

Homi Jehangir Bhabha, the main architect of Indian Atomic Energy programme, was born in a rich Parsi family on 30 October 1909 in Mumbai. He received his early education at Mumbai's Cathedral Grammar School and did his college in Elphinstone College. He went to Cambridge University, forced by his father and his uncle Dorabji Tata, who wanted him to get a degree in mechanical engineering so that on his return to India he can join the Tata Mills in Jamshedpur as a metallurgist.

Bhabha's illustrious family background had a long tradition of learning and service to the country. The family, both on his father's and his mother's side was close to the house of Tatas, who had pioneered projects in the fields of metallurgy, power generation and science and engineering, in the early half of the twentieth century. The family imbibed a strong nationalistic spirit, under the influence of Mahatma Gandhi and the Nehru family. The family also had interests in fine arts, particularly Western classical music and painting, that aroused Bhabha's aesthetic sensibilities, and it remained a dominant influence in all the creative work he undertook during his life time.

Bhabha, after completion of his engineering, switched over to physics. During the period 1930–39, Bhabha carried out outstanding original research relating to cosmic radiation. This earned him a Fellowship of the Royal Society in 1940, at the young age of 31. Bhabha returned to India in 1939, and had to stay back on account of the outbreak of the Second World War. He was selected to work at the Indian Institute of Science, Bangalore, where Sir C.V. Raman, India's first Nobel laureate in Science, was at the time Head of the Department of Physics. Initially appointed as a Reader, Bhabha was soon designated as Professor of Cosmic Ray Research.

Bhabha's leadership of the atomic energy programme spanned 22 years, from 1944 till 1966. The Tata Institute of Fundamental Research was formally inaugurated in December 1945 in 'Kenilworth' building, which was Bhabha's ancestral home. In January 1966, Bhabha died in a plane crash near Mont Blanc while heading to Vienna, Austria, to attend a meeting of the International Atomic Energy Agency.

Vikram Ambalal Sarabhai

Fondly referred to as the 'Father of the Indian space programme', Vikram Sarabhai was born in Ahmedabad on 12 August 1919 to an affluent family. It was his early years at a private school that shaped his scientific bend of mind. After studying at the Gujarat College in his hometown in 1937, he left for England to study physics at St. John's College, Cambridge. There, Sarabhai earned an undergraduate tripods degree. That was the year 1940 and the world was facing the Second World War. So, Sarabhai returned to India and became a research scholar at the Indian Institute of Science, Bangalore, where he studied the effects of cosmic rays.

It was at Bangalore, under the direct guidance of Nobel laureate, Dr C.V. Raman that he started setting up observatories in Bangalore, Pune and the Himalayas. Soon after the war was over, he returned to UK for a while. Sarabhai received a PhD from Cambridge University for his pathbreaking work.

His real work began in 1947 along with meteorologist, K.R. Ramanathan, who helped him establish the Physical Research Laboratory, Ahmedabad. Initially, it consisted of rooms at the Science Institute of the Ahmedabad Education Society. Analys`ing and studying cosmic rays and atmospheric physics, the scientists set up two dedicated teams at the site. Sarabhai's team realized that evaluating the weather was not enough to comprehend variations in the cosmic rays; they had to relate it to variations in solar activity. He was the pioneer researcher in the field of solar physics.

With such a big breakthrough in hand, Sarabhai soon received financial support from the Indian Council of Scientific and Industrial Research and the Department of Atomic Energy. And the support did not just end there. He was asked to organize the Indian programme for the International Geophysical Year of 1957. Around this time, the erstwhile Soviet Union launched Sputnik-1. India, not too far behind, decided to set up the Indian National Committee for Space Research chaired by Sarabhai.

The visionary scientist set up India's first rocket launching station, TERLS in Thumba on the coast of the Arabian Sea on 21 November 1963 with the support of Homi Bhabha from the Atomic Energy Commission. In 1966, Sarabhai was appointed as Chairman of the Indian Atomic Energy Commission following Bhabha's untimely demise. Sarabhai's greatest achievement was the establishment of the Indian Space Research Organization (ISRO). He died in his sleep at 52 on 31 December 1971.

The pioneering work on space science and research done by Dr Vikram Sarabhai earned him Shanti Swarup Bhatnagar Medal in 1962 and Padma Bhushan in 1966.

Varghese Kurien

Fondly called the 'Milk Man of India', Varghese Kurien was born on 26 November 1921 in Kozhikode, Kerala. His father was a civil surgeon in Cochin. He graduated in physics from Loyola College, Madras in 1940, and then did BE (mechanical) from the University of Madras. After completing his degree, he joined the Tata Steel Technical Institute, Jamshedpur, from where he graduated in 1946. He then went to USA on a government scholarship to earn his Masters in metallurgical engineering from Michigan State University.

He is famously known as the architect of Operation Flood, the largest dairy development programme in the world. Kurien helped modernize the Anand model of cooperative dairy development and thus engineered the White Revolution in India, and made India the largest milk producer in the world. He is the founder of the Gujarat Cooperative Milk Marketing Federation, the cooperative organization that manages the Amul food brand. Amul is a globally recognized Indian brand and involves millions of Indians and gives direct control to farmers. Kurien and his team were pioneers in inventing the process of making milk powder and condensed milk from buffalo's milk instead of cow's milk. Quality packed milk is now available in more than 1000 cities throughout the length and breadth of India. And this milk is with a difference—pasteurized, packaged, branded, owned by farmers. He was awarded the Padma Vibhushan in 1999. He passed away in September 2012.

M.S. Swaminathan

Mankombu Sambasivan Swaminathan was born on 7 August 1925 in Kumbakonam, Tamil Nadu. This famous geneticist is known as the man behind India's 'Green Revolution', a programme, which revolutionized India's farming scenario by introducing high yielding crops. *The Time* magazine placed him in the Time's 20 list of most influential Asian people of the twentieth century. He is the Founder and Chairman of the M.S. Swaminathan Research Foundation.

His physician father was an ardent follower of Gandhi and it instilled a sense of patriotism in him. In college, he rejected more lucrative professions and studied agriculture. He almost became a police officer, but a 1949 fellowship to study genetics in the Netherlands changed his career path. In 1952, he earned his PhD in genetics from Cambridge University and then did further studies at the Wisconsin University. There he turned down a professorship. He was clear about coming back to India and working here for the betterment of our country's poor food scenario.

He nurtured a vision to see a world devoid of hunger and poverty and advocated the cause of sustainable development. He also emphasized on the preservation of biodiversity. Swaminathan brought into India seeds developed in Mexico by the US agricultural guru, Norman Borlaug, and, after cross-breeding them with local species, created a wheat plant that yielded much more grain than traditional types. Scientists at International Rice Research Institute (IRRI) accomplished the same miracle for rice. Imminent tragedy turned to a new era of hope for Asia, paving the way for the Asian economic miracle of the 1980s and 90s. Today, India grows about 70 million tonne of wheat a year, compared to 12 million tonne in the early ’60s. He served as the Director

General of the Indian Council of Agricultural Research from 1972–79 and became Union Minister for Agriculture from 1979–80. He also was Director General of the IRRI and became President of the International Union for the Conservation of Nature and Natural Resources. He received the Ramon Magsaysay Award for Community Leadership in 1971 and Indira Gandhi National Integration Award in 2013.

M.K. Vainu Bappu

Manali Kallat Vainu Bappu was born on 10 August 1927 to a senior astronomer in the Nizamiah Observatory, Hyderabad. M.K. Vainu Bappu is credited as the man behind the creation of the Indian Institute of Astrophysics. One of the greatest astronomers of India, Vainu has contributed much to the revival of optical astronomy in independent India. Bappu joined the prestigious Harvard University on a scholarship after receiving his Masters in physics from Madras University.

Within a few months of his studies, he discovered a comet, which was then named Bappu-Bok- Newkirk after him and his colleagues Bart Bok and Gordon Newkirk. He completed his PhD in 1952 and joined the Palomar University. He and Colin Wilson made an important observation about the luminosity of a particular kind of star and it came to be known as the Bappu-

Wilson effect. He returned in 1953 and played a major role in building the Uttar Pradesh State Observatory in Nainital. In 1960, he took over as Director of Kodaikanal Observatory and contributed a lot towards its modernization. He established the observatory with a powerful telescope in Kavalur, Tamil Nadu.

Awarded with the prestigious Donhoe Comet Medal by the Astronomical Society of the Pacific in 1949, he was elected President of the International Astronomical Union in 1979. He was elected Honorary Foreign Fellow of the Belgium Academy of Sciences and was an Honorary Member of the American Astronomical Society. He succeeded to establish Indian Institute of Astrophysics in Bangalore. His ambition of setting up a powerful 2.34m telescope materialized in 1986, four years after his death. Today, Bappu is regarded as the father of modern Indian astronomy.

A. P. J. Abdul Kalam

Born on 15 October 1931 at Rameswaram, Tamil Nadu, Dr Avul Pakir Jainulabdeen Abdul Kalam is a man of great distinction. Known as the Missile Man of India worldwide, he also became very popular as India's eleventh president.

Kalam had inherited his parent's honesty and discipline which helped him in his life. He specialized in Aeronautical Engineering from the Madras Institute of Technology. Before becoming the President of India, he worked as an aerospace engineer with the Defence Research and Development Organization (DRDO). Kalam's contribution in the development of ballistic missiles and space rocket technology is noteworthy. He also played a pivotal organizational, technical and political role in India's Pokhran-II nuclear tests in 1998.

He was a visiting Professor at IIM, Ahmedabad, IIM, Indore, and Chancellor of Indian Institute of Space Science, Thiruvananthapuram among many others. Dr Kalam played a vital role as a Project Director to develop India's first indigenous Satellite Launch Vehicle SLV-III which successfully put the Rohini satellite in the near earth orbit in July 1980 and made India an exclusive member of Space Club. He was responsible for the evolution of ISRO's launch vehicle programme, particularly the PSLV configuration. Dr Kalam was responsible for the development and operation of AGNI and PRITHVI Missiles. His books—*Wings of Fire*, *India 2020—A Vision for the New Millennium*, *My Journey*, and *Ignited Mind: Unleashing the Power within India* —have become household names in India and among the Indian nationals abroad. These books have been translated in many Indian languages.

Dr Kalam was one of the most distinguished scientists of India with the unique honour of receiving honorary doctorates from 30 universities and institutions. He has been awarded the coveted civilian awards—Padma Bhushan (1981), Padma Vibhushan (1990) and the highest civilian award Bharat Ratna (1997). He passed away on 27 July 2015 at Shillong.

Sam Pitroda

Satyanarayan Gangaram Pitroda, popularly known as Sam Pitroda, was born on 4 May 1942 at Titlagarh, Odisha. His parents were originally from Gujarat and were strict Gandhians. So Pitroda was sent to Gujarat to imbibe Gandhian philosophy. He completed his schooling from Vallabh Vidyanagar in Gujarat and his Masters in physics and electronics from Maharaja Sayajirao University in Vadodara. He went to the US thereafter, and obtained

a Masters in electrical engineering from Illinois Institute of Technology in Chicago.

This technocrat is an innovator, entrepreneur and policymaker. He has been advisor on Public Information Infrastructure and Innovations to the prime minister of India, Dr Manmohan Singh. He is widely considered to have been responsible for bringing in revolutionary changes in India's telecom sector. As technology advisor to Prime Minister Rajiv Gandhi in 1984, Dr Pitroda not only heralded the telecom revolution in India, but also made a strong case for using technology for the benefit and betterment of society through several missions on telecommunications, literacy, dairy, water, immunization, oilseeds, and so on.

He has served as Chairman of the National Knowledge Commission (2005–08), a high-level advisory body to the prime minister of India, set up to give policy recommendations for improving knowledge-related institutions and infrastructure in the country. Dr Pitroda holds around 100 key technology patents, has been involved in several start-ups, and lectures extensively around the world. He lives mainly in Chicago, Illinois, since 1964 with his wife and two children.

Anil Kakodkar

Dr Anil Kakodkar, the famous Indian nuclear scientist, was born on 11 November 1943 in Barawani, a village in Madhya Pradesh. His parents Kamala Kakodkar and P. Kakodkar were both Gandhians. He did his schooling in Mumbai and graduated from the Ruparel College. Kakodkar then joined Veermata Jijabai Technological Institute, Mumbai, in 1963 to obtain a degree in mechanical engineering. In 1964, Anil Kakodkar joined the Bhabha Atomic Research Centre (BARC), Mumbai.

He was the Chairman of the Atomic Energy Commission of India (AECI) and Secretary to the Government of India, Department of Atomic Energy. He was also the Director of the Bhabha Atomic Research Centre at Trombay during the period 1996–2000, before leading India's nuclear programme.

Anil Kakodkar was part of the core team of architects of India's Peaceful Nuclear Tests that were conducted during the years 1974 and 1998. He also led the indigenous development of the country's Pressurised Heavy Water Reactor Technology. Anil Kakodkar's efforts in the rehabilitation of the two reactors at Kalpakkam and the first unit at Rawatbhatta are noteworthy as they were about to close down.

In 1996, Anil Kakodkar became the youngest Director of the BARC after Homi Bhabha himself. From 2000–09, he headed the Atomic Energy Commission of India Dr Anil Kakodkar has been playing a crucial role in demanding sovereignty for India's nuclear tests. He strongly advocates the cause of India's self-reliance by using thorium as a fuel for nuclear energy.

G. Madhavan Nair

Dr G. Madhavan Nair was born on 31 October 1943 in Thiruvananthapuram, Kerala. This former Chairperson of the India Space Research Organization (ISRO) is known as the man behind Chandrayaan, India's first unmanned mission to the moon.

Nair did his graduation in electrical and communication engineering from the University of Kerala in 1966. He then underwent training at Bhabha Atomic Research Centre (BARC), Mumbai. He joined the Thumba Equatorial Rocket Launching Station (TERLS) in 1967. During his six years' tenure at ISRO, as many as 25 successful missions were accomplished. He took a keen interest in programmes such as tele-education and tele-medicine for meeting the needs of society at large. As a result, more than 31,000 classrooms have been connected under the EDUSAT network and tele-medicine is extended to 315 hospitals—269 in remote rural/district hospitals including 10 mobile units and 46 super specialty hospitals.

He also initiated the Village Resource Centres (VRCs) scheme through satellite connectivity, which aims at improving the quality of life of the poor people in the villages. More than 430 VRCs have now access to information on important aspects like land use/land cover, soil and groundwater prospects, enabling farmers to take important decisions based on their queries.

In the international arena, Dr Madhavan Nair has led the Indian delegations for bilateral cooperation and negotiations with many space agencies and countries, especially with France, Russia, Brazil, Israel, and so on, and has been instrumental in working out mutually beneficial international cooperative agreements. G. Madhavan Nair has led the Indian delegation to the S&T Sub-Committee of United Nations Committee on Peaceful Uses of Outer Space (UN-COPUOS) since 1998. He was awarded the Padma Vibhushan, India's second highest civilian award in 2009.

Vijay Bhatkar

Dr Vijay Pandurang Bhatkar is one of the most acclaimed scientists and IT leaders of India. He is best known as the architect of India's first supercomputer 'Param' and as the founder Executive Director of C-DAC, India's national initiative in supercomputing. He is credited with the creation of several national institutions, notably amongst them being C-DAC, ER&DC, IIITM-K, I2IT, ETH Research Lab, MKCL and India International Multiversity.

As the architect of India's Param series of supercomputers, Dr Bhatkar has given India GIST multilingual technology and several other pathbreaking initiatives. Born on 11 October

1946 at Muramba, Akola, Maharashtra, Bhatkar obtained his Bachelors in engineering from VNIT Nagpur in 1965. This was followed by Masters from MS University, Baroda and a PhD in engineering from IIT Delhi, in 1972.

He has been Member of Scientific Advisory Committee to the Cabinet of Government of India, Governing Council Member of CSIR and Chairman of e-Governance Committees, governments of Maharashtra and Goa.

A Fellow of IEEE, ACM, CSI, INAE and leading scientific, engineering and professional societies of India, he has been honoured with Padmashri and Maharashtra Bhushan awards. Few of the many recognitions he has received include Saint Dnyaneshwar World Peace Prize, Lokmanya Tilak Award, HK Firodia and Dataquest Lifetime Achievement Awards. He was a nominee for the Petersburg Prize and is a Distinguished Alumni of IIT, Delhi.

Dr Bhatkar has authored and edited 12 books and 80 research and technical papers. His current research interests include Exascale Supercomputing, Artificial Intelligence, Brain-Mind- Consciousness and Synthesis of Science and Spirituality. He is presently the Chancellor of India International Multiversity, Chairman of ETH Research Lab, Chief Mentor of I2IT, Chairman of the Board of IIT-Delhi and National President of Vijnana Bharati.

23. Kalpana Chawla

Kalpana Chawla was born on 17 March 1962 in Haryana’s Karnal district. She was inspired by India’s first pilot J.R.D. Tata and had always wanted to fly. She did her schooling from Karnal’s Tagore School, and later studied aeronautical

engineering from Punjab University. To give wings to her aeronautical dream, she moved to America. After obtaining a Masters of Science in aerospace engineering from the University of Texas in 1984, four years later, Chawla earned a doctorate in aerospace engineering from the University of Colorado. In the same year, she started working at NASA's Ames Research Center. Soon, Chawla became a US citizen and married Jean-Pierre Harrison, a freelance flying instructor. She also took keen interest in flying, hiking, gliding, travelling and reading. She loved flying aerobatics, tail-wheel airplanes. She was a strict vegetarian and was an avid music lover.

Chawla joined NASA's space programme in 1994 and her first mission to space began on 19 November 1997 as part of a six-astronaut crew on Space Shuttle Columbia Flight STS-87. She logged more than 375 hours in space, as she travelled over 6.5 million miles in 252 orbits of the earth during her first flight. While onboard, she was in charge of deploying the malfunctioning Spartan Satellite. Interestingly, she was not only the first Indian-born but also the first Indian-American in space.

As a mission specialist and primary robotic arm operator, Chawla was one of the seven crew members who died in the Space Shuttle Columbia disaster in 2003.

Sunita Williams Pandya

Born on 19 September 1965 to Dr Deepak and Bonnie Pandya at Ohio in the US, Sunita Williams Pandya holds three records for female space travellers—longest space flight (195 days), number of space walks (four) and total time spent on space walks (29 hours and 17 minutes).

Williams's roots on her father's side go back to Gujarat in India and she has been to India to visit her father's family.

Williams attended Needham High School in Needham, Massachusetts, graduating in 1983. She went on to receive a Bachelor of Science in physical science from the United States Naval Academy in 1987, and a Master of Science in engineering management from Florida Institute of Technology in 1995. The 47-year-old Williams has been on her expedition to space in July 2012. She was a flight engineer on the station's Expedition 32 crew and was designated commander of Expedition 33 on reaching the space station.

Sunita is very fond of running, swimming, biking, triathlons, windsurfing, snowboarding and bow hunting. She is married to Michael J. Williams, a Federal Police Officer in Oregon. The two have been married for more than 20 years, and both flew helicopters in the early days of their careers.

25. Sabeer Bhatia

Sabeer Bhatia was born in Chandigarh on 30 December 1968. He grew up in Bangalore and had his early education at The Bishop's School in Pune and then at St. Joseph's Boys' High School in Bangalore. In 1988, he went to the US to obtain his Bachelors degree at the California Institute of Technology after a foreign transfer from BITS Pilani, Rajasthan. He earned a Masters in electrical engineering from the Stanford University.

After graduation, Sabeer briefly worked for Apple Computers as a hardware engineer and for Firepower Systems Inc. While working there, he was amazed at the fact that he could

access any software on the internet via a web browser. He, along with his colleague Jack Smith, set up Hotmail on 4 July 1996.

In the twenty-first century, Hotmail became one of world's largest e-mail providers with over 369 million registered users. As President and CEO, he guided Hotmail's rapid rise to industry leadership and its eventual acquisition by Microsoft in 1998. Bhatia worked at Microsoft for a little over a year after the Hotmail acquisition and in April 1999, he left Microsoft to start another venture, Arzoo Inc., an e-commerce firm.

Bhatia started a free messaging service called JaxtrSMS. According to him, JaxtrSMS, would do 'to SMS what Hotmail did for e-mail'. Claiming it to be a disruptive technology, he says that the operators will lose revenue on the reduction in number of SMSs on their network but will benefit from the data plan that the user has to buy.

Bhatia's success has earned him widespread acclaim. The venture capital firm Draper Fisher Jurvetson named him 'Entrepreneur of the Year 1997'; MIT chose him as one of 100 young innovators who are expected to have the greatest impact on technology and awarded 'TR100'; San Jose Mercury News and *POV* magazine selected him as one of the 10 most successful entrepreneurs of 1998; and *Upside* magazine's list of top trendsetters in the New Economy named him 'Elite 100'.

Sabeer was inducted into Eta Kappa Nu (HKN) as an undergraduate student.

Smt. Anna Mani

Anna Mani was an Indian physicist and meteorologist. She was the Deputy Director General of the Indian Meteorological Department.

Anna Mani was born in Peerumedu, Travancore on 23 August 1918. Since childhood, she had been a voracious reader. She wanted to pursue medicine, but she decided in favour of physics because she liked the subject. In 1939, she graduated from Presidency College Madras, with a B.Sc Honors degree in physics and chemistry. Thereafter, she worked under Professor C. V. Raman, researching on the optical properties of ruby and diamond. She authored five research papers, but she was not granted a PhD because she did not have a Masters in physics. Then she moved to Britain to pursue physics, but she ended up studying meteorological instruments at Imperial College London. After returning to India in 1948, she joined the Meteorological department in Pune. She retired as the deputy director general of the Indian Meteorological department in 1976. She conducted research and had published numerous papers on solar radiation, ozone and wind energy as well as on meteorological instrumentation. She was believed in Gandhian principles. In 1994, she suffered from a stroke, and died on 16 August 2001 in Thiruvananthapuram. The main publications by Anna Mani are *Wind Energy Resource Survey in India*, *Solar Radiation over India* and *The Handbook for Solar Radiation Data for India*.

27. E. K. Janaki Ammal

Janaki Ammal Edavaleth Kakkat was an Indian botanist who conducted scientific research in cytogenetics and phytogeography. Her most notable work involves those on sugarcane and the eggplant. She had collected various valuable plants of medicinal and economic value from the rain forests of Kerala.

Janaki Ammal was born in 1897, in Thalassey, Kerala. Her

father was Dewan Bahadur Edavalath Kakkat Krishnan, sub-judge of the Madras Presidency. After schooling in Thalassery, she moved to Madras where she obtained her Bachelors from Queen Mary's College, and an honors degree in botany from Presidency College in 1921. Ammal taught at Women's Christian College, Madras, with a sojourn as a Barbour Scholar at the University of Michigan in the US where she obtained her Masters in 1925. Returning to India, she continued to teach at the Women's Christian College. She went to Michigan again as the first Oriental Barbour Fellow and obtained her D.Sc. in 1931. She returned as professor of botany at the Maharaja's College of Science, Trivandrum, and taught there from 1932–34. From 1934–39, she worked as a geneticist at the Sugarcane Breeding Institute, Coimbatore.

Ammal made several intergeneric hybrids: *Saccharum x Zea*, *Saccharum x Erianthus, Saccharum x Imperata* and *Saccharum x Sorghum*. Ammal's work at the Institute on the cytogenetics of *Saccharum officinarum* (sugarcane) and interspecific and intergeneric hybrids involving sugarcane and related grass species and general such as *Bambusa* (bamboo) were epochal.

From 1940–45, she worked as assistant cytologist at the John Innes Horticultural Institution in London, and as cytologist at the Royal Horticultural Society at Wisley from 1945–51. *The Chromosome Atlas of Cultivated Plants* which she wrote jointly with C.D. Darlington in 1945 was a compilation that incorporated much of her own work on many species. On the invitation of Jawaharlal Nehru, she returned to India in 1951 to reorganize the Botanical Survey of India (BSI). She was appointed as Officer on Special Duty to the BSI on 14 October 1952. She served as the Director General of the BSI.

Following her retirement, Ammal continued to work focusing special attention on medicinal plants and ethno botany. She settled down in Madras in November 1970, working as an Emeritus Scientist at the Centre for Advanced Study in Botany, University of Madras. She lived and worked in the Centre's Field Laboratory at Maduravoyal near Madras until her demise on 7February 1984.

Ammal was elected Fellow of the Indian Academy of Sciences in 1935, and of the Indian National Science Academy in 1957. The University of Michigan conferred an honorary LL.D. on her in 1956. The Government of India conferred the Padmashri on her in 1977. In 2000, the Ministry of Environment and Forestry of the Government of India instituted the National Award of Taxonomy in her name.

11

Conventional, Non-conventional and Clean Energy Sources of India

Energy is an inevitable requirement for growth. Researchers will tell you that the more energy a society consumes per capita, the better is its quality of life. Whenever in the history of mankind we have made a breakthrough in our lifestyle, our energy consumption has also significantly increased—be it when people settled into villages to start farming or at the time of the Industrial Revolution.

As a developing country, India is in a state of transition in energy usage and has rapidly increasing energy demands to support its growth story. Growing energy demands and concerns for energy security are now spurring us to look for alternative energy sources. We have abundant reserves of coal and more than 50% of our energy needs are met by coal. But we do not have enough petroleum reserves, hence, we import more than 70% of our petroleum needs. Reducing our dependence on foreign sources of oil is one more reason why we are exploring new avenues of energy.

This is where we want the renewable and non-conventional energy resources to step in. Though it is difficult to estimate when the world will run out of fossil fuels, it is certain that we will run out of them. Some estimates will tell you two decades while others would say we have enough for the next two centuries. For dependable sources of energy in future, we have to look beyond coal and petroleum and explore energy sources that might be entirely new or the old ones we have forgotten about.

Often the terms ‘renewable’ and ‘non-conventional’ are erroneously used interchangeably. A **renewable** energy resource is one whose reserves can be replenished from time to time. Many tried and trusted energy forms such as wood, charcoal, bio-wastes are all renewable. Archaeological digs tell us about metal works in ancient world that had kept their furnaces fired up for thousands of years by renewably utilizing stretches of forest lands. If it is a renewable source of energy, it does not have to be non-conventional and neither does it need to be clean.

Non-conventional energy sources are those which have not been historically used. So, the technology for their use is still developing and scientists are working continuously to make their utilization process more efficient. Examples are hydroelectricity, solar photovoltaic plants and nuclear energy. One must remember that coal or petroleum did not just become ubiquitous sources of energy overnight. A considerable amount of research and scientific genius, starting from the nineteenth century, went into getting them to where they are today in terms of reliability and large-scale use. Hence, it should not be surprising or perplexing that growth of non-conventional energy sources would also require similar volumes of research and patience.

A non-conventional energy source need not always be clean and renewable, example being nuclear energy. India has a well-developed, indigenous nuclear power programme and considerable amount of fuels in the form of Thorium sands for the breeder reactors. Though during the process of power production, no pollutants are emitted from a nuclear plant, the problem starts with the spent nuclear fuel rods. Even though they can no longer be used for power production, these fuel rods are still considerably radioactive, which makes their disposal a problem. As of now, these fuel rods are disposed off by burying them in concrete inside deep mines or bore holes from where their radiation cannot affect living beings. But considering that some of these radioactive elements can remain active for thousands of years, the hope is to arrive at better disposal technology. While it is scary to think of what an accident at a nuclear power plant might do to the neighbouring areas, these perils are well known to the plant designers who make a nuclear power plant more robust and safer than other conventional power plants.

India has vast potentials for developments in all three forms of energy—renewable, non-conventional and clean. But, it is anticipated by most researchers that the drive to move to renewable energy would not so much be due to end of fossil fuels as due to the harmful effect that fossil fuels have on our environments. So, here, we shall primarily confine our discussion to clean and renewable sources.

Clean and Renewable Energy Sources:

India has limited potential in the field of **hydroelectricity** and much of it has already been realized. Currently, there is much stress and interest regarding micro-hydroelectric projects. These would result in small hydro-turbines running on small or large rivers and a series of such turbines along the river can meet the energy requirements of a number of villages instead of one. Also, the construction of gigantic dams across rivers can be avoided.

Most of our country's renewable energy potential lies in the development of **wind** energy. Wind energy surveys of large parts of the country are still in progress. We might have an even larger potential than estimated. Till mid-2016, more than 17 GW wind energy production capacity had been installed.

Being located in the Tropical zone, India receives plenty of sunlight. But regular rains due to monsoon results in having very few areas—like parts of Gujarat and Rajasthan—of uninterrupted sunshine to generate electricity through solar energy. Currently, all solar power projects are photovoltaic in nature while small-scale solar thermal installations are operational in cities like Chennai and Bengaluru giving hot water, water purification and other heating requirements for private homes and hotels. There are future plans of establishing large-scale solar thermal power plants in regions of Rajasthan. Such a plant would use the sun's energy to vapourize water and the steam to drive a turbine for power production. There are, of course, the usual barriers to development of solar power, namely, large initial investment and large land area requirement.

Another viable mean of energy production is conversion of organic waste into energy. We have had some success in this regard through pilot biogas projects in several villages across the country. Researchers are developing more and new ways of making energy from organic matters, waste or otherwise. One of the ways is production of Syngas, which can be used to produce hydrocarbons and synthetic petroleum in the long run.

One vital aspect of energy use, apart from power generation, is transportation. This sector has also seen the growth of new fuels that could end our dependence on imported petrol. Amongst alternative fuels, we now use liquefied petroleum gas (LPG), compressed natural gas (CNG), mixtures of CNG and hydrogen. Future plans include use of hydrogen in petrol-burning engines too. Biodiesels—derived from oil of plants like *jatropha*, *karanja* and even from algae and mixed with diesel in a 20:80 ratio—are used, though in limited scope. The greatest advantage of developing alternative fuels is that they can be used in the current vehicles with minimal to no changes. And most importantly, these alternative fuels have minimal adverse effects on atmosphere compared to fossil fuels.

Parallel to developing and exploring new energy sources, we should also emphasize on the economic use of our resources. No replacement for fossil fuels is going emerge suddenly out of

A wind farm

the blue. Even if it does, with a growing population, our energy demands are increasing much faster than ever before in history. The need of the hour is efficient use of energy and end of all wasteful usage. We need to have more efficient refrigerators and air-conditioners. We should stress on building efficient lighting systems and street lights that would light up and shut off depending on amount of surrounding light. We need more efficient power plants that may burn coal but do it more completely and cause lesser pollution. If we continuously strive towards these goals, we are bound to attain energy security on a long-term basis.

12

Science and Its Various Branches

Human beings differ from other animals in many ways. Of particular importance is the ability to think, communicate and use language. This, in turn, gives us the skill to pass on information from one generation to the next. This ability has been more or less responsible for the growth of a systematic analysis of different questions. Systematic analysis of any question can be called science. Science is in no way limited to the laboratories or classrooms. What your mother does as part of her cooking process in her kitchen, skills that have been honed over years of experimentation and careful observation, is not far from a scientist experimenting in a lab.

Once any query is analysed in a particular, rational modus operandi, it is obvious to gather some views and answers. Next comes the second litmus test for science: results must be repeatable and reproducible. What one person does in a lab in India, she/he should be able to get the same result multiple times by someone else in a lab located in a different country. For instance, Japan should also get the same result using the same input and instruments. It is easy at times to think that what appears in scientific writings are the author's personal views. However, when something is actually circulated as part of the larger body of scientific knowledge in reputed scientific publications, it has been cross-checked by multiple independent researchers and the rational thought process of all related scholars agrees with those facts. This ensures that 'false science' and erroneous claims cannot be sustained for any considerable duration.

The person who invented the wheel, the person who discovered fire, the tribe that discovered agriculture, they were all scientists in their own right. From the times of the early Greeks till the times of Galileo and Newton, those whom we, in present days refer to as scientists were actually philosophers or naturalists. Archimedes was a philosopher as was Galileo; even Darwin was a naturalist. A more stringent categorization of science into branches came about with the growth of scientific knowledge. People like Archimedes and Aristotle contributed to all branches of human knowledge without bothering about the divisions of physics, chemistry or biology. This trend can also be seen among philosophers like Galileo, Leonardo da Vinci, Johannes Kepler and Newton; they also did not have a fixed area or branch of study. They analysed nature as they observed it and tried to come up with suitable explanations. Sometimes when they felt the need to extend the range of human senses, they also invented devices like a telescope or a microscope. In those times, you could also find a person like Benjamin Franklin, who was a politician and a diplomat, but was also a skilled observer of nature; he proved that lightning was a manifestation of electric discharge and also invented bifocal lenses.

Science and mathematics have always been closely interrelated. Mathematics enjoys the undisputed position of being the universal language of science, irrespective of your branch of interest. Many a times in history, it becomes difficult to classify people as just scientists or mathematicians. Newton himself is equally famous as both, though his *Philosophiæ Naturalis Principia Mathematica* often referred to as simply the *Principia* would primarily be considered as a mathematical text. One comes across names like Gauss, Euler, Bernoulli, Pascal—people who made breakthroughs in mathematics and then applied them to the natural sciences to further our understanding of the natural world.

As the body of scientific knowledge increased and the study of science became part of university curriculums, it was found that for one person to be able to assimilate and work on such a variety of topics would be impossible. So people needed to specialize and develop topics of study such as physics, life sciences, chemistry, and so on. In the past, we had people like Faraday who made excellent contributions to physics and chemistry; his two major contributions being laws of electromagnetism and laws of electrolysis. We also have Louis Pasteur who graduated with honors in physics and mathematics but worked mainly in the field of chemistry, and alongside, discovered that most diseases are caused by microscopic germs. Later, life sciences branched out into botany and zoology—studying plants and animals, respectively. Eventually, those studying chemistry, took leave of their colleagues pursuing too. Broad divisions of science emerged on the basis of their subject matter, with chemistry forming a kind of feeble bond between all three. With time, more specialized topics arose like organic chemistry, astrophysics and paleobotany (study of fossilized plants). With increasing understanding and knowledge, the degree of specialization has also increased and has grown narrower every day. To paraphrase what the famous science fiction writer Isaac Asimov once said: As we increase our knowledge of the world we live in, people will be more and more specialized in their chosen topics and the only people to know something about all branches of science would be science fiction writers.

In recent years, however, with deeper understanding, the inherent connection between the different branches has been increasingly felt. The subject matters are still too vast for one person to be able to work on two different fields of knowledge. But the growing feeling is that to be able to better answer the questions about nature that still baffle us or to be able to face the new challenges, greater coordination and sharing of knowledge is required amongst experts from various fields. For example, consider the MRI machine in a hospital. To ensure that this machine works and can be used for diagnosis, a coordinated effort by mathematicians, physicists, engineers, software programmers and doctors is needed to take place. Works of different domains of science are starting to intersect more and more and some of the best research is being carried out by interdisciplinary endeavours. Some interesting examples that are at the intersection of two or more disciplines are bioinformatics, biomechanics, quantum computing and molecular biology. Some of the areas of concern that use multidisciplinary research include global warming, sustainable development, land management and disaster relief.

Another important differentiation exists among scientists in terms of how they work on their respective fields. There are theoretical researchers who study problems, try to hypothesize solutions and attempt to model the problem as well as solution using mathematics. Then we have experimentalists who design a set-up and conduct experiments either to verify a hypothesis made by the theoreticians or to learn more about the system being studied. A newly emergent approach—due to massive increase in use of computers—is the computational approach where one may simulate a system on a computer and try to solve its equations or simulate certain experiments being performed on the system.

An interesting differentiation of the disciplines occurs quite naturally from their scale of studies. We have scientists who study things as big as the galaxies to scientists studying sub atomic particles. In between these two extremes, you can imagine a whole range of sizes where the interests of different scientists lie. You could have a biologist dealing with normal living organisms, the ones we see in our everyday lives. Then you might have a microbiologist studying microorganisms or molecular biologists studying the fundamental molecules that sustain and propagate life. The diversity is ever increasing.

13

Ayurveda and Medicinal Plants

Ayurveda and Its Various Treatment Methods

Ayurveda, which literally translates as 'the knowledge for long life', is a form of alternative medicine which originated in India over 5000 years ago and is a time-tested health- care science. The *Sushruta Samhita* and *Charaka Samhita* are considered as the encyclopedias of medicine and are regarded as the foundational works of Ayurveda. Over the centuries, practitioners of Ayurveda developed a number of medicinal preparations and surgical procedures for the treatment of various ailments. Kerala, the southern state of India, is popular worldwide for its booming Ayurvedic treatment centres. In Kerala, Ayurveda is not treated as alternative but more as a mainstream treatment process.

Ayurveda emphasizes in restoring the balance of *Vata*, *Pitta* and *Kapha* in the body through diet, lifestyle, exercise and body cleansing, and thereby enhancing the health of the mind, body and spirit. It is now very popular in treating problems such as obesity, skin and body purification, stress management, spondylitis, arthritis, psoriasis, insomnia, constipation, Parkinson's disease, frozen shoulder, Tennis elbow, and so on. Some of the popular Ayurvedic treatment methods are listed below.

Abhyangam **:** Abhyangam is a special type of oil massage and is very useful in treating obesity and diabetic gangrene (a condition developed due to lack of blood circulation in certain parts of the body). The massage is done with a combination of specially prepared Ayurvedic herbal oils and applied all over the body stimulating the vital points. This treatment is good for the general health of the skin and prevents early aging and relieves muscular aches and pain.

Dhara: In the Dhara treatment process, herbal oils, medicated milk, buttermilk, and so on are allowed to flow on the forehead in a special rhythmic method for about 45 minutes in a day for 7 to 21 days. This treatment is ideal for insomnia, mental disorders, neurasthenia, memory loss and certain skin diseases.

In *Thakra Dhara*, after giving head massage, medicated buttermilk is poured in an uninterrupted flow from a hanging vessel to the forehead and scalp. This is good in treating scalp problems such as dandruff, Psoriasis, hypertension, diabetes, hair loss and other skin complaints. In *Siro Dhara*, after giving a good head massage, herbal oil is poured in an uninterrupted flow from a hanging vessel to the forehead and scalp. This is considered good in relieving stress and strain and generates sleep.

Sirovasthy: In Sirovasthy, a cap is fitted on the patient's head and then medicated lukewarm oil is poured into it for about half an hour. It effectively treats insomnia, facial paralysis and numbness in the head, dryness of nostrils, throat and headaches.

Pizhichil: In Pizhichil, warm herbal oil is applied to the entire body in a rhythmic style for about an hour. The vigorous sweating in the process treats problems like arthritis, paraplegia, paralysis, sexual dysfunction and many nerve-related problems.

Virechanam: Virechanam is the method of cleaning and evacuation of the bowels through the use of purgative medicines. It eliminates excess bile toxins from the intestines. People with digestion-related problems resort to this form of treatment. When the digestive tract is clean and toxic-free, it benefits the entire body system. It helps increase appetite and proper assimilation of the food.

Kayavasthy: In Kayavasthy, the body is treated with warm medicated oil. The oil is kept on the lower back of the patient for 30 to 45 minutes in a boundary made of herbal pastes. It treats back pain and other problems in the lower vertebral area.

Medicinal Plants

Ayurveda and medicinal plants are synonymous. In rural India, 70 per cent of the population depends on traditional medicines or Ayurveda. Many medicinal herbs and spices are used in Indian style of cooking, such as onion, garlic, ginger, turmeric, clove, cardamom, cinnamon, cumin, coriander, fenugreek, fennel, ajwain, anise, bay leaf, hing (asafoetida) and black pepper. Ayurvedic medicine uses all of these either in diet or in the form of medication. Some of these medicinal plants have been featured on Indian postage stamps also.

As per the National Medicinal Plants Board, India has 15 agro climatic zones and 17,000–18,000 species of flowering plants. Out of this, 6000–7000 species are estimated to have medicinal usage. About 960 species of medicinal plants are estimated to be in trade, of which 178 species have annual consumption levels in excess of 100 metric tonne.

Medicinal plants are not only a major resource base for the traditional medicine and herbal industry but also provide

A few herbs that have medicinal value

livelihood and health security to a large segment of the Indian population. India is the largest producer of medicinal plants. The domestic trade of the AYUSH industry is of the order of 80–90 billion. Indian medicinal plants and their products also account for exports to the tune of 10 billion.

There is a global resurgence in traditional and alternative health-care systems, resulting in increased world herbal trade. The world herbal trade, which stands at 120 billion US dollars today, is expected to reach 7 trillion US dollars by 2050. India's share in the world trade, at present, however, is quite low.

Some of the most popular medicinal plants in India are listed below:

Guggulu is a shrub found in the arid and semiarid zones of India, particularly Rajasthan. It is used in the treatment of various categories of ailments such as neurological conditions, leprosy, skin diseases, heart ailments, cerebral and vascular diseases and hypertension.

Brahmi is a herb that spreads on ground with fleshy stems and leaves. It is found in moist or wet places in all parts of India. Brahmi is useful for treating brain diseases and to improve memory power. It is prescribed in rheumatism, mental disorders, constipation, and bronchitis. It is also a diuretic.

Amla or the Indian gooseberry is a medium- sized deciduous tree found throughout India. The pale yellow fruit is known for its varied medicinal properties. It is regarded as a digestive, carminative, laxative, anti-pyretic and tonic. It is prescribed in colic problems, jaundice, haemorrhages, flatulence, etc.

Amla or Indian gooseberry

Ashwagandha is a small- or medium-sized shrub found in the drier parts of India. It is prescribed for nervous disorders and is also considered as an aphrodisiac. It is used to treat general weakness and rheumatism.

Arjuna tree holds a reputed position in both Ayurvedic and Unani systems of medicine. According to Ayurveda, it is useful in curing fractures, ulcers, heart diseases, biliousness, urinary discharges, asthma, tumours, leucoderma, anaemia, excessive perspiration, and so on.

Aloe Vera is a popular medicinal plant. It contains over 20 minerals, all of which are essential to the human body. The

Tulsi, a common medicinal plant

human body requires 22 amino acids for good health, eight of which are called ‘essential’ because the body cannot fabricate them. Aloe Vera contains all of these eight essential amino acids, and 11 of the 14 ‘secondary’ amino acids. Aloe Vera has Vitamins A, B1, B2, B6, B12, C and E. In India, Aloe Vera is believed to help in sustaining youth, due to its positive effects on the skin.

Neem is famous for its blood purifying properties. Many herbalists recommend chewing the leaves, taking capsules of dried leaf, or drinking the bitter tea. It helps the gastrointestinal system, supports the liver and strengthens the immune system. It is extremely effective in eliminating bacterial and fungal infections or parasites. Its antiviral activity can treat warts and cold sores.

History of the Organized Development of Ayurveda in Modern India

Ayurveda, as such, does not need any introduction to the people of India. Till recently, Ayurveda has been practiced by most households and stayed as a mainstream health care system in the country. In March 1995, the Department of Indian Systems of Medicine and Homoeopathy (ISM&H) was created by the Government of India. Later, in November 2003, this Department was renamed as the Department of AYUSH (Ayurveda, Yoga, Unani, Siddha, Homoeopathy) under the Ministry of Health and Family Welfare, Government of India. The primary objective of the Department of AYUSH is to provide focused attention to the development of education and research in Ayurveda, yoga and naturopathy, Unani, Siddha, and homoeopathy systems of medicines. The Department lays emphasis on upgradation of AYUSH educational standards, quality control and standardization of drugs, improving the availability of medicinal plant material, research and development, and awareness generation about the efficacy of the systems domestically and internationally. Today, almost all state governments have a Department of AYUSH pushing traditional Indian systems of medicine to the mainstream.

The National Rural Health Mission (2005–12) is a major programme of the Government of India. The NRHM seeks to provide effective health care to the rural population throughout the country with special focus on 18 states, which have weak public health indicators and/or weak infrastructure. Among its various goals, the one that pertains to the Ayurveda sector is its goal on revitalizing local health traditions and mainstreaming AYUSH systems of medicines into the public health system.

With the efforts of the government and several non-governmental organizations, Ayurveda is slowly and steadily coming back to its pre-eminent position. One of the awareness generation activities needs special mention here. The World Ayurveda Congress and AROGYA Expo, organized by Vijnana Bharati, which is ably supported by the Department of AYUSH, is a massive promotional event on Ayurveda that attracts all stakeholders, both national and international. Began in 2002 and held every two years, the World Ayurveda Congress has completed its Sixth edition in 2014 at New Delhi. The Honourable Prime Minister of India Shri Narendra Modi has given the valedictory address in the Sixth edition of the World Ayurveda Congress and immediately after three hours, a new ministry for AYUSH was declared by the Union Government. In each of its editions, the AROGYA Expo—an exhibition that displays Ayurvedic products, treatment methodologies and educational institutions—generates awareness among lakhs of common citizens. Today, the Government of India, actively promotes Ayurveda in various countries as well.

14

Indigenous Agriculture, Biotechnology and Nano –technology

Agriculture

'India is an agrarian country'. This statement today remains as true as it was 69 years ago in spite of agriculture not making up the largest part of our economy. As our economy stands now, the major growth and portion of the national income comes from the services sector, but the largest part of our working population is engaged in agriculture and related activities. Most Indians still make their livelihoods from the country's farmland. There are two aspects to what makes the agricultural sector important to our country. One is the need to feed our ever-growing population without depending on food imports. The other is about the basic strength of any economy. While short-term growth spurts can be achieved by economic activities based on value addition (like the services sector), for the long- term health of an economy and for it to have strong basics, primary sectors that generate products (such as agriculture) need to be strong.

After Independence, our agricultural sector was suffering from many ills including lack of irrigation facilities, inequitable distribution of land and almost zero use of technology to improve production. As such, at that point too, we were heavily dependent on importing grains to feed our population. In the 1960s, this situation was not unique to India. Several Third

World countries had got their independence and they were struggling to feed their populations. At this point of time, the introduction of Green Revolution is supposed to have saved the lives of one-third of the world's population. The man who is credited with it is Dr Norman Borlaug. In 1963, he introduced high-yielding varieties of wheat in India. That was the turning point for our agriculture and we have been moving ahead from there. Several measures were introduced to improve agricultural production along with the use of high-yielding crop varieties.
In this task, the group of indigenous scientists led by Dr M.S. Swaminathan played a major role. The other steps taken include: development of irrigation facilities, more widespread use of chemical fertilizers, pesticides, insecticides, land reforms and consolidation of land holdings under *chakabandi*, use of mechanized instruments in land tilling, harvest and post-harvest functions, easier and smoother availability of agricultural loans and rural electrification to facilitate running of farm machineries.

A typical result of Green Revolution

Simultaneously, the government also invested in opening agricultural universities and research laboratories to develop indigenous technologies. This led to developing wheat and paddy crop varieties that are typically suited to our climate and the vagaries of monsoon—flooding or droughts—are pest resistant and have better yield, thereby lowering the risks for farmers.

Unfortunately, for long after the Green Revolution, there were very few changes made in our approach to agriculture and as a result, production suffered. This occurred in spite of the high yield crops we talked about previously. What we have realized is that over the last couple of decades, the total land area under production has decreased, our population has kept increasing as ever and our agricultural productions have been forced to cope with the growing demand. Unfortunately, this had caused long and indiscriminate use of chemicals in our farms. Farmers no longer depend on any natural manures or crop rotation to revitalize their fields. Long use of synthetic chemicals leads to fields reaching their maximum capacity of production while the weeds, pests and insects grow resistant.

Now is the ideal time for a second Green Revolution. For the past decade, agricultural scientists have been focusing on finding organic alternatives to the chemical fertilizers and insecticides and there has been some considerable success. Irrigation facilities have also been improved and people are growing more conscious of maintaining a stable underground water table. The plans are to make our fields less dependent on the monsoons, thus eliminating a highly variable factor from the production. Initiatives are concentrating on completing rural electrification with dependable power supply and recycling groundwater through techniques like rainwater harvesting. By consulting agricultural scientists, farmers are able to better determine the specifics of when to use what kind of chemical aids, the precise quantum to beused precisely and what organic supplements to use so that they can give better yields without over-stressing the land. This has decreased the indiscriminate use of chemicals in our farms and, hence, the contamination of neighbouring areas and water resources too. There is a growing trend of soil testing and field evaluations of local conditions, which has enabled the researchers to provide better suggestions to the farmers. This has made the process of farming much more scientific and has also reduced the expenses of the farmers as now they have to use specific amounts of fertilizers or pesticides.

Biotechnology and Nano technology

There has been considerable hope put on biotechnology and nanotechnology. Biotechnology deals with applications of living organism to improve human initiatives. When we talk of biotechnology in India, we tend to talk primarily of its use in health and agricultural sectors. In medicine, it would mean better and cheaper medicines, new therapies to deal with age-old adversaries like cancer, vaccinations and diagnostics. In agriculture, the expectations are in terms of developing higher yielding seeds by manipulating the very genes of plants, bio pesticides and bio-fertilizers, and food preservation and processing. Food preservation is essential as we still lose almost 30% of our food grain production a year due to poor storage facilities.

Nanotechnology, on the other hand, is a relatively unexplored area with only government-funded research so far. But the hopes associated with it are great. Nanotechnology is a technology of very small scales—a thousand times smaller than the thickness of a human hair. At such scales, though the basic nature of matter remains the same, a lot of structural flaws can be removed making things stronger, catalysts more efficient and medicines working faster. The current goal is to direct nanotechnology research to enhance agricultural productivity by helping genetic improvements, treatment of polluted water resources, and making crops more resistant to pest or insect attacks. In future, we could have nano particles-based insecticides where we would need to spray just a small quantity of it over an entire hectare.

There are several hurdles to be overcome before these goals can be achieved, especially assessment of long-term use of nanotechnology and biotechnology on human health. Today, India seems to be on the right track and the future looks promising.

15

Traditional Wisdom of Astronomy

Development of astronomy in India has come a long way since the Vedic times and now ISRO heads our space exploration and research in astronomy.

When mentioning Indian astronomy, an image that automatically comes to our mind is that of the Jantar Mantar. It was built by Sawai Jai Singh of Jaipur in the eighteenth century. These collections of huge instruments for astronomical observations were fundamentally based on ancient India's astronomy texts. Five Jantar Mantars were built to revise the calendars and make a more accurate collection of tables that could predict the motions of the major stars and planets. This data was to be used for more accurate time measurement, improved predictions of eclipses and better tracking of positions of stars and planets with relation to earth. They are so large in scale that it is supposed to have been aimed at increasing their accuracy. In the Jantar Mantar, one can find the world's largest sundial and literally see the sun's shadow move every second. Records also show that telescopes were built and used in certain observations. This kind of accuracy helped produce in those ages some remarkably accurate results, which even contemporary Europeans could not beat.

One important lesson to learn from the Jantar Mantars is that the Raja built five of them. He could have built just one and been happy with the results. He built five so that the results given by one observatory could be verified against those of another. This kind of verification obviously reduced the human error involved when taking readings on an instrument. Also, the five observatories were in five different cities. Thus, one could check the position readings of heavenly bodies from different parts of earth and again verify the overall results. This shows a strong display of the scientific enquiry method in the minds of our past astronomers.

The ideas behind Jantar Mantar came from ancient Indian texts written by Aryabhata, Varahamihira, Bhaskaracharya and others. The most important texts of ancient Indian astronomy had been compiled between the fifth and fifteenth century CE— the classical era of Indian astronomy. The more familiar ones among these works are *Aryabhatiya*, *Aryabhatasiddhanta*, *Pancha-siddhantika* and *Laghubhaskariyam*. Ancient Indian astronomers were notable in several respects. Their achievements are even more baffling considering they never used any kind of telescopes. They put forth the sun-centric theory for the solar system, elliptical orbits for planets instead of circular ones, reasonably accurate calculations for the length of a year and the

Jaipur's Nadi Valve Yantra tells you the sun's hemispheric position.

earth's dimensions, and the idea that our sun was no different from the countless other stars in the night sky.

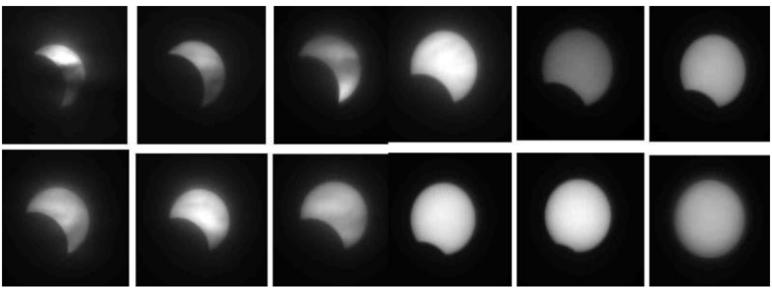
Somewhere during the Middle Ages, progress in the field of astronomy stood still and an admixture of astronomy and astrology arose. With colonization, the European school of astronomy displaced our own. The last remarkable astronomer in pre-Independence India was Samanta Chandrasekhara. His book *Sidhant Darpana* and his use of simple instruments in getting accurate observations earned him praise even from the British.

In our present era, the Indian space programme stands on the contributions made by two giants in the field of physics—Homi J Bhabha and Vikram Sarabhai. It was their tireless efforts, which initiated work in space research under the Department of Atomic Energy.

Over this period of time, India also produced some remarkable astronomers and astrophysicists. Meghnad Saha and Subrahmanyan Chandrasekhar are two world renowned names in astrophysics. On the side of the observational

Kavalur Observatory

astronomy, we had Dr M.K. Vainu Bappu—till date the only Indian to have a comet named after him/her. Currently, the Giant Meter-wave Radio Telescope (GMRT) at Khodad near Pune is the largest of its kind in the world. The Kavalur observatory, named after Dr Bappu, is one of the best equipped in the eastern hemisphere.



Partial Solar Eclipse
Images taken at the VBO, Kavalur

Jantar Mantar—Ancient Astronomical Observatories of India and Some Instruments

Historically, Indian astronomy developed as a discipline of Vedanga.
The oldest known text is the *Vedanga Jyotisha*, dated between 1400–1200 BCE.

Indian astronomy was in its peak in the fifth–sixth centuries with Aryabhata and his *Aryabhatiya* representing the pinnacle of astronomical knowledge. Later, Indian astronomy influenced Muslim astronomy, Chinese astronomy, European astronomy and others significantly. Other astronomers of the classical era, who further elaborated on Aryabhata's work, include Brahmagupta, Varahamihira and Lalla.

An identifiable astronomical tradition remained active throughout the medieval period and into the eighteenth century, especially within the Kerala school of astronomy and mathematics founded by Sangamagrama Madhava (1350–1425 AD) of Irinjalakkuda in Kerala.

The classical era of Indian astronomy begins in the late Gupta era, in the fifth–sixth centuries. The *Panchasiddhantika* (Varahamihira, 505 CE) approximates the method for determination of the meridian direction from any three positions of the shadow using Gnomon or Sanku.

Once, while visiting the court of Emperor Muhammad Shah, Maharaja Jai Singh II of Jaipur overheard a loud argument about how to calculate the most astronomically advantageous date for the purpose of the emperor beginning a journey. To the Maharaja, the debate highlighted the need for education in the field of astronomy and for an observatory that could make accurate astronomical calculations. The idea for the Jantar Mantars or calculation instruments was born.

The Jantar Mantar consists of a number of structures in stone, brick and marble, each of them marked with astronomical scales and designed to serve a specific purpose. Of the observatories originally built at Delhi, Jaipur, Mathura, Ujjain and Varanasi, all observatories still exist except the one in Mathura.

Among the devices used for astronomy was Gnomon, known as Sanku, in which the shadow of a vertical rod is applied on a horizontal plane in order to ascertain the cardinal directions, the latitude of the point of observation and the time of observation. This device finds mention in the works of Varahamihira, Aryabhatta, Bhaskara, Brahmagupta, among others.

The armillary sphere was used for observation in India since early times, and finds mention in the works of Aryabhatta (476 CE). The Goladipika—a detailed treatise dealing with globes and the armillary sphere was composed between 1380–1460 CE by Parameswara. Probably, the celestial coordinates of the junction stars of the lunar mansions were determined by the armillary sphere since the seventh century. There was also a celestial globe rotated by flowing water.

The seamless celestial globe invented in Mughal India, specifically in Lahore and Kashmir, is considered to be one of the most impressive astronomical instruments and remarkable feats in metallurgy and engineering. All globes, before and after this, were seamed, and in the twentieth century, creating a seamless metal globe was believed by metallurgists to be technically impossible, even with modern technology.

Laghu Samrat Yantra in Jaipur

The small Sun dial or Laghu Samrat Yantra is the instrument used for time calculation. From one side, the wall is inclined at an angle of 27 degrees, which is equivalent to the latitude of Jaipur. It is graduated to the scale of tangent to find out the declination angle of the sun.

Samrat Yantra

The Samrat Yantra may be described as a gigantic sun dial. Literally, it means the king of all the instruments. It is not only the biggest of all the yantras but is also the most extraordinary in accuracy and excellence of its construction

Rashivalaya (Star Sign)

It is a group of 12 instruments with graduated quadrants on both the sides. As mentioned in books, the purpose of constructing these 12 instruments was to get the direct determination of celestial latitude and longitude. The method of observing celestial latitude and longitude is precisely the same as that described for Samrat Yantra, and just as the quadrant of the latter represents the equator, so also the quadrants of the Rashivalaya represent the ecliptic at the moment of observation. The instruments are constructed in such a scientific way that one of these 12 is used, at the moment, when each sign of the zodiac reaches the local meridian.

Ram Yantra

Ram Yantra measures the altitude of the sun, according to the height of the shadow cast by the Gnomon (the dark upright pole to the centre right). In this photo, the reflected glare from the sun has washed out the scale grid in the central section. It is more visible on the upright sections to the left and right. As the sun rises and falls, the shadow falls and rises correspondingly, moving around the instrument.

Misra Yantra

The Delhi observatory has one feature, the Misra Yantra, which is not included at any of the other sites. In fact, this is the only part of the Jantar Mantar structures that was not created

The Jantar Mantar in Delhi

by Jai Singh II. The Misra Yantra is thought to have been added by Jai Singh II's son, Maharaja Madho Singh, who continued his father's efforts towards modernization.

Five separate instruments make up the Misra Yantra, including a smaller scale Samrat or sun dial. Two pillars adjoining the Misra Yantra indicate the year's shortest and longest days. The giant device could also show when it was noon in a number of cities around the world.

Some of the Great Ancient Indian Astronomers

Lagadha (1st millennium BCE): He had written the earliest astronomical text, *Vedanga Jyotica*,which provides details on several astronomical attributes, generally applied for timing social and religious events. It also explains astronomical calculations and calendar studies, and establishes rules for empirical observation. *Vedanga Jyotica* has connections with Indian astrology and mentions important aspects of the time and seasons, including lunar months, solar months, and their adjustment by a lunar leap month of *Adhimasa*. *Ritu*s and *Yuga*s are also described. It also mentions of 27 constellations, eclipses, seven planets and 12 signs of the zodiac known at that time.

Aryabhata (476–550 CE): Aryabhata was the author of the *Aryabhatiya* and the *Aryabhatasiddhanta*. Aryabhata explicitly mentioned that the earth rotates about its axis, thereby causing what appears to be an apparent westward motion of the stars. Aryabhata also mentioned that reflected sunlight is the cause behind the shining of the moon. Aryabhata's followers were particularly strong in South India, where his principles of the diurnal rotation of the earth, among others, were followed and a number of secondary works were based on them.

Brahmagupta (598–668 CE): His *Brahmasphuta-siddhanta* (Correctly Established Doctrine of Brahma, 628 CE) dealt with both Indian mathematics and astronomy. Brahmagupta also calculated the instantaneous motion of a planet, gave correct equations for parallax and computation of eclipses. His works introduced the Indian concept of mathematics-based astronomy into the Arab world. He also theorized that all bodies with mass are attracted to the earth.

Varahamihira (505 CE): Varahamihira was an astronomer and mathematician who studied Indian astronomy as well as the many principles of Greek, Egyptian and Roman astronomical sciences. His *Panchasiddhantika* is a treatise and compendium drawing from several sources.

Bhaskara I (629 CE): His works on astronomy are *Mahabhaskariya*, *Laghubhaskariya* and *Aryabhatiyabhashya* (629 CE), a commentary on the *Aryabhatiya.* Baskara devised methods for determining the parallax in longitude directly, the motion of the equinoxes and the solstices, and the quadrant of the sun at any given time.

Lalla (eighth century CE): His work *Uisyadhivrddhida* corrects several assumptions of *Aryabhatiya*. The *Sisyadhivrddhida* of Lalla deals with planetary calculations, determination of the mean and true planets, three problems pertaining to diurnal motion of Earth, eclipses, rising and setting of the planets, various cusps of the moon, planetary and astral conjunctions and complementary situations of the sun and the moon. The second part, titled *Goladhyaya* (Chapters XIV–XXII), deals with graphical representation of planetary motion, astronomical instruments, spherics, and emphasizes on corrections and rejection of flawed principles. Lalla also authored the *Siddhantatilaka*.

Bhaskara II (1114 CE): His two works are *Siddhantasiromani* and *Karanakutuhala* (Calculation of Astronomical Wonders). He reported his observations of planetary positions, conjunctions, eclipses, cosmography, geography, mathematics and the astronomical equipment used in his research at the observatory in Ujjain, which he headed.

Sripati (1045 CE): Sripati was an astronomer and mathematician who followed the Brahmagupta school and wrote *Siddhantasekhara* (The Crest of Established Doctrines) in 20 chapters, thereby introducing several new concepts, including moon's second inequality.

Mahendra Suri (fourteenth century CE): Mahendra Suri authored the *Yantra-raja* (The King of Instruments, written in

1370 CE)—a Sanskrit work on astrolabe, which was introduced in India during the reign of the fourteenth-century Tughlaq dynasty ruler Firuz Shah Tughluq (1351–88 CE). Suri seems to have been a Jain astronomer in the service of Firuz Shah Tughluq.

Nilakanthan Somayaji (1444–1544 CE): In 1500, Nilakanthan Somayaji of the Kerala school of astronomy and mathematics in his Tantrasangraha, revised Aryabhata's model for the planets Mercury and Venus. His equation of the centre for these planets remained the most accurate until the time of Johannes Kepler in the seventeenth century. Nilakanthan Somayaji, in his *Aryabhatiyabhasya*, a commentary on Aryabhata's *Aryabhatiya*, developed his own computational system for a partially heliocentric planetary model, in which Mercury, Venus, Mars, Jupiter and Saturn orbit the Sun, which in turn orbits the Earth. He also authored a treatise titled *Jyotirmimamsa* stressing the necessity and importance of astronomical observations to obtain correct parameters for computations.

Acyuta Pisaradi (1550–1621 CE): His work *Sphutanirnaya* (Determination of True Planets) details an elliptical correction to existing notions. *Sphutanirnaya* was later expanded to *Rasigolasphutaniti* (True Longitude Computation of the Sphere of the Zodiac). Another work of Acyuta Pisaradi, *Karanottama* deals with eclipses, complementary relationship between the sun and the moon and the derivation of the mean and true planets. In *Uparagakriyakrama* (Method of Computing Eclipses), Acyuta Pisaradi suggests improvements in methods of calculation of eclipses.

16

India in Space: A Remarkable Odyssey

The Dream and Realization of Space Flight

For thousands of years, humans have curiously gazed at the night sky and dreamt of travelling to space and explore the distant heavenly bodies there. But that long cherished dream became a reality only after they developed large rockets capable of carrying satellites and humans to space. After reaching space, those rockets were powerful enough to make satellites, robotic spacecraft or spacecraft carrying humans to either circle the earth or proceed towards the other worlds of our solar system. Besides satisfying the human urge to explore space, devices launched into space by humans have made our lives here on Earth easier and safer. Thus, benefits offered by space are truly revolutionary.

Now, let us understand the term 'space'. When we talk of space research or space flight today, the word 'space' refers to the region which is outside the Earth's atmosphere. Today, many scientists agree that space begins at an altitude of about 100km from the Earth's surface. Thus, all heavenly bodies including the sun, moon, planets, stars and galaxies are in space. Artificial satellites revolve round the Earth in space. Humans living in the huge International Space Station today are circling the Earth in space.

The Uniqueness of the Indian Space Programme

India is one of the few countries that have taken up the challenge of exploring space and utilizing space for the benefits of the common man. For this, the country has developed various technologies which few other countries have done.

India's achievements in space today are the result of the far-sightedness of Dr Vikram Sarabhai, one of the greatest sons of India. Sarabhai was a great dreamer and showed the path to realize those dreams. He had firm belief in the power of space technology to bring about rapid and overall development of India.

Professor Satish Dhawan, who succeeded Dr Sarabhai as the head of the Indian space programme, made immense contributions to the Indian space programme by assigning great importance to developing and mastering space technologies through indigenous efforts. He also laid emphasis on the involvement of the Indian industry to meet the needs of the country's space programme. Professor U.R. Rao, Dr K. Kasturirangan, Dr G. Madhavan Nair and Dr K. Radhakrishnan, who succeeded Professor Dhawan, have made their own unique contributions to the Indian space programme.

The Beginning

Though India today is considered as one of the prominent countries conducting many space activities, the Indian space programme began in a modest way with the formation of the Indian National Committee on Space Research by the Government of India in1962. The programme formally began on 21 November 1963 with the launch of a 28-feet long American 'Nike- Apache' Sounding Rocket from Thumba, near Thiruvananthapuram. It carried a small French payload (scientific instrument) to study the winds in the upper atmosphere. Sounding rockets are small research rockets that carry instruments to study upper atmosphere and space. They cannot launch satellites.

Launch of Nike-Apache Rocket

Nearly 50 years later, on 9 September 2012, India celebrated its 100th space mission. That historic mission was performed by India's Polar Satellite Launch Vehicle (PSLV-C21) which launched a French and a Japanese satellite, together weighing 750 kg very accurately into the required orbit. This shows as to how far India has travelled in space and has attained mastery over space technology.

PSLV-C21 launch, the 100th space mission of India

During the 1960s, India conducted space research mostly through sounding rockets. But the country also established a ground station to conduct various useful experiments using communication satellites.

India's Space Capabilities

Indian Space Research Organization, which is widely known as ISRO, is the agency which implements the country's space programme on behalf of India's Department of Space. ISRO came into existence in 1969, the same year when humans set foot on the moon for the first time.

Various centres of ISRO are now spread all over India. They include Vikram Sarabhai Space Centre (VSSC) situated in Thiruvananthapuram, which designs huge rockets capable of launching large satellites. In the same city is the Liquid Propulsion Systems Centre (LPSC) that develops liquid rocket engines and the more efficient and highly complex cryogenic rocket engines.

Bangalore can be called as the space city of India. It has got many space-related facilities including the ISRO Satellite Centre (ISAC), which builds Indian satellites. The famous Chandrayaan-1 spacecraft that conclusively discovered water on the moon was built here. Moreover, the ISRO headquarters and the Department of Space, which steer the Indian space programme, are in Bangalore. ISRO's Space Applications Centre at Ahmedabad develops payloads for satellites.

National Remote Sensing Centre (NRSC) is another important centre of ISRO. It is situated in Hyderabad and performs the important task of receiving the pictures sent by India's remote sensing satellites in the form of radio waves.

The island of Sriharikota in the Bay of Bengal has ISRO's Satish Dhawan Space Centre and it is the space port of India. Sriharikota lies about 80 km to the North of Chennai and lies in the Nellore district of Andhra Pradesh. This is the place from where 38 Indian built rockets have lifted off (as on April 2013) and have travelled towards space. It also has facilities to assemble huge satellite launch vehicles as well as launch and track them.

Into the Satellite Era

In the 1970s, India took a giant leap into space with the launch of its first satellite Aryabhata. Named after the famous ancient Indian astronomer, the satellite weighed 360 kg at the time of its launch.

Aryabhata looked like a large box with many faces (polyhedron). The satellite's entire body was covered with solar cells that generated electricity when they were exposed to sunlight. Aryabhata was built to understand the challenges

Aryabhata Satellite

involved in building a sophisticated device like a satellite. Nevertheless, it was a scientific satellite as it carried three scientific instruments to study the sun, distant heavenly bodies and the Earth's ionosphere. On 19 April 1975, a Soviet Rocket carried Aryabhata into a 600 km high orbit. Aryabhata laid a firm foundation to India's satellite programme. With this, Indian scientists moved ahead and began building Bhaskara 1 satellite, which was intended to conduct Earth observations.

Bhaskara 1 was also launched by a Soviet rocket into orbit in June 1979. It carried a TV camera for taking the pictures of Earth's surface. Besides, it carried a microwave radiometer, an instrument to study the Earth. A similar satellite, Bhaskara 2, was launched in 1981 on another Soviet rocket. The experience gained during the Bhaskara programme was the foundation stone for the later Indian Remote Sensing (IRS) satellite programme.

Geosynchronous orbit lies at a height of about 36,000 km from the surface of the Earth, which of course, is almost one-tenth of the way to moon. A satellite circling the Earth at that height takes 24 hours to go round the earth once. Since the

Earth also takes 24 hours to spin around its own axis once, the satellite's speed is synchronized with the Earth's spin, hence the name 'geosynchronous orbit'. A satellite in such an orbit placed over the equator is called a geostationary satellite.

In the late 1970s and early 80s, ISRO scientists also built the Rohini series of satellites and gained additional experience in building satellites. Rohini satellites were launched by India's first indigenous launch vehicle SLV-3.

Satellite as a Catalyst of Development

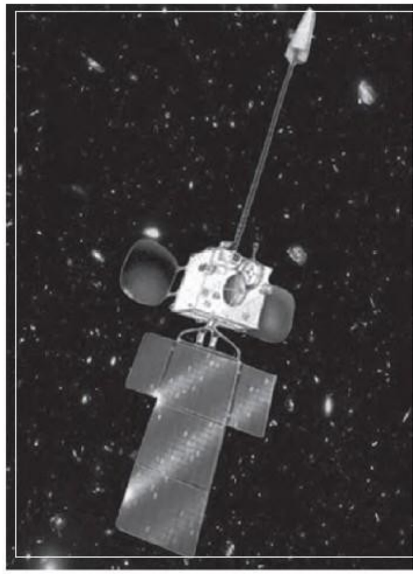
In the early 1980s, the power of the artificial earth satellites to bring about phenomenal growth in India's television broadcasting and telecommunication sectors was glaringly demonstrated by a satellite called Indian National Satellite -1B (INSAT-1B). It was the second satellite in the INSAT-1 series. Because of the failure of its predecessor INSAT-1A, Indian space scientists were very much concerned, but INSAT- 1B brought in a major revolution in India's telecommunications, television broadcasting and weather forecasting sectors in a very short and unthinkable time.

INSAT - 1B

INSAT-1B facilitated the rapid expansion of essential telecommunication facilities like telephone, telegraph and fax across the country. Through INSAT-1B, mountainous, inaccessible and isolated regions of the North and Northeast India as well as island territories of Andam ans and Lakshadweep could be accessed easily.

Enhanced Services from our INSATs

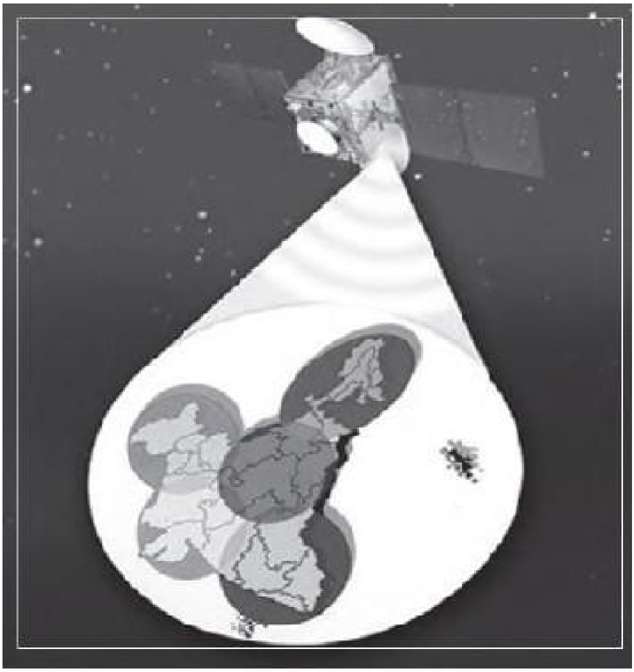
The indigenously built INSAT-2A had one and a half times the service capability of the earlier INSAT-1 satellites and weighed almost twice at launch! Like INSAT-1 satellites, it too carried transponders for telecommunications, TV broadcasting and an instrument for weather observation. Besides, it carried another special instrument capable of sensing distress signals sent by special transmitters in vehicles and even held by individuals in danger.


INSAT - 2A

As time progressed, three more satellites were launched in the INSAT-2 series. They also carried 'mobile service transponders' to facilitate communication between vehicles and stationary users.

Special mention has to be made about GSAT-3 or EDUSAT, which was a satellite dedicated to the field of education. It facilitated the provision of quality educational services to rural students through ISRO's tele-education programme. Today, there are about 56,000 classrooms in the EDUSAT network.

Another such service provided by INSAT/GSAT satellites today is the telemedicine service. ISRO's telemedicine programme links doctors at super specialty hospitals in urban areas to patients at rural hospitals through audio/video facilities via satellite. One more interesting aspect of GSAT series of satellites is that GSAT-8 and 10, launched in 2011 and 2012, respectively, carry a 'GAGAN' transponder that broadcasts navigation signals. GAGAN programme boosts the quality,



EDUSAT - Concept

reliability and availability of navigation signals broadcast by American GPS series of navigation satellites. In addition to communication satellites, India has built another type of satellite called the remote sensing satellites. In fact, India has emerged as one of the world leaders in the field of remote sensing satellites.

Eyes in the Sky

So, what are these remote sensing satellites? What do they do? How are they useful to the society?

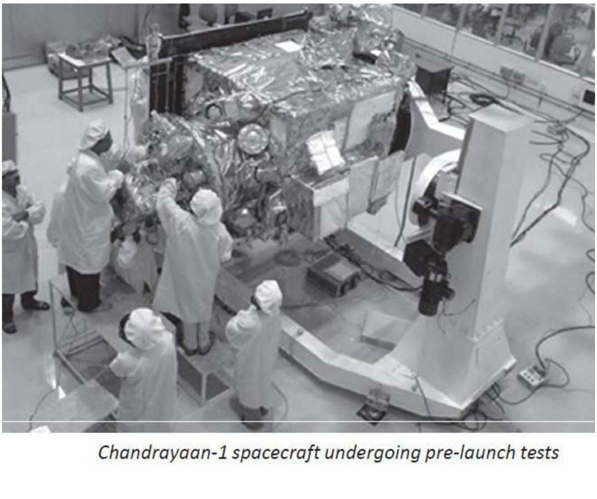
To understand this, let us begin with the word 'remote sensing'. When we say remote sensing, it means that it is a method of collecting information about an object or a phenomenon without having any physical contact with it. Satellites carrying very sensitive cameras or radars and circling the Earth in space hundreds of kilometres high are known as remote sensing satellites. They transmit the pictures to ground stations through radio. Such pictures, taken in different colours or in black and white, show a lot of details. Trained scientists can manipulate and analyse those pictures in computers to understand several facts, like estimating the net sown area, underground water availability, mineral deposits through rock colour, environment assessment, pollution levels, wasteland development, and so on.

Quenching the Thirst for Knowledge

Chandrayaan-1 orbiting the moon, in an artist's view

Communication satellites, weather satellites and remote sensing satellites are satellites that make our life easy, interesting and safe. In addition to this, ISRO scientists have built scientific satellites that quench the human thirst for knowledge, especially to understand our universe.

But the satellite or to be more precise the spacecraft which revealed the prowess of Indian scientists to efficiently explore space was Chandrayaan-1. Since



Chandrayaan-1 spacecraft undergoing pre-launch tests

Chandrayaan-1 went towards some other heavenly body instead of permanently circling the Earth, it is appropriate to call it a spacecraft rather than a satellite.

Chandrayaan-1 demonstrated many things including India's ability to do meaningful science at low cost, its ability to assume leadership in a cooperative space venture and develop the essential technology within stipulated time. Chandrayaan-1 made the outside world to look at India with enhanced respect and galvanized student community within India. It became a prominent milestone not only in the history of Indian space programme, but in the history of India itself.

One of the main objectives of Chandrayaan-1 was to further expand the knowledge about the moon, make more progress in space technologies, especially by decreasing the various internal 'organs' of a satellite or a spacecraft and provide challenging opportunities to India's large younger generation of scientists to conduct research about the moon.

Having proved India's ability to successfully explore another heavenly body, Chandrayaan-1 collected massive

An ISRO Scientist readying Moon Impact Probe of Chandrayaan-1 amount of scientific data (information), including pictures. Chandryaan-1 had detected water molecules on the moon. This was a path-breaking discovery indeed!

32 metre antenna at Byalalu that communicated with Chandrayaan-1

Before Chandryaan-1 went to moon, scientists were not certain about the presence of water on the moon. Thus, it was India's Chandrayaan-1 which made a major discovery about the moon. Along with this, scientists were able to sense the height and depth of various features on the lunar surface. Chandrayaan-1 thus became a symbol of India's success in space.

Bringing Back from Space

Another remarkable achievement of ISRO is related to bringing back an object from space safely. The experiment which was performed in this regard was called Space Capsule Recovery Experiment-1 (SRE-1). The 550 kg SRE-1 capsule carrying two experiments was launched on 10 January 2007 in PSLV and the following 12 days, it circled the Earth at about 600 km height. Thus, the very first attempt of India to bring back a device which it had launched into space earlier, was a great success.

SRE-1 being recovered over Bay of Bengal

Launch of 20 satellites through a single rocket

An Example of Frugal Engineering

ISRO crossed a milestone on 22 June 2016 by launching 20 satellites through a single rocket. It crossed its own record of launching 10 satellites in a single mission. ISRO is second to Russian rocket launching a record of 37 satellites in a single mission in 2004. In this major milestone mission, besides the primary Cartosat-2 series satellite, the PSLV C-34 rocket launched two satellites from Indian Universities (Sathyabhama University, Chennai and College of Engineering, Pune) and 17 foreign satellites including one for a Google Company. The 725.5 kg Cartosat- 2 series of satellite will be for Earth observations and its imagery would be useful for cartographic applications, urban and rural applications, coastal land use and regulation and utility management like road networking.

There are 35 Indian satellites in the orbit and about 70 satellites are needed in the next five years, besides the contracts signed with foreign companies. Hence, ISRO will go for more multiple launch missions than single mission.

Indian Space Programme is one of the important sources of foreign revenue. ISRO's commercial branch generated a revenue of about Rs 1800 crore during the last fiscal year ,and a major share of revenue was obtained by leasing out transponders. During 2016–17 more multiple satellite launching will take place from Sriharikota.

Indian Space Programme is attractive to foreign firms since the mission has low budget in comparison with those of the other countries. Engineering programme with minimum budget providing maximum gain is called frugal engineering. Indian Space Programme is the best example of frugal engineering.

The success of Chandrayaan mission initiated the quest for Mars through the Mars Orbitor Mission or the Mangalyaan. India became the only country to orbit Mars in the first attempt. The success of Mangalyaan put India on the elite club of nations to have achieved interplanetary missions.

The successful testing of air-breather propulsion system and the scramjet rocket engine has put India among the space technology giants of the globe. With Antrix Corporation bagging deals of foreign satellite launches, it is certain that in future ISRO is set to rise as the most sought after governmental space agency.

17

Discovery of Gravitational Waves—The Indian Contributions

One of the landmark discoveries of the twentieth and twenty-first centuries so far is the discovery of Gravitational Waves (GW). The existence of GW was predicted exactly 100 years ago by Albert Einstein based on his General Theory of Relativity. It is interesting to know that he did not believe that the GW will be discovered in the laboratory. Why? It is because the amplitude of the GW will be so small (10^{-21}m) that no experiments will be able to measure this small displacement, corresponding to about 1 millionth of the diameter of proton.

The beauty of the theory made the experimentalists design appropriate experiments to detect such a small displacement. For the last 25 years, about 1000 scientists from more than 25 countries are actively involved in this task. In this team, there are 37 Indian scientists working in various academic and research institutions in India. On 14 September, 2015, scientists were able to detect the arrival of a GW that originated about 1.3 billion years ago. They were able to observe GW using the facilities at two Laser Interferometer Gravitational Observatories (LIGO) in the US. They got the wave pattern exactly as predicted by Albert Einstein using his General Theory of Relativity.

Einstein showed that the space time surrounding a massive object is curved. And any particle moving in the vicinity of this object will trace a curved path instead of a straight line. The curved path taken up by the particle will appear as though it is being attracted by a force from the massive object. This generates what is called gravitational field. The curvature of the space surrounding a massive object will depend on the mass of the object. Any significant event in the universe will generate disturbances in the gravitational field and will produce GW. There are 37 Indian scientists from IISER Thiruvananthapuram and Kolkata, IIT Ahmedabad, TIFR, Institute of Mathematical Sciences, Chennai, Inter University Consortium for Astronomy and Astrophysics (IUCAA) Pune , Raman Research Institute , Bangalore and Indian Institute of Science, Bangalore, who are active participants in this global initiative of LIGO experiments.

The machines that gave scientists their first-ever glimpse at GW are the most advanced detectors ever built for sensing tiny vibrations in the universe. The two US-based underground detectors are known as the Laser Interferometer Gravitational-wave Observatory or LIGO for short. India is aiming to get the world's third LIGO at an estimated cost of 1,000 crore. As part of the ongoing Indo–US cooperation in science and technology, America will provide India with nearly $140 million worth of equipment. Professor C. S. Unnikrishnan from TIFR is the leader of Indian LIGO experiment. He is one of the 137 authors of the research paper published in *Physical Review Letters* in February 2016. It is hoped that the Indian LIGO will be functional within a couple of years.

The GW opens up another window for astronomy. The observatory will be operated jointly by IndIGO and LIGO and would form a single network along with the LIGO detectors in the USA and Virgo in Italy. The design of the detector will be identical to that of the Advanced LIGO detectors in the USA.

18

Discovering Samgamagrama Madhavan

Introduction

It is without doubt that mathematics today owes a huge debt to the outstanding contributions made by Indian mathematicians over many hundreds of years divided into ancient (Apastamba, Baudhayana, Katyayana, Manava, Panini, Pingala and Yajnavalkya); classical (Vararuchi, Aryabhata, Varahamihira, Brahmagupta); medieval (Narayana Pandita, Bhaskaracharya, Samgamagrama Madhavan, Nilakanda Somayaji, Jyestadeva, Acyuta Pisaradi, Melpathur Narayan

Bhattathiri, Sankaravarman); and modern (Srinivas Ramanujan, Harish Chandra, Narendra Karmakar S. Chandrasekhar, S.N. Bose) periods. The beautiful number system (zero and decimal system) invented by the Indians on which mathematical development has rested is complimented by Laplace. '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. It was Einstein who said we should be grateful to Indians who taught us how to count.'

While the rest of the world was in the dark ages, India made strides in mathematics and holds a 3000-year legacy through the works of Sulbakaras (800–600 BCE), Aryabhata, Varahamihira, Brahmagupta, Bhaskaracharya, Samgamagrama Madhavan, Nilakanda Somayaji, Jyestadeva, Sankaravarman extending to Srinivasa Ramanujan, S N Bose, Harish Chandra Prasanta Chandra Mahalanobis and reaching to the current period of Narendra Karmakar, Jayan Narlikar, S.R. Srinivasa Varadhan, E.C.G. Sudarsan and Thanu Padmanabhan.

Discovering Sangamagrama Madhavan

Of all the mathematicians of the medieval period, the name of Sangamagrama Madhavan is the most important who founded a continuous chain of the *guru–shishya parampara* from fourteenth to eighteenth century, which is generally referred as the Kerala School of Mathematics. Sangamagrama Madhavan and his school were known to the Western world through the series of papers published by Mr Charles Whish during 1834 in the journal called *Transactions of Asiatic Society of Great Britain and Ireland*. One of the members of the Kerala School, namely, Jyestadeva needs a special mention. While the rest of the scholars wrote their works in Sanskrit, Jyestadeva wrote his book *Yukti Bhasha*, a treatise in mathematics and astronomy, in Malayalam to provide wider accessibility of the knowledge.

Place of Birth and Period of Sangamagrama Madhavan

The place of birth of Sangamagrama Madhavan can be known from the thirteenth sloka of his only surviving book, *Venuaroham*, which runs as follows:

Bekuladhishtitatwena viharoyo visishyate
Grihanamanisoyam syannigenamanimadhava.

Madhavan belongs to the house described as the *bekuladhishtita vihar* or in Malayalam *Iranji (Bakulam) Ninna Palli*. Even to this date there is a house named Iringatappally in Kallettunkara near Iringalakkuda. Ulloor describes Sangamagrama Madhavan as belonging to Iringatappally house in Sangama grama (village of Sagameswara, diety of Koodal Manikya Temple-Iringalakkuda). From the writings of his disciples, the period of his life time can be fixed as 1350 –1425, three hundred years before the life time of Newton, Gregory and Leibnitz.

Some of the main Contributions of Sangamagrama Madhavan

We know that one of the major contributions of Indian mathematics is the concept of zero and the decimal number system. One cannot pinpoint to any particular person to the discovery of zero. The concept was prevalent during the Vedic periods. Another important valuable contribution to the world of mathematics is the concept of infinity imported to mathematics credit of which goes to Sangamagrama Madhavan. He was able to show that one can get a finite value by adding infinite terms or a finite value can be expressed as infinite series. It is quite interesting to note that both the concepts of zero and infinity are contributions of India which influenced the Indian systems of philosophy to a great extent. Rudimentary concept of infinity could have been there in the mind of Indian philosophers. That is why we have the sloka in *Isavasyopanishad:*

Poornamada, poornamidam Poornad Pooranm udachate,
Poornasya poornamadaya Poornamevavasisshyate

meaning that is infinite, this is infinite; when infinity is added to infinity, infinity remains and when infinity is taken from infinity, infinity remains. This is true for zero also. No wonder that Indians represents the infinite extension of the sky with number zero in Bootasankhya representation of numbers. Sangamagrama Madhavan was the pioneer to invent the infinite series in trigonometry for sine and cosines of angles.

Madhavan used the infinite series formula to evaluate the value of π correct to 11 decimal places 3.14159265359. Recent studies show that calculus, an important branch of modern mathematics, had originated in the Kerala School well before the time of Newton and Leibnitz. In Jyestadeva's *Yukti Bhasha* which dates hundreds of years before the time of Newton and Leibnitz, we find the formulae for integration and differentiation. It is said that *Yukti Bhasha* is the first textbook in the world dealing with calculus. Another wonderful contribution of Sangamagrama Madhavan is his table for sine of an angle from 0–90 degrees at an interval of 3.75 degrees. He was also an expert in spherical geometry and was usually called '*Golavid*' (an expert in Spherical Geometry).

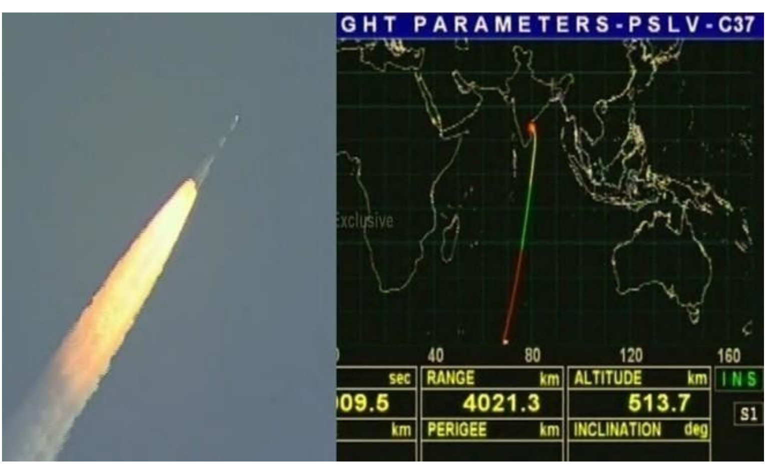
19

Latest Achievement July 2016 Onwards

1. ISRO sets space record with successful PSLV launch of Cartosat-2 and 103 other satellites

Indian Space Research Organisation (ISRO) made India proud when it created a world record by launching 104 satellites in a single rocket. The satellites were launched from Sriharikota of Andhra Pradesh, and it has made India the first country to launch such a huge number of satellites together.

Indian Space Research Organization (ISRO) made India proud when it created a world record by launching 104 satellites in a single rocket. The satellites were launched from Sriharikota of Andhra Pradesh, and it has made India the first country to



launch such a huge number of satellites together. India, apart from outdoing its own previous achievements, has also moved ahead of Russia by a long margin. Russia had held the record earlier, for the most satellite launches in a single mission and the number was 37. Russia had achieved that feat in 2014. This record is followed by the US space agency NASA, which has launched 29 satellites in a single mission. When ISRO had put into earth's orbit 10 satellites on the PSLV-C10 on June 2008, it had created a world record. But it was subsequently broken many times by Russian and American rockets.

ISRO had commenced the 28-hour countdown for the launch on Tuesday, which was the shortest for any Polar Satellite Launch Vehicle ever. The PSLV-37 is ISRO's workhorse and on its 39th mission, carried the 104 satellites. This single mission launch is India's second attempt and the first time it had launched 23 satellites in one go. That mission was launched in June 2016. India's most powerful rocket the XL variant, which was used in the momentous Chandrayaan and during the Mars Orbiter Mission (MOM) has been used by ISRO in this launch too. In the launch, 100 satellites are foreign made, including some from the US, and rest of the 3 belong to India, which in itself is a big achievement. Earlier, ISRO had reportedly planned

to launch 83 satellites by January end. But later 20 more were added. PM Modi's pet South Asian satellite project is scheduled to be launched in March 2017 and it will be a part of GSAT-9, that will be launched in March 2017. Meanwhile, Modi congratulated to the space organisation for the successful launch of PSLV-C37 and CARTOSAT satellite together with 103 nanosatellites.

This was ISRO's first space mission for the year 2017, and the most complicated mission it has ever carried out. Prime Minister Narendra Modi and President Pranab Mukherjee congratulated the space agency for the historic event that significantly boosts India's space programme.

The PSLV-C37/Cartosat2 Series satellite mission included the primary satellite (Cartosat-2) and 101 international nano satellites. It also launched two of its own nano satellites, INS-1A and INS-1B.PSLV first launched the 714 kg Cartosat-2 Series satellite for earth observation, followed by the INS-1A and INS-1B, after it reached the polar Sun Synchronous Orbit. It then went on to inject 103 co-passenger satellites, together weighing about 664 kg, in pairs.

2. ISRO drones help to map disasters in north-east

The Indian Space Research Organization (ISRO) is using drones to map disasters in north-eastern States by collecting land details and add it to data from remote sensing satellites. In this regard, ISRO's Shillong-based North-Eastern Space Applications Centre (NE-SAC) has tested unmanned aerial vehicles (UAVs) to map various problems and disasters.

Key facts NE-SAC has taken the initiative for design and assembling of UAVs for various applications to assess several regional problems in the northeast region. UAVs can perform efficient surveys for disaster-prone or physically inaccessible areas. It can undertake quick damage assessment of floods, landslides and earthquakes and enable timely relief measures.

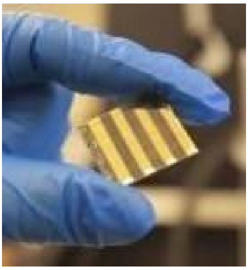
These drones providing ground-based details which are generally combined with data from ISRO's remote sensing satellites.

Recently they were used for to map the area affected by landslides along NH40, Meghalaya's life line. It also gave the extent of damage caused to pest-infested paddy fields in Naramari village of Assam.

About North-Eastern Space Applications Centre (NE-SAC)

NE-SAC is a joint initiative of Department of Space (DoS) and North Eastern Council. It was started in the year 2000. It is located at Umiam (near Shillong), Meghalaya.It aims to provide developmental support to the North Eastern region using Space technology-based communication and technology.Its mandate is to develop high technology infrastructure support to enable NE states to adopt space technology for their development. NE-SAC provides developmental support by undertaking specific application projects using remote sensing, satellite communication, GIS and conducts space science research.

3. IISc researchers develop low-cost, sensitive CO sensor



Indian Institute of Science (IISc) researchers from Bengaluru have developed a highly sensitive, low cost nanometre-scale carbon monoxide (CO) sensor, with potential applications in environmental pollution monitoring. The sensor was developed using novel fabrication technique that does not involve costly and time consuming lithography technology.

Carbon Monoxide (CO)

CO is a colorless, odorless gas. It is harmful when inhaled in large amounts The greatest source of CO is internal combustions (IC) engines of cars, trucks and other vehicles or machinery that burn fossil fuels. Breathing high concentration of CO reduces the amount of oxygen that can be transported in the blood stream to critical organs like the heart and brain.

Key Facts

The nanometer-sized sensor was made using zinc- oxide (ZnO) nanostructure on a silicon wafer substrate. Tiny polystyrene beads were also used on the wafer. These beads were first added on the on the oxidised silicon wafer arrange themselves into what is called a hexagonal close-packed structure.

Reasonable level of vacuum is maintained between the wafer and beads. When a high voltage is applied, it etches away the surfaces of the beads until a gap of desired thickness is formed between adjacent beads. Then ZnO is deposited on the system. This occupies the spaces between the beads, forming a honeycomb like nano-mesh that can function as a nanosenor.

Significance

The nanometre-scale CO sensor is able to detect a difference in CO level as low as 500 parts per billion (ppb). It can selectively respond to CO even in the presence of other gases. It also significantly cuts down the time and cost involved in making nanostructured gas sensors.

4. IISc scientists develop sensor to detect *E. coli* bacterium

A group of scientists at the Indian Institute of Science (IISc) has successfully designed a sensor to detect the presence of harmful E. coli bacterium in food and drinking water.

The sensor has been designed by the research teams of Dr Sai Siva Gorthi and Prof SundarrajanAsokan of Department of Instrumentation and Applied Physics and Robert Bosch Centre for Cyber Physical Systems, IISc.

The sensor is designed using a photo-sensitive optical fibre and is called a 'bare Fiber Bragg grating (bFBG) sensor', which is coated with antibodies specific to *E. coli*. When a beam of light comprising a band of wavelengths is passed through the bFBG sensor, it reflects one particular wavelength of light. When exposed to a sample in which e-coli cells are present, the e-coli cells bind specifically to the sensor.

5. Model to predict monsoon

Scientists at IISc have also proposed a new model to detect rainfall over localized land regions in real-time using satellite images.

Dr J Indu and Prof D Nagesh Kumar of Department of Civil Engineering, IISc, have developed the model from satellite microwave sensor data. Their work was recently published in the Hydrological Sciences Journal.

The team carried out their research in the Mahanadi basin area which is prone to large-scale flooding. Observations in such a diverse region can be used to improve the existing algorithms to detect rainfall, according to the researchers.

6. Captive flight trials of anti-radiation missile soon

Captive flight trials of an advanced, state-of-the-art Anti-Radiation Missile (ARM) are planned for April-May this year, and the maiden flight test by year-end by the missile technologists of the Defence Research and Development Organisation.

The air-to-surface tactical missile being developed by Defence Research and Development Laboratory (DRDL) will target the enemy's air defense capabilities by attacking radars and communication facilities. The range of the missile is 100 to 125 km and it will be mounted on combat aircraft Sukhoi (Su-30) and Tejas-Light Combat Aircraft. The missile picks up the radiation or signals of radars and communication facilities and homes on to the targets to destroy them.

According to DRDO sources, scientists will evaluate the performance of the seeker, navigation and control system, structural capability and aerodynamic vibrations during the captive flight trials. These will be followed by ground testing and the missile will be fired from Su-30 during the actual flight trial by year-end. Instead of thrust propulsion, the missile uses dual pulse propulsion system as in the case of LR-SAM. The dual pulse propulsion will widen the envelope as well as the engagement capability of the missile. After coasting the missile for the required duration by firing the first pulse, the second pulse will be initiated just before interception of the target or during the terminal phase, the sources added.

The entire missile is being developed indigenously, including the seeker. The missile will be inducted in about two years after conducting a number of developmental trials. Only a few countries, including the U.S. and Germany, have ARMs at present, the sources added. The dual pulse propulsion system could be configured with other air-to-surface and air-to-air missiles, the sources added.

Meanwhile, the induction of LR-SAM (Long Range Surface-to-Air Missile), jointly developed by India and Israel, will begin September-October this year. It was successfully test-fired from INS Kolkata to intercept an aerial target last year and the missile is slated to be launched from warships, INS Kochi and INS Chennai, for similar trials later this year.

7. Science Catches Up With Astrology: Planets Cause Quakes, Says New Study

Predicting earthquakes has always been an iffy science but a group of Indian experts claims to have found a possible way out. They have come up with a list of "earthquake-sensitive" days for 2016 and even claim that their predicted quake dates for January have been validated. A study by JeganathanChockalingam of the Birla Institute of Technology at Mesra in Ranchi and two co-authors found that there is very clear evidence of planetary configurations creating orbital perturbations on the earth, which finally results in an earthquake. Motivated by astrology, Chockalingam and his team wanted to test whether there is any possible link between earthquakes and planets. They started their observations seriously after the 2004 tsunami which killed thousands of people in India, Indonesia and Sri Lanka to understand planetary configurations and major earthquakes. The study says gravitational interactions among the bigger planets such as Jupiter, Saturn, Uranus, and Neptune create invisible resultant gravity vectors (IRGV) that act as an imperceptible planetary force when an inner planet crosses them. "Whenever our Earth crossed these IRGVs, there invariably were major earthquakes. Other inner planetary crossings showed similar results as well," says the study published in the latest issue of the International Journal of Advances in Remote Sensing, GIS and Geography.

Even simple two-planetary alignments were checked out for their contribution to earthquakes, the study said, adding that the researchers consistently identified a link between a particular planetary configuration and earthquakes. "Overall, the explanation capabilities of each possible configuration were critically crosschecked and we hope that the study will give a new dimension to the field of earthquakes, gravity anomalies and their prediction. Finally, the study predicted the sensitive days for 2016 and researchers may validate our concepts and results based on actual ground shaking," said Chockalingam. The authors visualised the solar system as a gravity lake having a lot of gravity waves (big and minor just like ocean), and that every planet travels across these waves during its orbit round the sun just like a ship travelling in the ocean. According to their assumption, these gravity waves can increase and decrease spatially and temporally. "All spatial locations of resultant gravity vectors (RGVs) resulting from all combinations of major planets were identified. The study revealed that whenever a planetary vector crosses those RGVs, a gravity ripple is created and it perturbs the earth's orbital path and hence alters the movement pattern on the surface of the earth as well as underground," the study said.

8. Two new species of Cycas discovered

Research conducted on Cycaspschannae, a lone tree found in the Acharya Jagadish Chandra Bose Indian Botanic Garden, West Bengal has revealed two new species of Cycas to the world. This discovery takes the total number of Cycas species found in India to 14.

Cycas

Cycas are one of the most ancient plants whose fossils date to the Jurassic period. They are often referred to as living fossils. They have evolved on the earth as the first seeded plants and they grow very slowly, adding only a few centimetres every year. Nearly 65% of Cycas are threatened. There are over 100 species of Cycas found across the globe.

Key Facts

Initial studies on the lone Cycaspschannae tree revealed that it was Cycas, a gymnosperm. Further research based on its anatomical and morphological characters led to the discovery of new species of Cycaspschannae and later Cycasdharmrajii in the Andaman and Nicobar Islands.

Cycasdharmrajii is characterised by the abnormal branching habit of its giant trunk and its swollen base. It has well-defined 10 to 28 hook-like structures in the apex of the mega sporophyll which makes it distinct from other

Cycas found in the country. Sporophylls are spore-bearing leaf-like female sex organ of the plant. The sporophylls of Cycaspschannae are characterised by the presence of two lateral horn-like structures.

9. Reliance Jio launches world's longest 100Gbps submarine cable system

MukeshAmbani led Reliance JioInfocomm has launched the Asia-Africa-Europe (AAE-1) submarine cable system. It is claimed to be world's longest 100Gbp technology-based submarine system.It stretches for over 25,000km from Marseille, France to Hong Kong. It will have 21 cable landings across Asia and Europe. Using it, Jio will continue to offer its customers the most exceptional high speed internet and digital service experience.

Key Facts

The AAE-1 project is a combination of leading telecom service providers from Europe, the Middle East and Asia. It will seamlessly link with other cable systems and fibre networks to deliver direct access to all global markets.It will feature diversified Points of Presence (PoP) in Asia (Hong Kong and Singapore), with three onward connectivity options in Europe (France, Ital and Greece). The cable system will pass through critical hubs, serving the demand for video centric data bandwidth that supports all types of communications, applications and content within India and beyond.

The advanced design and route of AAE-1 system will offer one of the lowest latency routes between Hong Kong, India, Middle East and Europe. Using it, Reliance Jio will provide the Network Operations & Management for AAE-1 Cable System.

Its Network Operations Center (NOC) will use a state of the art facility in Navi Mumbai.

New Terminologies in Science & Technology

1. Nirbhay = sub-sonic cruise missile Nirbhay is India's equivalent of Tomahawk, a long-range, sub-sonic cruise missile, developed by the U.S. This is developed by Defence Research and Development Organisation (DRDO) will travel at a sub-sonic speed (less than the speed of sound).
2. NAG = 'fire and forget' anti-tank missile. It can destroy enemy tanks four km away.
3. NAMICA = Nag Missile Carrier
4. It is a vehicle to carry and launch NAG missles
5. Helina = the helicopter-fired version of Nag. Helina = Helicopter + Nag
6. LAHAT = Laser Homing Attack or Laser Homing Anti-Tank missile anti-tank missile, will be used in the upgraded Arjun battle tanks.
7. Tropex-2012 = theatre-level readiness and operational exercise conducted by the Indian Navy. To test new platforms, weapons sensors, communication systems and tactics in order to optimise the network combat power of the fleet.
8. Shoor Veer = Combat exercise in the Thar Desert in 2012 To test Army's operational readiness to undertake swift multiple thrusts across the border. Army and IAF tested new battle fighting concepts with real time pictures of the battle zone provided to a centralized command using fighter jets, unmanned aerial vehicles and attack helicopters National Large Solar Telescope (NLST) = world's largest solar telescope set up by the Department of Science and Technology, in Ladakh. It aims to study the sun's microscopic structure.
9. RISAT 1 = RISAT 1 is India's first radar imaging satellite. It can scan the earth surface during both day and night under all-weather condition. It will help in paddy monitoring and

management of natural disaster like flood and cyclone.

10. ISRO's 100th mission = Using PSLV-C21 rocket, ISRO launched two foreign satellites SPOT 6 : French satellite Proiteres: Japanese micro satellite From Satish Dhawan Space Centre, Sriharikota in Andhra Pradesh
11. Project Glass = a research and development program by Google. It resembles a pair of normal eyeglasses where the lens is replaced by a heads-up display. Project Glass is a wearable computer that provides information not through a screen, but rather through your "eyes." It gives you data about your surroundings without the need to whip out your smartphone and know what to search. For example, if you go into a bookstore, Google Glass will be able to provide you with an indoor map of the place, and lead you to your desired book.
12. Glivec := blood cancer drug Novartis is fighting a patent case in India for this drug. Treatment of Glivec costs Rs.1,20,000 per month per patient. But Novartis maintains they give it free of cost to the needy patients.

₹250.00

ISBNXXXXXXXX