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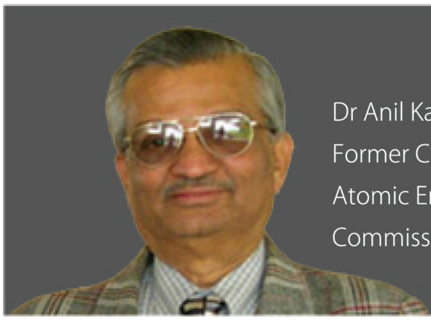

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ENROLL TODAY

HURRY!

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"It is India that gave us the ingenious method of expressing all numbers by means of ten symbols, each symbol receiving a value of position as well as an absolute value; a profound and important idea which appears so simple to us now that we ignore its true merit. But its very simplicity and the great ease which it has lent to all computations put our arithmetic in the first rank of useful inventions; and we shall appreciate the grandeur of this achievement the more when we remember that it escaped the genius of Archimedes and Apollonius, two of the greatest men produced by antiquity."

Pierre-Simon Laplace (Quoted in Will Durant, "Our Oriental Heritage, Vol. I of the "Story of Civilization", 11 volumes, Simon and Schuster, New York 1954.

"Almost exactly twelve hundred years ago, Abdullah Al Mansur, the second Abbasid Caliph celebrated the founding of his new capital, Baghdad, by inaugurating an International scientific conference. To this conference were invited Greek, Nestorian, Byzantine, Jewish as well as Indian scholars. The theme of the conference was observational astronomy. Al Mansur was interested in more accurate astronomical tables than available then. He wanted, and he ordered at the conference, a better determination of the circumference of the Earth. No one realised it then but there was read at the conference a paper destined to change the whole course of mathematical thinking. This was a paper read by the Indian astronomer, Kankah, on numerals, then unknown to anyone outside India".

----- Abdus Salam in a paper presented at the International Conference on Low Energy Physics, Dhaka), 16-25 January 1967

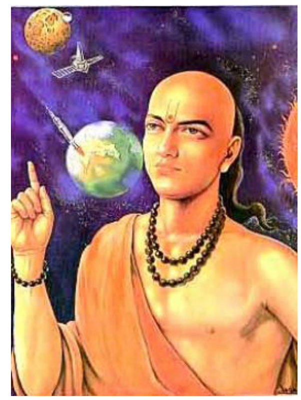
The Sulba-sutras

The Sulba-sutras form part of the Kalpa-sutras. They are the oldest Indian works on geometry, irrational numbers and other mathematical topics. The word sulba (also spelt as sulva) means a 'cord', a 'rope' or a 'string' and its root sulb signifies 'measuring' or 'act of measurement'. Thus the Sulba-sutras may be defined as a collection of rules concerning measurements with the help of a cord. The Sulba-sutras the compositions, in the form of manuals for construction of altars and fire-platforms enunciated various geometric principles.

The earliest Sulba-sutra, the Baudhayana Sulvasutra, was composed during 600 -500 BC. This is also the largest of all the Sulba-sutras. It contains 525 sutras and they are divided into three chapters. The first chapter contains 116 sutras and it describes geometrical propositions needed for the construction of altars, their relative positions and spatial magnitudes. The second chapter containing 86 sutras describes with various fire-altars (agnis) and their spatial relationships. The third chapter contains 323 sutras and it deals with kamya agnis or sacrificial altars designed to attain desired goals.

The other three Sulba-sutras are the Manava Sulba-sutra, the Apstamba Sulba-sutra and the Katyayana Sulba-sutra. There are other minor sulba-sutras but they do not throw any additional light.

The Pythagorean Theorem was discussed over two hundred years before Pythagoras by the sulbakars. In fact all the four major extant Sulba-sutras contain clear statement of the theorem. They studied the problem of finding a circle with the same area as a square and vice versa. They also achieved a good approximation to the square root of 2.



Aryabhata is regarded as the greatest astronomer of ancient India "The importance of Arybhata lies in the fact the he probably was in the vanguard of the new astronomical movement resulted in the recasting of this branch of knowledge about fifth century AD. Piecemeal efforts might have started earlier, as is evident from Varahamihira's account of five siddhantas, and before and about the time when Aryabhata flourished there were certainly astronomers of repute who were variously engaged in reforming astronomy, but little is known about their contributions as their works have not survived. As matters stand, the Aryabhatia is the earliest astronomical text bearing the name of individual of the scientific period of Indian astronomy. Moreover, his place at the head of this movement is assured by the great influence his works and teachings wielded among astronomers of subsequent ages, and by the existence of a long line of followers who propagated his views through excellent commentaries."

S. N. Sen in "A Concise History of Indian Astronomy", D. M. Bose, S. N. Sen and B. V. Subbarayappa (Eds), Indian National Science Academy, New Delhi, 1989.

Ancient Indians had shown great proficiency in astronomy since Vedic times. Aryabhata described his astronomical ideas in his celebrated treatise Aryabhatiya (also called Arybhatiyam). This work laid the foundation of Aryabhata Siddhantic School of Astronomy. Aryabhata is one of the most important figures in history of India's astronomy. Commenting on the status of Indian astronomy at the time of Aryabhata, M. L. Sharma of the Sampurananda Sanskrit University, wrote: "…at the time of Aryabhata, Indian astronomy had reached the state of development where it possessed all mathematical, astronomical and instrumental knowledge which was ideal for the higher study of astronomy. To reach that state of development a lot of time was needed. So the beginning of Siddhanta astronomy in India must have taken place much earlier than it is usually supposed. It may be said that Indian astronomy was facing problem also at the time. In this background of astronomical knowledge we enter the period of Aryabhata."

Aryabhata was the first Indian astronomer to propose the rotation of Earth to explain the daily westward motion of the stars in the sky. He stated that rising and setting of the Sun, the Moon and other heavenly bodies are due to the relative motion caused by the Earth's rotation about its axis once a day. He introduced many new concepts such as an alphabetical system of expressing numbers, rules for extraction of squares and cube roots, construction of trigonometric sine tables and eccentric-epicentric model of planetary motion. He worked out the value of pi as 3.1416 for the first time in India, which is correct to the first four decimal places. He knew that the value given by him was 'asanna', that is, approximate. This is because pi is irrational or incommensurate. He also believed that eclipses were caused by the shadows

Moon and the Earth and not by Rahu-Ketu as it was believed. Ayabhata was aware of the spherical shape of the Earth.

Almost nothing is known about his life. His name is sometime spelled as 'Aryabhatta'. It may be noted there is another astronomer of the name Aryabhata who lived in tenth century AD. To distinguish the two, they are called Aryabhata I and Aryabhata II (c. 950). Aryabhata II was basically a compiler and he was adherent to orthodox views. Arabic scholars referred to Aryabhata as arjbhar or ajabhar. Abu Raihan Muhammad ibn Ahmad Al-Biruni (973-1048) (usually referred to simply as Al-Biruni) wrote: "They (Alfazari and Y'kub) apparently did not understand him and imagined that Arybhata means a 'thousand part''". Al-Biruni, a mathematician and astronomer of some repute came to India in the eleventh century. He travelled to India during 1017 and 1030 as a political hostage with Mahmud of Ghazni, the first Sultan of the Ghaznavi dynasty in Afghanistan, in the course of the latter's invasion of India.

Earlier scholars thought that Aryabhata was either born in Kusumpura, a suburb of Pataliputra (modern-day Patna) or taught there. Some scholars identified Kusumpura with Pataliputra. Aryabhata himself in one the verses of Ganitapada stated: "…he (Aryabhata) sets forth in his work the science which is held in high esteem at Kusumpura." However, recent studies on the works of Bhaskara, the greatest exponent of Aryabhata's system of astronomy and other medieval commentators of Aryabhata, reveal that earlier held belief is not correct. In these works, Aryabhata is often referred to as 'asmaka' that is one who comes from Asmaka region located in southern India, possibly in modern-day Kerala, and his work Asmaka sphutatantra. Another fact which supports the view that Aryabhata came from Kerala is that most of the commentaries of Aryabhatiya and works based on it have come largely from southern India, especially from Kerala. Further, majority of the astronomers belonging to Aryabhata school come from South India.

Aryabhata wrote Aryabhatiya in AD 499 at the age of 23, which gives AD 476 as the year of his birth. Bhau Daji (1822-1874), a famous physician and an Indologist based on his serious studies published a paper on Aryabhata in the Journal of the Asiatic Society in 1865. A revised Sanskrit version of Aryabhatiya was published by J. H. C. Kern in Leiden, Holland, in 1874. A French translation was published in 1879. A definitive Enflish translation of this work was prepared by Walter Eugene Clark, A Sanskrit professor of the Harvard University and it was published by the Chicago University Press in 1930. It may also be noted that Aryabhatiya was translated into Latin in the 13th century by an Italian mathematician.

According to Clark, Aryabhatiya is "the earliest preserved Indian mathematical and astronomical text bearing the name of an individual author, the earliest Indian text to deal specifically with mathematics, and the earliest preserved astronomical text…of Indian astronomy." There were many other works of astronomy written before Aryabhata, but we do not know the names of their authors with certainty.

Aryabhatia is written in verse couplets. It is a small work containing about 121 slokas or stanzas. It is divided into four sections called padas, namely, Gitikapada, Ganitapada, Kalakriyapada and Golapada.

The Gitikapada is the shortest of the four sections. It has 13 stanzas including the verses meant for dedication and conclusion. Out of the 13 stanzas 10 are in Gitika metre and that is why it is also known as Dashagitika. "One who knows these verses, one who knows the movements of planets and nakstras, goes much beyond them and attains the Absolute Brahma", says the author. In this section the basic definitions and important astronomical parameters and tables are given. It also explains the rules of a unique method of writing numbers in Sanskrit alphabets.

The Ganitapada deals exclusively with mathematics. It has 33 stanzas. The topics covered in this section include varga (squares), Ghana (cubes), vargamula (square-roots), ghanamula (cube-roots), area of a triangle and volume of a prism, area of a circle and volume of a sphere, area of visamacaturasa (quadrilateral), circumference of a circle, bahu (the base of a right-angled triangle), karna (hypotenuse of the right-angled triangle), trairasika (rule of three), vysta (reverse rule of three) and kuttakara-ganita (the theory of pulveriser).

The remaining two sections Kalakriyapada and Golapada deal with astronomical principles and methods of computations in very condensed form. The section Kalakriyapada (Kalakriya means reckoning of time) has 25 stanzas. It includes topics like 'division of time and the circle, definitions of solar year, lunar month, civil day, sidereal day, intercalary months, omitted lunar days, planetary orders and movements, the eccentric-epicycle models, use of these models for the calculations of the true planetary positions from the Earth' and other related topics.

The Golapada is the longest section and it is for this section Aryabhata is most famous. Gola means sphere. It has 50 stanzas. In this section Aryabhata explains the methods of representing planetary motions in a celestial sphere. He also defines such terms like prime vertical, meridian, horizon, hour circle, equator, parallax, and ecliptic. He discusses the pata (ascending nodes) of the planets and the shadow of the Earth movement on the path of the Sun (arka-apanamandala). Aryabhata asserts that the Earth is the centre of the universe and it revolves around its axis. In fact, Aryabhata was the first Indian astronomer to consider the rotation of the Earth for explaining the apparent daily motions of the fixed stars. But his idea did not find support among his contemporaries or later astronomers. It was not unexpected, as in those days the prevailing belief was that the Earth was not only at the centre of the universe but it was fixed.

The system of astronomy taught in Aryabhatia is usually referred to as the Audyayika system because the day beginning is reckoned from the mean sunrise (udya) at Sri Lanka, a place situated close to the Earth's equator. Aryabhata was also the originator of another system of astronomy called ardhratrika in which the day beginning is reckoned from the mean midnight (ardharatri) at Lanka (Sri Lanka). Varahamihira wrote: "Aryabhata maintains that the beginning of the day is to be reckoned from midnight at Lanka; and the same teacher again says that the day begins from sunrise at Lanka". Brahmasphuta-siddhanta talks about these two systems of astronomy described by Aryabhata. Brahmagupta himself followed ardharatrika system.

Aryabhata was severely criticised by several of his contemporaries and astronomers who followed him. Thus Brahmagupta commenting on Aryabhata wrote: "Since Aryabhata knows nothing of mathematics, celestial shere or time, I have not mentioned separately his demerits." Further as S. N. Sen writes: "Brahmagupta attacked Aryabhata for dividing the yuga into four equal parts, for upholding the rotatory motion of the Earth, for believing in the eclipses caused by the shadows of the Moon and the Earth and not in accordance with the traditional Rahu-Ketu theory." Al-Biruni was apparently not convinced with Brahmagupta's views on Aryabhata. Thus he writes: "He (Brahmagupta) is rude enough to compare Aryabhata to a worm, eating wood, by chance describes certain characters in it, without understanding them and without intending to draw them. In such offensive terms he attacks Aryabhata and maltreats him…" Al-Biruni not only noticed undue criticism of Aryabhata but he also acknowledged the merit of his ideas.

Brahmagupta was an important astronomer in his own right. It may be noted that Brahmagupta's attitude towards Aryabhata changed with time. The abovementioned highly critical remarks were written by him in, composed at the age of 30. However, his Khandakhadyaka, composed at the age of 67 was primarily based on Aryabhata's ardharatrika system. It may be noted that Brahmagupta's works were translated into Arabic by Muhammad ibn Ibrahim al-Fazari (died 796 or 800) Ya'qub ibn Tariq (died 796) as Sindhind (a translation of Brahmasphuta-siddhanta) and the Arakand (a translation of Khadakhadyaka).

Commenting on the contributions of Aryabhata, the noted Indian astrophysicist J. V. Narlikar writes: "Aryabhata gives a table of the trigonometric sine functions, calling them jya in Sanskrit. The table gives the sines of angles at intervals of 3045'. The sine tables are needed to work out the geometrical measurements of positions of stars and planets on the celestial sphere. Thus we see that Aryabhata was conversant with the notions of spherical trigonometry. Moreover, at the conceptual level, his awareness of the spherical shape of Earth and its spin around an axis reflect how advanced he was with respect to his contemporaries. For example, he argues in one verse of the Aryabhatia that although the stars appear to go westwards, they are in fact fixed and we are observing them from the moving platform of the spinning Earth."

The name of Pandurangasvami, Latadeva, Prabhakara and Nishanku are cited as direct desciples of Aryabhata. However, it was Bhaskara I (c.600), who contributed greatly in propagating Aryabhata's work. "Aryabhata's cryptic and aphoristic style would have made it extremely difficult to understand his text, but for the detailed exposition of the system by Bhaskara (c.600)", writes S. Balachandra Rao. Bhaskara was native of either western India or south India (possibly Kerala). He was associated with both these regions. So it might be that he was a native of either of these two regions and migrated to the other. His major work, the Mahabhaskariya, was an elaborate exposition of the three astronomical chapters of Aryabhatiya. As S. N. Sen has described in a Concise History of Science in India, it consists of eight chapters dealing with following topics:

- Mean longitude of planets and indeterminate analysis.
- Longitude correction.
- Time, place and direction, spherical trigonometry, latitudes and lunar eclipses.
- True longitudes of planets.
- Solar and lunar eclipses.
- Rising, setting and conjunction of planets.
- Astronomical constants.
- Tithi and miscellaneous examples.

Bhaskara introduced many new methods of his own. While Aryabhata postulated rules for indeterminate analysis, it was Bhaskara who elaborated it and its application to astronomy. Bhaskara prepared an abridged version of his main work known as Laghubhaskariya.

The works and teachings of Aryabhata exerted strong influence on later generations of astronomers in India. A long list of his followers propagated his views through their excellent commentaries.

The first Indian-built satellite launched by a rocket of erstwhile Soviet Union in April 1975 was named after Aryabhata.

For further reading

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On the Development of the Decimal System and the use of zero

"The decimal value system of writing numbers together with the use of 0, is known to have blossomed in India in the early centuries AD and spread to the west through the intermediacy of the Persians and Arabs. There were actually precursors to the system, and various components of it are found in other ancient cultures such as Babylonian, Chinese, and Mayan. From the decimal representation of the natural numbers the system was to evolve further into the form that is now commonplace and crucial in various walks of life, with decimal fractions becoming part of the number system in the 16th century Europe, though this again has some intermediate history involving the Arabs."

S. G. Dani , "Ancient Indian Mathematics—A Conceptus", Resonance, March 2012

The Bakhshali manuscript

The Bakhshali manuscript was discovered in 1881. It shows the advanced level of arithmetic and algebra that India achieved so early. The manuscript was so named because it was found near the village Bakhshali (or Bakhshalai) of the Yusufzai subdivision of the Peshawar district (now in Pakistan). Only a portion of the manuscript, about 70 leaves of birch baik (bhoojparas), survived to the time of discovery. The manuscript was written in Sharada script and in Gatha dialect of Prakrit. Rudolf Hoernle of the Calcutta Madrasa gave a description of the manuscript before the Asiatic Society of Bengal in 1882. Later he gave a detailed account at the Seventh Oriental Conference held at Vienna in 1886. In 1902, he presented the Bakhshali Manuscript to the Bodleian Library, Oxford.

Hoernle placed the Bakhshali manuscript between the third and fourth centuries A.D. and many other historians of mathematics scholars agreed with this dating. B. Datta based on his detailed study of the mathematical contents proposed that the manuscript was a running commentary on an earlier work. Datta's observation supported Hoernle's view that 'there is every reason to believe that the Bakhsali arithmetic is of a very earlier date than the manuscript in which it has come down to us.' The surviving portion of the manuscript is devoted mainly to arithmetic and algebra except a few problems on geometry and mensuration. The manuscript is a handbook of rules and illustrative examples together with their solutions. It contains mathematical results of high order. The portion dealing with arithmetic includes fractions, square roots, progressions, rule of three and summation of complex series. The algebraic operations discussed in the manuscript include simple and simultaneous linear equations, quadratic equations, surds, unknown quantities, negative signs, the method of false positions and other interesting details.

Here is another equalisation problem taken from the manuscript which has a unique solution:-

Two page-boys are attendants of a king. For their services one gets 13/6 dinaras a day and the other 3/2. The first owes the second 10 dinaras. calculate and tell me when they have equal amounts.

Now I would solve this by saying that the first gets 13/6 - 3/2 = 2/3 dinaras more than the second each day. He needs 20 dinaras more than the second to be able to give back his 10 dinaras debt and have them with equal amounts. So 30 days are required when each has 13 × 30/6 - 10 = 55 dinaras. This is not the method of the Bakhshali manuscript which uses the "rule of three".

The rule of three is the familiar way of solving problems of the type: if a man earns 50 dinaras in 8 days how much will he earn in 12 days. The Bakhshali manuscript describes the rule where the three numbers are written

8 50 12

The 8 is the "pramana", the 50 is the "phala" and the 12 is the "iccha". The rule, according to the Bakhshali manuscript gives the answer as

phala × iccha/pramana

or in the case of the example 50 × 12/8 = 75 dinaras.

Applying this to the page-boy problem we obtain equal amounts for the page-boys after n days where

$13 \times n/6 = 3 \times n/2 +20$

so n = 30 and each has 13 × 30/6 - 10 = 55 dinaras.

Another interesting piece of mathematics in the manuscript concerns calculating square roots. The following formula is used

$\sqrt{Q} = \sqrt{(A2 + b)} = A + b/2A - (b/2A)2/(2(A + b/2A))$

This is stated in the manuscript as follows:-

In the case of a non-square number, subtract the nearest square number, divide the remainder by twice this nearest square; half the square of this is divided by the sum of the approximate root and the fraction. this is subtracted and will give the corrected root.

Taking Q = 41, then A = 6, b = 5 and we obtain 6.403138528 as the approximation to √41 = 6.403124237. Hence we see that the Bakhshali formula gives the result correct to four decimal places.

The Bakhshali manuscript also uses the formula to compute √105 giving 10.24695122 as the approximation to √105 = 10.24695077. This time the Bakhshali formula gives the result correct to five decimal places.

The Kerala School of astronomy and mathematics

The Kerala School of mathematics flourished between the 14th and 16th centuries. It was founded by Madhava of Sangamagrama (1340-1425). Among its members were Parameshvara, Neelkanta, Somayaji, Jyestadeva, Achyut Pisharati, Narayana Bhattathiri and Achyuta Panikkar. It seems that the original discoveries of the school ended with Narayana Bhattahari (1559-1632).

In their attempt to solve astronomical problems they developed a number of important mathematical concepts. In attempting to solve astronomical problems, the Kerala School independently created a number of important mathematics concepts.

Madhava developed a formula for calculating the circumference of a circle to a high degree of accuracy. Madhava is also known as Golavid. Madhava's work was discussed in detail in Kriyakramakari commentary of Lilavati written by Sankara and Narayana. Madhava' works had implications for Kerala School of calculus and mathematical analysis. Madhava worked out an exact formula for pi, two centuries before Leibniz, and he obtained a value of pi correct to an astonishing 13 decimal places.

Yukthibhasa by Jyesthadeva is considered to be the first calculus text ever written. It is a major treatise in mathematics and it was written in Malayalam.

The mathematicians belonging to the Kerala School were aware of the basic principles of algebra, geometry and trigonometry. Their achievements included the anticipatation of modern mathematical findings namely, Taylo series expansion for sine and cosine, Newton-Gauss interpolation formula, Infinite G P Convergent series, Gregory-Leibnitz series for the inverse tangent and approximation. In 1835, Charles Whish in his paper published in the Transactions of the Royal Asiatic Society of Great Britain and Ireland brought out the fact the mathematicians of Kerala had anticipated some of the results of the Europeans on calculus nearly 300 years before. However, it took 100 years before the historians of mathematics agreed that the claims made by Wish were essentially true.

Surya Siddhanta

Surya Siddhanta is the first among the traditions or doctrines (siddhanta) in archaeo-astronomy of the Vedic era. Infact, it is the oldest ever book in world which describes earth as sphere but not flat, gravity being reason for objects falling on earth etc. Going by calculations of Yugas, first version of Surya Siddhanta must have been known around 2 million years ago. However, the present version available is believed to be more than 2500 years old, which still makes it the oldest book on earth in Astronomy.

This book covers kinds of time, length of the year of gods and demons, day and night of god Brahma, the elapsed period since creation, how planets move eastwards and sidereal revolution. The lengths of the Earth's diameter, circumference are also given. Eclipses and color of the eclipsed portion of the moon is mentioned.
This explains the archeo-astronomical basis for the sequence of days of the week named after the Sun, Moon, etc. Musings that there is no above and below and that movement of the starry sphere is left to right for Asuras (demons) makes interesting reading. Citation of the Surya Siddhanta is also found in the works of Aryabhata. The work as preserved and edited by Burgess (1860) dates to the Middle Ages. Utpala, a 10th-century commentator of Varahamihira, quotes six shlokas of the Surya Siddhanta of his day, not one of which is to be found in the text now known as the Surya Siddhanta. The present version was modified by Bhaskaracharya during the Middle Ages. The present Surya Siddhanta may nevertheless be considered a direct descendant of the text available to Varahamihira (who lived between 505–587 CE)

Few excerpts from Surya Siddhanta

The average length of the tropical year as 365.2421756 days, which is only 1.4 seconds shorter than the modern value of 365.2421904 days!

The average length of the sidereal year, the actual length of the Earth's revolution around the Sun, as 365.2563627 days, which is virtually the same as the modern value of 365.25636305 days. This remained the most accurate estimate for the length of the sidereal year anywhere in the world for over a thousand years!

Not content to limit measurements to Earth, the Surya Siddhanta also states the motion, and diameters of the planets! For instance the estimate for the diameter of Mercury is 3,008 miles, an error of less than 1% from the currently accepted diameter of 3,032 miles. It also estimates the diameter of Saturn as 73,882 miles, which again has an error of less than 1% from the currently accepted diameter of 74,580.

Aside from inventing the decimal system, zero and standard notation (giving the ancient Indians the ability to calculate trillions when the rest of the world struggled with 120) the Surya Siddhanta also contains the roots of Trigonometry.

It uses sine (jya), cosine (kojya or "perpendicular sine") and inverse sine (otkram jya) for the first time!

Planetary Diameters in Surya Siddhanta

Surya Siddhanta also estimates the diameters of the planets. The estimate for the diameter of Mercury is 3,008 miles, an error of less than 1% from the currently accepted diameter of 3,032 miles. It also estimates the diameter of Saturn as 73,882 miles, which again has an error of less than 1% from the currently accepted diameter of 74,580. Its estimate for the diameter of Mars is 3,772 miles, which has an error within 11% of the currently accepted diameter of 4,218 miles. It also estimated the diameter of Venus as 4,011 miles and Jupiter as 41,624 miles, which are roughly half the currently accepted values, 7,523 miles and 88,748 miles, respectively.

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 (Aksha). Paramanu (beyond atom) was considered to be the smallest particle, which cannot be divided further. Dividing the same is producing nuclear energy today.

It would be surprising for many today to know that the concepts of atom (Ann, Parmanu) and relativity (Sapekshavada) were explicitly stated by an Indian philosopher nearly 600 years before the birth of Christ. These ideas which were of fundamental import had been developed in India in a very abstract manner. This was so as their exponents were not physicians in today's sense of the term. They were philosophers and their ideas about the physical reality were integrated with those of philosophy and theology.

The Five Basic Physical Elements

From the Vedic times, around 3000 B.C. to 1000 B.C., Indians (Indo-Aryans) had classified the material world into four elements viz. Earth (Prithvi), fire (Agni), air (Maya) and water (Apa). To these four elements was added a fifth one viz. ether or Akasha. Ac cording to some scholars these five elements or Pancha Mahabhootas were identified with the various human senses of perception; earth with smell, air with feeling, fire with vision, water with taste and ether with sound. Whatever the validity behind this interpretation, it is true that since very ancient times Indians had perceived the material world as comprising these 5 elements. The Buddhist philosophers who came later, rejected ether as an element and replaced it with life, joy and sorrow.

Atomic Physics

Since ancient times Indian philosophers believed that except Akash (ether), all other elements were physically palpable and hence comprised miniscule particles of matter. The last miniscule particle of matter which could not be subdivided further was termed Parmanu. The word Parmanu is a combination of Param, meaning beyond, and any meaning atom. Thus the term Parmanu is suggestive of the possibility that, at least at an abstract level Indian philosophers in ancient times had conceived the possibility of splitting an atom which, as we know today, is the source of atomic energy. This Indian concept of the atom was developed independently and prior to the development of the idea in the Greco-Roman world. The first Indian philosopher who formulated ideas about the atom in a systematic manner was Kanada who lived in the 6th century B.C. Another Indian philosopher, Pakudha Katyayana who also lived in the 6th century B.C. and was a contemporary of Gautama Buddha, had also propounded ideas about the atomic constitution of the material world.

These philosophers considered the Atom to be indestructible and hence eternal. The Buddhists believed atoms to be minute objects invisible to the naked eye and which come into being and vanish in an instant. The Vaisheshika school of philosophers believed that an atom was a mere point in space. Indian theories about the atom are greatly abstract and enmeshed in philosophy as they were based on logic and not on personal experience or experimentation. Thus the Indian theories lacked an empirical base, but in the words of A.L. Basham, the veteran Australian Indologist "they were brilliant imaginative explanations of the physical structure of the world, and in a large measure, agreed with the discoveries of modern physics."

Anu and Parmanu

Kanada first propounded the the Parmanu (atom) was an indestrutible particle of matter. According to the material universe is made up of Kana. When matter is divided and sudivided, we reach a stage beyond which no division is possible, the undivisible element of matter is Parmanu. Kanada explained that this indivisible, indestructible y cannot be sensed through any human organ.

In saying that there are different types of Parmanu for the five Pancha Mahabhootas, Earth, water, fire, air and ether. Each Parmanu has a peculiar property which depends, on the substance to which it belongs. It was because of this conception of peculiarity of Parmanu (atoms) that this theory unded by Kanada came to be known Vaisheshika-Sutra (Peculiarity Aphorisms). In this context Kanada seems to arrived at conclusions which were surpassed only many centuries after him.

Chemistry

Ancient India's development in chemistry was not confined at an abstract level like physics, but found development in a variety of practical activities. In any early civilization, metallurgy has remained an activity central to all civilizations from the Bronze Age and the Iron Age, to all other civilizations that followed. It is believed that the basic idea of smelting reached ancient India from Mesopotamia and the Near East.

Coinage dating from the 8th Century B.C. to the 17th Century A.D. Numismatic evidence of the advances made by smelting technology in ancient India.

Nataraja the God of Dance is made of five metals Pancha-Dhatu.

In the 5th century BC, the Greek historian Herodotus has observed that Indian and the Persian army used arrows tipped with iron. Ancient Romans were using armor and cutlery made of Indian iron.

In India itself, certain objects testify to the higher level of metallurgy achieved by the ancient Indians. By the side of Qutub Minar, a World heritage site, in Delhi, stands an Iron Pillar. The pillar is believed to be cast in the Gupta period around circa 500 AD. The pillar is 7.32 meters tall, tapering from a diameter of 40 cm at the base to 30 cm at the top and is estimated to weigh 6 tonnes. It has been standing in the open for last 1500 years, withstanding the wind, heat and weather, but still has not rusted, except very minor natural erosion. This kind of rust proof iron was not possible till iron and steel was discovered few decades before.

The advance nature of ancient India's chemical science also finds expression in other fields, like distillation of perfumes and fragment ointments, manufacturing of dyes and chemicals, polishing of mirrors, preparation of pigments and colours. Paintings found on walls of Ajanta and Ellora (both World heritage sites) which look fresh even after 1000 years, also testify to the high level of chemical science achieved in ancient India.

Universities

Nalanda

Towards the Southeast of Patna, the Capital City of Bihar State in India, is a village called the 'Bada Gaon', in the vicinity of which, are the world famous ruins of Nalanda University.

Founded in the 5th Century A.D., Nalanda is known as the ancient seat of learning. 2,000 Teachers and 10,000 Students from all over the Buddhist world lived and studied at Nalanda, the first Residential International University of the World.

A walk in the ruins of the university, takes you to an era that saw India leading in imparting knowledge, to the world - the era when India was a coveted place for studies. The University flourished during the 5th and 12th century.

Although Nalanda is one of the places distinguished as having been blessed by the presence of the Buddha, it later became particularly renowned as the site of the great monastic university of the same name, which was to become the crown jewel of the development of Buddhism in India. The name may derive from one of Shakyamuni's former births, when hewas a king whose capital was here.Nalanda was one of his epithets meaning "insatiable in giving."

This place saw the rise and fall of many empires and emperors who contributed in the development of Nalanda University. Many monasteries and temples were built by them. Kingarshwardhana gifted a 25m high copper statue of Buddha and Kumargupta endowed a college of fine arts ere. Nagarjuna- a Mahayana philosopher, Dinnaga- founder of the school of Logic and Dharmpala- the Brahmin scholar, taught here.

The famous Chinese traveller and scholar, Hieun-Tsang stayed here and has given a detailed description of the situations prevailing at that time. Careful excavation of the place has revealed many stupas, monasteries, hostels, stair cases, meditation halls, lecture halls and many other structures which speak of the splendour and grandeur this place enjoyed,when the place was a centre of serious study.

A large number of ancient Buddhist establishments, stupas, chaityas, temples and monastery sites have been excavated and they show that this was one of the most important Buddhist centres of worship and culture.Regarding the historicity of Nalanda, we read in Jaina texts that Mahavira Vardhamana spent as many as fourteen rainy seasons in Nalanda.

Pali Buddhist Literature, too, has ample references to Nalanda, which used to be visited by Lord Buddha. During the days of Mahavira and Buddha, Nalanda was apparently a very prosperous temple city, a great place of pilgrimage and the site of a celebrated university. It is said that King Asoka gave offerings to the Chaitya of Sariputra at Nalanda and erected a temple there.Taranath mentions this and also that Nagarjuna, the famous Mahayana philosopher of the second century A.D.,studied at Nalanda.Nagarjuna later became the high-priest there.

The Gupta kings patronised these monasteries, built in old Kushan architectural style, in a row of cells around a courtyard.Ashoka and Harshavardhana were some of its most celebrated patrons who built temples and monasteries here. Recent excavations have unearthed elaborate structures here. Hiuen Tsang had left ecstatic accounts of both the ambiance and architectureof this unique university of ancient times.

Modern historians have tentatively dated the founding of a monastery at Nalanda as being in the fifth century.However, this may not be accurate. For example,the standard biographiesof the teacher Nagarjuna, believed by most historians to have been born around 150 AD, are quite specific about his having received ordination at Nalanda monastery when he was seven years old. Further, his teacher Rahulabhadra is said to have lived there for some time before that. We may infer that there were a monastery or monasteries at Nalanda long before the foundation of the later Great Mahavihara.

At the time Hsuan Chwang stayed at Nalanda and studied with the abbot Shilabhadra, it was already a flourishing centre of learning. In many ways it seems to have been like a modern university.There was a rigorous oral entry examination conducted by erudite gatekeepers, and many students were turned away.To study or to have studied at Nalanda was a matter of great prestige. However, no degree was granted nor was a specific period of study required. The monks' time, measured by a water clock, was divided between study and religious rites and practice.There were schools of study in which students received explanations by discourse, and there were also schools of debate, where the mediocre were often humbled, and the conspicuously talented distinguished. Accordingly, the elected abbot was generally the most learned man of the time.

The libraries were vast and widely renowned, although there is a legend of a malicious fire in which many of the texts were destroyed and irrevocably lost.

During the Gupta age,the practice and study of the mahayana, especially the madhyamaka, flourished. However, from 750 AD, in the Pala age, there was an increase in the study and propagation of the tantric teachings.This is evidenced by the famous pandit Abhayakaragupta, a renowned tantric practitioner who was simultaneously abbot of the Mahabodhi, Nalanda and Vikramashila monasteries. Also Naropa, later so important to the tantric lineages of the Tibetan traditions, was abbot of Nalanda in the years 1049-57.

Much of the tradition of Nalanda had been carried into Tibet by the time of the Muslim invasions of the twelfth century. While the monasteries of Odantapuri and Vikramashila were then destroyed, the buildings at Nalanda do not seem to have suffered extensive damage at that time, although most of the monks fled before the desecrating armies. In 1235 the Tibetan pilgrim Chag Lotsawa found a 90 year old teacher, Rahula Shribhadra, with a class of seventy students. Rahula Shribhadra managed to survive through the support of a local Brahmin and did not leave until he had completed educating his last Tibetan student.

Puspagiri

The school in Puspagiri was established in the 3rd century AD as present Odisha, India. As of 2007, the ruins of this Mahavihara had not yet been fully excavated. Consequently, much of the Mahavihara's history remains unknown. Of the three Mahavihara campuses, Lalitgiri in the district of Cuttack is the oldest. Iconographic analysis indicates that Lalitgiri had already been established during the Sunga period of the 2nd century BC, making it one of the oldest Buddhist establishments in the world. The Chinese traveller Xuanzang (Huien Tsang), who visited it in AD 639, as Puphagiri Mahavihara, as well as in medieval Tibetan texts. However, unlike Takshila and Nalanda, the ruins of Puspagiri were not discovered until 1995, when a lecturer from a local college first stumbled upon the site. The task of excavating Puspagiri's ruins, stretching over 143 acres (0.58 km2) of land, was undertaken by the Odisha Institute of Maritime and South East Asian Studies between 1996 and 2006. It is now being carried out by the Archaeological Survey of India (ASI). TheNagarjunakonda inscriptions also mention about this learning center.

Taxila

Taxila or Takshashila, in ancient India (modern-day Pakistan), was an early Hindu and Buddhist centre of learning. According to scattered references that were only fixed a millennium later, it may have dated back to at least the fifth century BC.Some scholars date Takshashila's existence back to the sixth century BC.The school consisted of several monasteries without large dormitories or lecture halls where the religious instruction was most likely still provided on an individualistic basis.

Takshashila is described in some detail in later Jātaka tales, written in Sri Lanka around the fifth century AD.

It became a noted centre of learning at least several centuries BC, and continued to attract students until the destruction of the city in the fifth century AD. Takshashila is perhaps best known because of its association with Chanakya. The famous treatise Arthashastra(Sanskrit for The knowledge of Economics) by Chanakya, is said to have been composed in Takshashila itself. Chanakya (or Kautilya), the Maurya Emperor Chandragupta and the Ayurvedic healer Charaka studied at Taxila.

Generally, a student entered Takshashila at the age of sixteen. The Vedas and the Eighteen Arts, which included skills such as archery, hunting, and elephant lore, were taught, in addition to its law school, medical school, and school of military science.

Civilian Sciences

Farming Techniques and Fertilizers

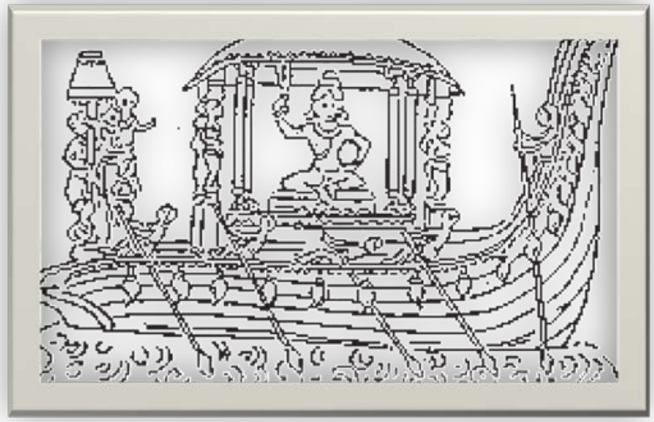
Indian farming technology was mostly indigenously developed and was ahead of its time. It included soil testing technique, crop rotation methods, irrigation plans, application of eco-friendly pesticides and fertilizers, storage methods for crops, etc.

Postal System

One of the earliest evidence of a systematic postal service using foot messengers is found during the reign of Chandragupta Maurya (322-298 B.C.). A courier service between the capital and the outlying provinces of the vast kingdom served the needs of intelligence gathering and collection of revenue data, whence regular messengers, doots andpigeons were used for conveying the royal communiqué. However its efficacy was lost upon his death and the system fell through. Emperor Ashoka also devised a very efficient means of communication that helped him create a vast empire. During his period, camels were also in use to carry mail in some parts of Eastern India, like Jajpur.

Shipping

Ancient Indian Ship Building & Navigation



In India, there existed a strange belief that if any one crossed the seas, he would lose his religion. When and why this belief came into being is not known. But taking a close look at our nation's maritime history we find evidence of a very large number of Indians who should have had lost their religion as they had crossed the seas to trade and build empires in distant lands.

Not only did these enterprising Indians, not lose their religion but they made India into one of the foremost maritime nations of those days and spread Indian culture overseas.

In those days India had colonies, in Cambodia (Kambuja in Sanskrit) in Java, (Chavakam or Yava Dwipa) in Sumatra, in Borneo, Socotra (Sukhadhara) and even in Japan. Indian traders had established settlements in Southern China, in the Malayan Peninsula, in Arabia, in Egypt, in Persia, etc., Through the Persians and Arabs, India had cultivated trade relations with the Roman Empire.

Sanskrit and Pali literature has innumerable references to the maritime activity of Indians in ancient times. There is also one treatise in Sanskrit, named Yukti Kalpa Taru which has been compiled by a person called Bhoja Narapati. (The Yukti Kalpa Taru (YKT) had been translated and published by Prof. Aufrecht in his 'Catalogue of Sanskrit Manu scripts'. An excellent study of the YKT had been undertaken by Dr. Radha Kumud Mookerji entitled 'Indian Shipping', Published by Orient Longman, Bombay in 1912.)

A panel was found at Mohenjodaro depicting a sailing craft. Vessels were of many types. Their construction is vividly described in the Yukti Kalpa Taru, an ancient Indian text on Ship-building. This treatise gives a technocratic exposition on the technique of shipbuilding. It sets forth minute details about the various types of ships, their sizes, the materials from which they were built. The Yukti Kalpa Taru sums up in a condensed form all the available information.

The Yukti Kalpa Taru gives sufficient information and date to prove that in ancient times, Indian shipbuilders had a good knowledge of the materials which were used in building ships. Apart from describing the qualities of the different types of wood and their suitability in shipbuilding, the Yukti Kalpa Taru also gives an elaborate classification of ships based on their size.

The primary division is into 2 classes viz. Samanya (ordinary) and Vishesha (Special). The ordinary type was for sea voyages. Ships that undertook sea voyages were classified into, Dirgha type of ships which had a long and narrow hull and the Unnata type of ships which had a higher hull.

The treatise also gives elaborate directions for decorating and furnishing the ships with a view to making them comfortable for passengers. Also mentioned are details about the internal seating and accommodation to be provided on the ships. Three classes of ships are distinguished according to their length and the position of cabins. The ships having cabins extending from one end of the deck to the other are called Sarvamandira vessels.

These ships are recommended for the transport of royal treasure and horses. The next are the Madhyamamandira vessels which have cabins only in the middle part of their deck. These vessels are recommended for pleasure trips. And finally there is a category of Agramandira vessels, these ships were used mainly in warfare.

Maccha Yantra (Ancient Indian Mariner's Compass)

There were Sanskrit terms for many parts of a ship. The ship's anchor was known as Nava- Bandhan-Kilaha which literally means 'A Nail to tie up a ship'. The sail was called Vata Vastra, which means 'wind-cloth'. The hull was termed StulaBhaga i.e. an 'expanded area'. The rudder was called Keni-Pata, Pata means blade; the rudder was also known as Karna which literally means a 'ear' and was so called because it used to be a hollow curved blade, as is found today in exhaust fans. The ship's keel was called Nava-Tala which means 'bottom of a ship'. The mast was known as Kupadanda, in which danda means a pole.

Even a sextant was used for navigation and was called Vruttashanga-Bhaga. But what is more surprising is that even a contrived mariner's compass was used by Indian navigators nearly 1500 to 2000 years ago. This claim is not being made in an overzealous nationalistic spirit. This has in fact been the suggestion of an European expert, Mr. J.L. Reid, who was a member of the Institute of Naval Architects and Shipbuilders in England at around the beginning of the present century. This is what Mr. Reid has said in the Bombay Gazette, Vol. xiii., Part ii., Appendix A, as follows.

"The early astrologers are said to have used the magnet, in fixing the North and East, in laying foundations, and other religious ceremonies. The compass was an iron fish that floated in a vessel of oil and pointed to the North. The fact of this older compass seems placed beyond doubt by the Sanskrit word Maccha Yantra, or fish machine, which Molesworth gives as a name for the mariner's compass".

It is significant to note that these are the words of a foreign Naval Architect and Shipbuilding Expert. It is thus quite possible that the Maccha Yantra (fish machine) was transmitted to the west by the Arabs to give us the mariner's compass of today.

Economic sciences

The known Economic sciences of India begins with the Indus Valley civilization. The Indus civilization's economy appears to have depended significantly on trade, which was facilitated by advances in transport. Around 600 BC, the Mahajanapadas minted punch-marked silver coins. The period was marked by intensive trade activity and urban development. By 300 B.C., the Maurya Empire united most of the Indian subcontinent. The political unity and military security allowed for a common economic system and enhanced trade and commerce, with increased agricultural productivity.

For the next 1500 years, India produced its classical civilizations such as the Rashtrakutas, Hoysalas and Western Gangas. During this period India is estimated to have had the largest economy of the ancient and medieval world between until 17th century AD, controlling between one third and one fourth of the world's wealth up to the time of Maratha Empire, from whence it rapidly declined during European colonization.

According to economic historian Angus Maddison in his book The World Economy: A Millennial Perspective, India was the richest country in the world and had the world's largest economy until the 17th century AD.

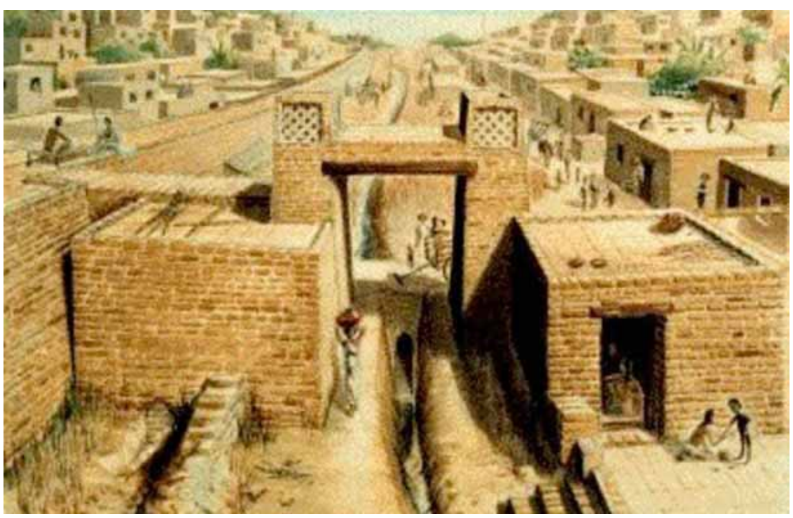
While India's many kingdoms and rulers issued coins, barter was still widely prevalent. Villages paid a portion of their agricultural produce as revenue while its craftsmen received a stipend out of the crops at harvest time for their services. Each village, as an economic unit, was mostly self-sufficient.

According to economic historian Angus Maddison in his book Contours of the world economy, 1–2030 AD: essays in macro-economic history, India had the world's largest economy during the years 1 AD and 1000 AD.

During the Maurya Empire (c. 321–185 BC), there were a number of important changes and developments to the Indian economy. It was the first time most of India was unified under one ruler. With an empire in place, the trade routes throughout India became more secure thereby reducing the risk associated with the transportation of goods. The empire spent considerable resources building roads and maintaining them throughout India. The improved infrastructure combined with increased security, greater uniformity in measurements, and increasing usage of coins as currency enhanced trade.

Engineering

Civil Engineering & Architecture



Gateway At Harappa: Indus Valley Civilization

India's urban civilization is traceable to Mohenjodaro and Harappa, now in Pakistan, where planned urban townships existed 5000 years before. From then onwards, the ancient Indian architecture and civil engineering continued to develop and grow. It found manifestation in construction of temples, palaces and forts across the Indian peninsula and the neighbouring regions. In ancient India, architecture and civil engineering was known as sthapatya-kala, literal translation of which means the art of constructing (something).

During the periods of Kushan Empire and Maurya empires, the Indian architecture and civil engineering reached to regions like Baluchistan and Afghanistan. Statues of Buddha were cut out, covering entire mountain faces and cliffs, like Buddhas of Bamiyan, Afghanistan. Over a period of time, ancient Indian art of construction blended with Greek styles and spread to Central Asia.

On the other side, Buddhism took Indian style of architecture and civil engineering to countries like Sri Lanka, Indonesia, Malaysia, Vietnam, Laos, Cambodia, Thailand, Burma, China, Korea and Japan. Angkor Wat is a living testimony to the contribution of Indian civil engineering and architecture to the Cambodian Khmer heritage in the field of architecture and civil engineering.

In mainland India of today, there are several marvels of ancient India's architectural heritage, including World heritage sites like Ajanta, Ellora, Khajuraho, Mahabodhi Temple, Sanchi, Brihadisvara Temple and Mahabalipuram.

Metallurgy

Zinc Technology

An important Indian contribution to metallurgy was the isolation, distillation and use of zinc. From natural sources, zinc content in alloys such as brass can go no higher than 28 per cent. These primitive alloys with less than 28 per cent zinc were prevalent in many parts of the world before India. However, to increase the zinc content beyond this threshold, one must first separate the zinc into 100 per cent pure form and then mix the pure zinc back into an alloy. A major breakthrough in the history of metallurgy was India's discovery of zinc distillation whereby the metal was vaporized and then condensed back into pure metal.

Brass in Taxashila has been dated from third century B.C to fifth century A.D. A vase from Taxashila is of particular interest because of its 34.34 per cent zinc content and has been dated to the third century.

B.C (Marshall 1951: 567-568). Recently two brass bangles belonging to the Kushana period have been discovered from Senuwar (Uttar Pradesh, India). They are also made of metallic zinc as they have 35 per cent zinc content (Singh 2004: 594).

There is evidence of zinc ore mining at Zawar in Rajasthan from the fifth century B.C, but unfortunately there is lack of evidence of regular production of metallic zinc until the eighth century A.D. The earliest confirmed evidence of zinc smelting by distillation is dated back to 840 +110 from Zawar (Craddock et al. 1985, 1989). This is the earliest date for zinc smelting and production of metallic zinc by distillation process anywhere in the world.

Europeans learnt it for the first time in 1743, when know-how was transferred from India. Until then, India had been exporting pure zinc for centuries on an industrial scale. At archeological sites in Rajasthan, retorts used for the distillation are found in very large numbers even today.

Once zinc had become separated into a pure metal, alloys could be made with the required zinc component to provide the required properties. For instance, strength and durability increase with higher zinc component. Also, copper alloys look like gold when the zinc component is higher than 28 per cent. Most early brass objects found in other countries had less than 10 per cent zinc component, and, therefore, these were not based on zinc distillation technology.

Alloys that exceed 10 per cent zinc are found earliest in Taxashila in the fourth century B.C. However, while Taxashila was distilling and manufacturing zinc on a small scale, it was in Zawar, Rajasthan, where this first became industrialized on a large scale. Zinc mines have been found in Dariba (11th century B.C), Agucha (sixth century B.C) and Zawar (fifth century B.C). These mines have pots and other manufacturing tools of these dates, but the mining could be even older.

Three important items are now proven about the history of zinc metallurgy: (i) zinc distillation and metallurgical usage was pioneered in India; (ii) industrial scale production was pioneered in Rajasthan; (iii) England transferred the technology of zinc from India in 1736. British metallurgy documents do not mention zinc at all prior to this transfer.

Copper Technology

Even the early Indus valley people were familiar with copper, its mining, metal making and use. Reduction of copper was done at the ore site itself to get copper ingots. Archaeological studies revealed a number of copper mining and smelting sites in Rajasthan, Uttar Pradesh and Bihar, some of them operating since 11th Century B.C. Some high purity copper ingots (99.81% pure) found in Lothal, suggest that Lothal metal workers had learnt the art of purification of metals. Three traditions of copper metaltury in ancient India are noted:

Harappans used copper vessels, which required technology of “joining”, "running on" and "revetting". Metallography of these objects shows that they knew slow cooling of castings and annealing after cold work. True saws, with teeth and body set alternately from side to side, appear at Mohenjodaro, perhaps for the first time in the world: Tin, lead, arsenic were found in alloys.

In the Chalcolithic Period (2000-900 B.C.) copper technology was at Kayatha, near Ujjain, the birthplace of Varahamihira. The people here had mastered the technology of copper, as seen from the fine copper axes with sharp cutting edges and a lenticular section. The most noteworthy feature is that they are made from casting in a mould. Another important location of copper technology in chalcolithic period is the Nasik Ahmednagar-Pune tri-district area. The technology flourished on the banks of Pravara, Ghod and Godavari rivers at places like Sangamner, Nevasa, Nasik, Chandoli, Inamgaon and Daimabad. This activity is proto-historic, or of early-bronze period.

The Magnificent Buddha in Copper

The Gandhara-Mathura traditions of sculpture strongly influenced the iconic tradition of the Gupta period. It reached its summit with the huge Sultanganj copper statue of Buddha 5th Century A.D. It is about two and a quarter metre, in height and weighs about a tonne. It was discovered in 1864 and is now housed in the Museum and Art Gallery of Birmingham, U.K.

Large Copper Bolt

A solid copper bolt, apparently shaped into form by hammer after being cast, has been found in the Rampurwa Asoka pillar near the frontier of Nepal. Historical evidence indicates that it is a product of the third century B.C. The bolt is barrel-shaped in appearance, slightly tapering at the two ends. It has a length of 60 cm and a circumference of 35 cm at the centre and 30 cm at both ends. The metal is pure copper and exquisitely worked into shape. The bolt was very likely employed for fixing the large stone capital of the Asoka pillar with the body of the pillar itself. It was presented by its discoverer, W. H.W Garrick, to the Indian Museum, Calcutta, in 1881, where it is still preserved in the Archaecological Section.

Bronze Technology

Bronze was known in the Indus-valley civilization even before 3000B.C. Bronze objects were made by cire purdue or lost-wax casting, heating and shaping by hammering. The art of casting bronze was an established industry in Mohenjodaro. Bronze was considered essential for making objects of decorative and artistic value. Two bronze icons of the late Harappan period 2000 to 1800 B.C. were found in Daimabad on the banks of Prawara, a tributary of Godavari.The tradition of icon making started in the Buddhist period. The first icons are the Amaravati group of Buddhist bronzes, now to be found in several musems at Chennai, Colombo, Kualalampur, Hanoi etc. A cast bronze icon of the Kushan period, 2nd century A.D., was found.

Strong icon-making traditions existed in Gujarat, Bihar (Nalanda) and Orissa. Several hundred Buddhist icons have been found in these regions.

Some 350 Buddhist and Brahmanical bronzes, belonging to the Chola Kings of Tanjore, have been found in Nagapattinam, Tamilnadu. The beautiful icons of that period are a matter of India's pride and a significant part of our artistic, philosophical and technological culture.

Brass Technology

The earliest occurrence of zinc in man- made artefacts is in the form of copper alloy, known as 'brass'. The earliest method of making brass, before zinc was separated as a metal, was perhaps the 'Cementation Process', in which fine copper pieces were mixed with roasted zinc ore and charcoal and heated to 1000°C in a closed crucible. Charcoal reduces zinc oxide and the zinc vapour reacts with copper, yielding brass. Below 960°C, zinc oxide is not reduced. Above 1083° C, copper melts and settles to bottom of crucible, giving less area for brass-forming reaction. This process can give a maximum of 28 percent zinc in brass. To have a brass with higher zinc percentage, zinc needs to be added separately.

The earliest found brass artefacts are from Lothal (Gujarat), before Greeks came to India. Brass technology culminated in the unique 4th century artefacts from Takshashila. The material might have been produced from zinc-bearing copper ore or by 'Cementation Process'. The raw material might have come from Ahar-Zawar area of Rajasthan. Similar materials have been found at Atranjikhera.

The earliest brass containing more than 28% zinc, which could be made only after isolation of pure zinc metal, came from Takshashila. A vase containing 34.34 percent zinc has been found, which is strong evidence of availability of metallic zinc in 4th century B.C. and possibly much earlier in Rajasthan. By the 6th and 7th century A.D., the brass revolution was in full swing in India and numerous brass objects were being made.

Gold & Silver Technology

A major source of gold in ancient India was the 'placer metal' found in the auriferrous sands of a number of rivers. Gold washing was practised in all parts of India. Surface collection of gold nuggets was also known to the Harappans. Much of the Mohenjodaro and Harappan gold is alloyed with a substantial percentage of silver. This native natural alloy of gold with silver, (upto 40%) known in Sanskrit as Rajita-Hiranyam and as electrum in English, is found in Kolar gold fields.

Lothal has yielded over 100 gold objects of various sizes, apart from a large number of microbeads used in necklaces. Thin foils and beads of gold found in Lothal and Takshashila suggest that sheet metal was beaten into foils. Joining was done by sweating, soldering and controlled heating. Copper was used as an alloy for soldering gold rings. Casting was also widely practised.

Silver was used more extensively than gold in Mohenjodaro. It was mainly extracted from argentiferrous galena (ore of lead). Over 200 items of silver, including jewellery, were found in Takshashila. These were made in either stone moulds or with copper or bronze dies.

Lead & Tin

The Harappans were acquainted with lead ores like galena (lead sulphide) and cerussite (lead carbonate) and their smelting process, which is simple due to the easy reducibility and low melting point of the metal. Lead is found associated with silver and sometimes with copper. Lead was extensively mined in various parts of India, mainly due to its association with silver. Discovery of high purity lead (99.54%) shows that purification methods of lead were practised. Forty five lead coins of 2nd - 4th centuryA.D. were found in Nagara, Gujarat.

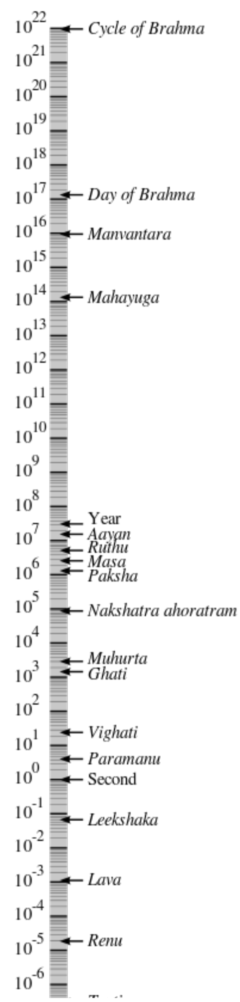
Tin occurs in small quantities as casserite in wester India and to some extent in Bihar and Orissa. Casserite is often found in the form of water-concentrated 'placer' deposit. Tin produced from it, is known as stream-tin. Ancient Indians must have exploited and exhausted deposits of 'stream-tin' rather than exploit vein deposits, which are hard to mine. Tin was not known as a separate metal in Mahenjodaro but only as an alloy with copper in bronze. Soldering was known to Indus valley people. It is likely that a simple tin-lead alloy solder was employed.

The Iron Pillar in Delhi—the Rustless Wonder

The Iron Pillar located in Delhi in the Qutub complex is noted for its rust-resistant composition. In fact the pillar stands as 'a living testimony to the skill of metallurgists of ancient India'. It is now generally believed that the pillar was made sometime in the 5th century and so it is at least 1600 years old. Further it is believed that it was originally located in a Vishnu temple somewhere in North India. The height of the

pillar, from the top of its capital to the bottom of its base, is 7.21 m (23.7 ft), 1.12 m (3 ft 8 in) of which is below ground. It is estimated to weigh more than six tons. The pillar carries a number of inscriptions of different dates. The oldest inscription on the pillar in Sanskrit, written in Gupta-period Brahmi script states that the pillar was erected in honour of Vishnu. For many years the secret for the stability of the pillar could not be explained satisfactorily. Many theories have been put forward from time to time to explain its rust-resistance property. Erich von Daenikin and other writers mention the Iron Pillar to point out that there was more to ancient cultures than we normally tend to believe. However, recently researchers have claimed that they have finally solved the problem. They found that the pillar was protected by a layer of 'misamite' formed catalytically around it due to a higher amount of phosphorus. It has 1 % phosphorus compared to today's usual 0.5%.

There are other ancient iron pillars in other parts of the country namely, at Dhar in Madhya Pradesh, Moorkambika Temple at Kollur situated in the Kodachadri Hills in the Western Ghats and the iron beams in the Surya temple at Konarak in central Orissa.



Indian units of time displayed on a logarithmic scale

Standardization & Calibration

Standard weights and measures have existed in the Indus Valley Civilization since the 5th millennium BCE. The centralized weight and measure system served the commercial interest of Indus merchants as smaller weight measures were used to measure luxury goods while larger weights were employed for buying bulkier items, such as food grains etc. Weights existed in multiples of a standard weight and in categories. Technical standardization enabled gauging devices to be effectively used in angular measurement and measurement for construction. Uniform units of length were used in the planning of towns such as Lothal, Surkotada, Kalibangan, Dolavira, Harappa, and Mohenjo-daro. The weights and measures of the Indus civilization also reached Persia and Central Asia, where they were further modified. Shigeo Iwata describes the excavated weights unearthed from the Indus civilization: A total of 558 weights were excavated from Mohenjodaro, Harappa, and Chanhu-daro, not including defective weights. They did not find statistically significant differences between weights that were excavated from five different layers, each measuring about 1.5 m in depth. This was evidence that strong control existed for at least a 500-year period. The 13.7-g weight seems to be one of the units used in the Indus valley. The notation was based on the binary anddecimal systems. Eighty-three percent of the weights which were excavated from the above three cities were cubic, and 68% were made of chert.

Rulers made from Ivory were in use by the Indus Valley Civilization prior to 1500 BCE.Excavations at Lothal (2400 BCE) have yielded one such ruler calibrated to about $^1/_{16}$ inch (1.6 mm). Ian Whitelaw (2007)—on the subject of a ruler excavated from the Mohenjo-daro site—writes that: 'the Mohenjo-Daro ruler is divided into units corresponding to 1.32 inches (33.5 mm) and these are marked out in decimal subdivisions with amazing accuracy—to within 0.005 of an inch. Ancient bricks found throughout the region have dimensions that correspond to these units. The Indus civilization constructed pan balances made of copper, bronze, and ceramics. One excavated pan balance from Mohenjo-daro (2600–1900 BCE) was constructed using a cord-pivot type fulcrum, a bronze beam, and two pans. A number of excavated surveying instruments and measuring rods have yielded evidence of early cartographic activity.

Weights and measures are mentioned throughout the religious and secular works of the Vedic period in India. Some sources that mention various units of measurement are Satapatha Brahmana, Apastamba Sutra, and the Eight Chapters of the grammarian Pāṇini. Indian astronomers kept a pañcānga for calculations of tithi (lunar day), vāra (weekday), naksatra (asterism), and karan (half lunar day) for social and religious events. Klostermaier (2003) states that: "Indian astronomers calculated the duration of one kalpa (a cycle of the universe during which all the heavenly bodies return to their original positions to be 4,320,000,000 years.

Water Management & Hydraulics

Water has been a crucial factor in setting up of any civilization. Indians have been developing water management techniques even before the Harappan time. Wells, ponds, lakes, dams and canals have been constructed with advancing technologies in whatever time and dynasty we consider. The water has been used for storage, drinking and irrigation purpose. It is estimated that even today, there are more than a million man-made ponds and lakes in India.

The importance of water for basic existence is a universally recognised fact – which does not, perhaps, require stressing or re-iteration here! Nor does the fact that access to water has long determined the positioning of habitational (and work-related) sites of humans (and, for that matter, of birds and animals). This applies to sites attributable to the prehistoric (i.e. Palaeolithic, or 'Old Stone Age', Neolithic, or 'New Stone Age', and Mesolithic) phases of human existence, as much as to the rural settlements, towns and cities that came up in different parts of South Asia in subsequent millennia. As such, one of the areas in which India's traditional knowledge systems have developed and survived from pre-historic to contemporary times is that of the development and management of water resources. This has enabled, even in zones marked by an absence of perennial rivers, a range of human activities, including agriculture, animal husbandry, different types and levels of economic and manufacturing activities, and the existence of prosperous kingdoms and states.

During the circa 3rd to 2nd millennia BC period, the urban sites of the Harappan Civilisation demonstrated a high degree of hydraulic engineering skills. One of the best known examples of this is the 'Great Bath' at the site of Mohenjodaro. This has a pool or tank portion measuring 12 metres in length (north to south), 7 metres in width, and 2.5 metres in depth, within a larger building complex. It was accessed by steps, to which wooden covers were fixed by bitumen or asphalt. The bricks used in constructing this Great Bath were laid on edge, and the floor and sides of the pool were waterproofed through the addition of gypsum in the building-mortar, with a backing of a bitumen course for further damp proofing. The sides of the pool were backed by a secondary set of walls, with the intervening space between the two being filled with a bitumen coating and earth, to ensure total waterproofing. Water for filling the pool of the 'Great Bath' came from a large well situated in one of the rooms fronting the open courtyard of the building-complex, while a corbelled baked-brick drain in the south-western portion of the Bath served to carry away the used water.

The 'dock-yard' (or water-reservoir according to some), found in the excavations at another well-known Harappan Culture site, namely, Lothal, is also worthy of especial note. Irrespective of the controversy about whether the structure was a dockyard or merely a reservoir, this remarkable lined structure, with evidence of channels for inlet and outlet of water, is a pointer to the hydraulic knowledge of protohistoric India! The presence of marine organisms in this complex strengthens the argument for its having been a dock. The structure – roughly trapezoidal area (western wall 218.23 m; eastern wall 215.03 m; southern wall 35.66 m and northern wall: 37.49 m), is enclosed by a 1.2m thick lining made up of a four-course wall of kiln-baked bricks, within broader mud-brick embankment walls. There are two inlets to this enclosure, one each in the northern and southernmost portions of the eastern side.

The monsoon runoff was carried to a series of reservoirs, gouged out in the sloping areas between the inner and outer walls of the Harappan period city, through inlet channels. These water reservoirs were separated from each other by bund-cum-causeways, which also served to facilitate access to different divisions of the city. The Dholavira excavators claim that at least 16 water reservoirs were created within the city walls. These covered some 17 hectares, or 36 per cent, of the walled area. In the southeastern corner of the city there was a reservoir covering about 5 hectares. The reservoirs had 4.5 to 7 m wide bunds around them, protected by brick masonry walls.

Evidence from one of the smaller Harappan Culture sites – Allahdino (near Karachi), suggests the possibility that the Harappans may have used wells for irrigated agriculture too. Besides this, individual houses possessed paved bathrooms with drains to carry out sullage water from the houses into the local city drainage system. This drainage system entailed well-covered street drains made of kiln-baked bricks, with covered manholes at intervals for purposes of cleaning and maintenance.

One may also note here a series of tanks excavated at the site of Sringaverapura, near Allahabad, which reportedly date to the end of the 1st century BC. (B.B. Lal, 'Excavations at Sringaverapura', 1993; & 'ABC of Sringaverapura', in Agrawal & Narain (Eds.) Dying Wisdom, 1997, p.16). This remarkable example of hydraulic engineering entailed a tank – described as "…the longest of its kind discovered so far – more than 250 m long" (Lal, 1997:16). The Sringaverapura tank-complex obtained water from the nearby river Ganga during the monsoon season, when the level of the river usually rose by about 7-8 metres. As a result, excess water used to spill over from the Ganga into an adjoining stream (nullah). From this stream, an 11m wide and 5m deep canal carried the water further into the Sringaverapura tanks.

The water first entered a settling chamber to enable the silt and debris to settle. The relatively clean water then entered a rectangular tank made of bricks. A stepped outlet from this tank allowed only clean water to trickle through to a second tank, also rectangular in shape. This second tank apparently constituted the primary source of water supply for Sringaverapura. There was also a third tank – this time a circular one – at right-angles to the second tank, which possessed an elaborate staircase allowing access to the lower levels of the water in that tank. The excavators of the site suggest that some shrines stood along the edge of this circular tank, and that the waters of this tank were used for ritual bathing and prayers. (Lal mentions terracotta sculptures, including of Siva and Kubera, recovered from the debris of this round tank). An elaborate waste weir, provided at an end of this tank, carried water out from the tank. This consisted of seven spill-channels, a crest and a final exit channel. The excess water was returned to the river, through this final exit channel. A series of wells in the bed of the tank allowed access groundwater even during the hot summer months. (Though no inscription associated with the tank has been found, Lal [1997:16] suggests, on grounds of circumstantial evidence, that a king Dhanadeva of Ayodhya built it).

One of the earliest artificial lakes known from ancient India – the 'Sudarshan' lake in Gujarat's Girnar area – is datable to the early period of the reign of the Mauryan dynasty emperors. This was first excavated during the reign of Emperor Chandragupta Maurya by one of his subordinates – an officer named Pushyagupta. Supplementary channels were later added, along with other improvements to the lake, by one 'Yavanaraja' Tushaspha during the reign of Emperor Ashoka (Chandragupta Maurya's grandson), in the 3rd Century BC. Nearly four centuries later, the lake was repaired by the Saka king, Mahakshatrapa Rudradaman of Ujjain, as is recorded in his Junagarh (or Girnar) Inscription of AD 150. The lake continued to exist over the ensuing period, as is attested by an inscription of AD 455, dating to the reign of Emperor Skanda Gupta of the Gupta Empire. This records that when the embankment-dam at Girnar broke, it was rebuilt in 455 AD by the local city governor, a man named Chakrapalita, son of Emperor Skanda Gupta's Provincial Governor, Parnadatta.

The largest known artificial lake of India was created in the middle of the 11th century by king Bhoj Parmar, the ruler of Dhar, at Bhojpur, near Bhopal, by constructing a vast embankment across two hills. The lake apparently received water from as many as 365 streams and springs. Though the lake has vanished, following the breaching of its embankment in 1434 AD, its traces indicate that the lake originally covered no less than 250 square miles, or over 65,000 hectares.

Health & Well Being

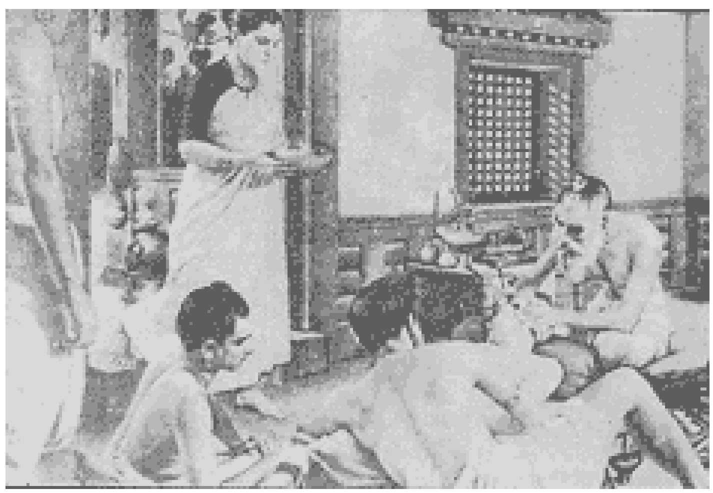
Ayurveda

Ayurveda as a science of medicine owes its origins in ancient India. Ayurveda consists of two Sanskrit words - 'ayur' meaning age or life, and 'veda' which means knowledge. Thus, the literal meaning of Ayurveda is the science of life or longevity. Ayurveda constitutes ideas about ailments and diseases, their symptoms, diagnosis and cure, and relies heavily on herbal medicines, including extracts of several plants of medicinal values. This reliance on herbs differentiates Ayurveda from systems like Allopathy and Homeopathy. Ayurveda has also always disassociated itself with witch doctors and voodoo.

Ancient scholars of India like Atreya, and Agnivesa have dealt with principles of Ayurveda as long back as 800 BC. Their works and other developments were consolidated by Charaka who compiled a compendium of Ayurvedic principles and practices in his treatise Charaka-Samahita, which remained like a standard textbook almost for 2000 years and was translated into many languages, including Arabic and Latin. 'Charaka-Samahita' deals with a variety of matters covering physiology, etiology and embryology, concepts of digestion, metabolism, and immunity. Preliminary concepts of genetics also find a mention, for example, Charaka has theorized blindness from the birth is not due to any defect in the mother or the father, but owes its origin in the ovum and the sperm.

Shalya Chikitsa

In ancient India, several advances were also made in the field of shalya chikitsa/medical surgery. Specifically these advances included areas like plastic surgery, extraction of cataracts, and even dental surgery. Roots to the ancient Indian surgery go back to at least circa 800 BC. Shushruta, a medical theoretician and practitioner, lived 2000 years before, in the ancient Indian city of Kasi, now called Varanasi. He wrote a medical compendium called 'Shushruta-Samahita. This ancient medical compendium describes at least seven branches of surgery: Excision, Scarification, Puncturing, Exploration, Extraction, Evacuation, and Suturing. The compendium also deals with matters like rhinoplasty (plastic surgery) and ophthalmology (ejection of cataracts). The compendium also focuses on the study the human anatomy by using a dead body.



In ancient India Medical Science supposedly made many advances. Specifically these advances were in the areas of plastic surgery, extraction of cataracts, and dental surgery. There is documentary evidence to prove the existence of these practices.

An artist's impression of an operation being performed in ancient India. In spite of the absence of anesthesia, complex operations were performed.

The practice of surgery has been recorded in India around 800 B.C. This need not come as a surprise because surgery (Shastrakarma) is one ofthe eight branches of Ayurveda the ancient Indian system of medicine. The oldest treatise dealing with surgery is the Shushruta Samahita (Shushruta's compendium). Shusruta who lived in Kasi was one of themany Indian medical practitioners who included Atraya and Charaka. He was one of the first to study the human anatomy. In the Shusruta, Samahita he has described in detail the study of anatomy withthe aid of a dead body. Shusruta's forte was rhinoplasty (Plastic surgery)and ophthalmialogy (ejection of cataracts). Shushruta has described surgery under eight heads Chedya (excision), Lekhya (scarification),Vedhya (puncturing), Esya (exploration), Ahrya (extraction), Vsraya (evacuation) and Sivya (Suturing).

In the 5th century BC, a celebrated Ayurvedic physician and surgeon, Sushruta, was blazing a path which would be trod by surgeons in the centuries to come. He lived, taught and practiced his art on the banks of the River Ganga in India. Many of Sushruta's contributions to medicine and surgery preceded similar discoveries in the Western world. He had a deep knowledge of anatomy, etiology, embryology, digestion, metabolism, genetics and immunity. Much of what we know about this inventive surgeon is contained in a series of volumes he authored, which are collectively known as the Susrutha Samhita. It may seem incredible, but Sushruta conducted complicated surgeries like cesareans, cataract, artificial limbs, fractures, urinary stones and even plastic surgery and brain surgery! He is considered to be the father of Plastic Surgery and Cosmetic Surgery since his technique for repairing the disfigured nose with a flap of skin from the forehead is practiced almost unchanged in technique to this day. Usage of anesthesia was well known in ancient India, and Sushruta was the first to prescribe the use of wine with incense of cannabis for anaesthesia. Sushruta was also perhaps the first surgeon in the world to describe different types of surgical instruments including endoscopes. In addition, he was the first surgeon to teach by performing operations on inanimate objects such as watermelons, clay plots and reeds- the forerunner of the modern practice of surgical workshops.

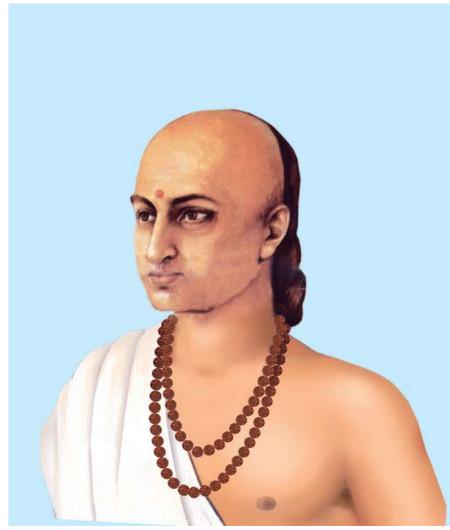
Yoga

Yoga is a system of exercise for physical and mental nourishment. The origins of yoga are shrouded in antiquity and mystery. Since Vedic times, thousands of years before, the principles and practice of yoga have crystallized. But, it was only around 200 BC that all the fundamentals of yoga were collected by Patanjali in his treatise, named Yogasutra, that is, Yoga-Aphorisms.

In short, Patanjali surmised that through the practice of yoga, the energy latent within the human body may be made live and released, which has a salubrious effect on the body and the mind. Now, in modern times, clinical practices have established that several ailments, including hypertension, clinical depression, amnesia, acidity, can be controlled and managed by yogic practices. The application of yoga in physiotherapy is also gaining recognition.

Ancient Indian Scientists

Aryabhatta



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

His most famous work, Aryabhattiya 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 was believed to have authored at least three astronomical texts 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 present demands.

He wrote that if 4 is added to 100 and then multiplied by 8 then added to 62,000 then divided by 20,000 the answer will be equal to the circumference of a circle of diameter twenty thousand. This calculates to 3.1416 close to the actual value 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 is evident through the writings of Aryabhata'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 (dhanur-yantra / chakra-yantra), a cylindrical stick yasti-yantra, an umbrella- shaped device called the chhatra-yantra, and water clocks of at least two types, bow- shaped and cylindrical.

Aryabhatta was aware that the earth rotates on its axis. 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 of the year as the exact length of the year. Aryabhatta also revealed that the circumference of the earth is 24,835 miles. The modern-day scientific calculation says it is 24,900 miles. Solar and lunar eclipses were also scientifically explained by Aryabhatta. India's first satellite Aryabhatta was named in his honour.

Bhaskara II

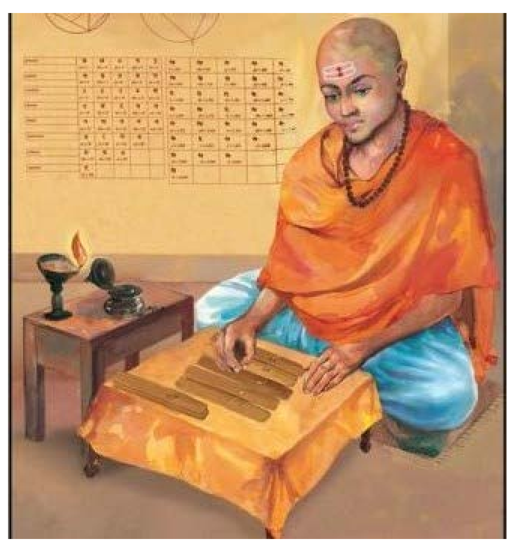
Bhaskara II, also known as Bhaskaracharya, was born in1114 AD near Vijjadavida or the modern-day Bijapur in the state of Karnataka. Born to a family of scholars, he learnt mathematics from his astrologer father Mahesvara. A leading mathematician of 12th century, he wrote his first work on the systematic use of the decimal number system. He also headed the astronomical observatory at Ujjain, the leading mathematical centre of ancient India.

His main work Siddhanta Sjhiromani, which has four parts, namely Lilavati, Bijaganita Grahaganita and Goladhaya and 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 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 7th 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 tradition has it that he named his first work, Lilavati after his famous mathematician daughter.

Brahmagupta

Brahmagupta (598–c.670 CE) was an Indian mathematician and astronomer who wrote two works on Mathematics and Astronomy: the Brāhmasphuṭasiddhānta (Extensive Treatise of Brahma) (628), a theoretical treatise, and the Khaṇḍakhādyaka, a more practical text. There are reasons to believe that Brahmagupta originated from Bhinmal.



Brahmagupta was the first to give rules to compute with zero. The texts composed by Brahmagupta were composed in elliptic verse, as was common practice in Indian mathematics, and consequently have a poetic ring to them. As no proofs are given, it is not known how Brahmagupta's mathematics was derived

It seems likely that Brahmagupta's works, especially his most famous text, the "Brahmasphutasiddhanta", were brought by the 8th Century Abbasid caliph Al-Mansur to his newly founded centre of learning at Baghdad on the banks of the Tigris, providing an important link between Indian mathematics and astronomy and the nascent upsurge in science and mathematics in the Islamic world.

In his work on arithmetic, Brahmagupta explained how to find the cube and cube-root of an integer and gave rules facilitating the computation of squares and square roots. He also gave rules for dealing with five types of combinations of fractions. He gave the sum of the squares of the first nnatural numbers as $n(n + 1)(2n + 1)/ 6$ and the sum of the cubes of the first nnatural numbers as $(n(n + 1)/2)^2$.

Brahmagupta's genius, though, came in his treatment of the concept of (then relatively new) the number zero. Although often also attributed to the 7th Century Indian mathematician Bhaskara I, his "Brahmasphutasiddhanta" is probably the earliest known text to treat zero as a number in its own right, rather than as simply a placeholder digit as was done by the Babylonians, or as a symbol for a lack of quantity as was done by theGreeks and Romans.

Brahmagupta established the basic mathematical rules for dealing with zero (1 + 0 = 1; 1 - 0 = 1; and 1 x 0 = 0), although his understanding of division by zero was incomplete (he thought that 1 ÷ 0 = 0). Almost 500 years later, in the 12th Century, another Indian mathematician, Bhaskara II, showed that the answer should be infinity, not zero (on the grounds that 1 can be divided into an infinite number of pieces of size zero), an answer that was considered correct for centuries. However, this logic does not explain why 2 ÷ 0, 7 ÷ 0, etc, should also be zero - the modern view is that a number divided by zero is actually "undefined" (i.e. it doesn't make sense).

Brahmagupta's view of numbers as abstract entities, rather than just for counting and measuring, allowed him to make yet another huge conceptual leap which would have profound consequence for future mathematics. Previously, the sum 3 - 4, for example, was considered to be either meaningless or, at best, just zero. Brahmagupta, however, realized that there could be such a thing as a negative number, which he referred to as "debt" as a opposed to "property". He expounded on the rules for dealing with negative numbers (e.g. a negative times a negative is a positive, a negative times a positive is a negative, etc).

Furthermore, he pointed out, quadratic equations (of the type $x^2 + 2 = 11$, for example) could in theory have two possible solutions, one of which could be negative, because $3^2 = 9$ and $-3^2 = 9$. In addition to his work on solutions to general linear equations and quadratic equations, Brahmagupta went yet further by considering systems of simultaneous equations (set of equations containing multiple variables), and solving quadratic equations with two unknowns, something which was not even considered in the West until a thousand years later, when Fermat was considering similar problems in 1657.

Brahmagupta even attempted to write down these rather abstract concepts, using the initials of the names of colours to represent unknowns in his equations, one of the earliest intimations of what we now know as algebra.

Brahmagupta dedicated a substantial portion of his work to geometry and trigonometry. He established $\sqrt{10}$ (3.162277) as a good practical approximation for π (3.141593), and gave a formula, now known as Brahmagupta's Formula, for the area of a cyclic quadrilateral, as well as a celebrated theorem on the diagonals of a cyclic quadrilateral, usually referred to as Brahmagupta's Theorem.

Madhava

Madhava sometimes called the greatest mathematician-astronomer of medieval India. He came from the town of Sangamagrama in Kerala, near the southern tip of India, and founded the Kerala School of Astronomy and Mathematics in the late 14th Century.

Although almost all of Madhava's original work is lost, he is referred to in the work of later Kerala mathematicians as the source for several infinite series expansions (including the sine, cosine, tangent and arctangent functions and the value of π), representing the first steps from the traditional finite processes of algebra to considerations of the infinite, with its implications for the future development of calculus and mathematical analysis.

Unlike most previous cultures, which had been rather nervous about the concept of infinity, Madhava was more than happy to play around with infinity, particularly infinite series. He showed how, although one can be approximated by adding a half plus a quarter plus an eighth plus a sixteenth, etc, (as even the ancient Egyptians and Greeks had known), the exact total of one can only be achieved by adding up infinitely many fractions. But Madhava went further and linked the idea of an infinite series with geometry and trigonometry. He realized that, by successively adding and subtracting different odd number fractions to infinity, he could home in on an exact formula for π (this was two centuries before Leibniz was to come to the same conclusion in Europe). Through his application of this series, Madhava obtained a value for π correct to an astonishing 13 decimal places.

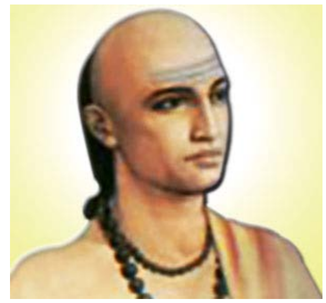
He went on to use the same mathematics to obtain infinite series expressions for the sine formula, which could then be used to calculate the sine of any angle to any degree of accuracy, as well as for other trigonometric functions like cosine, tangent and arctangent. Perhaps even more remarkable, though, is that he also gave estimates of the error term or correction term, implying that he quite understood the limit nature of the infinite series.

Madhava's use of infinite series to approximate a range of trigonometric functions, which were further developed by his successors at the Kerala School, effectively laid the foundations for the later development of calculus and analysis, and either he or his disciples developed an early form of integration for simple functions. Some historians have suggested that Madhava's work, through the writings of the Kerala School, may have been transmitted to Europe via Jesuit missionaries and traders who were active around the ancient port of Cochin (Kochi) at the time, and may have had an influence on later European developments in calculus.

Madhava series is any one of the series in a collection of infinite series expressions all of which are believed to have been discovered by Madhava, the founder of the Kerala school of astronomy and mathematics. These expressions are the infinite power series expansions of the trigonometric sine, cosine and arctangent functions, and the special case of the power series expansion of the arctangent function yielding a formula for computing π. The power series expansions of sine and cosine functions are respectively called Madhava's sine series and Madhava's cosine series. The power series expansion of the arctangent function is sometimes called Madhava–Gregory seriesor Gregory–Madhava series. These power series are also collectively called Taylor–Madhava series. The formula for π is referred to as Madhava–Newton series or Madhava–Leibnitz series or Leibniz formula for pi or Leibnitz–Gregory–Madhava series. These further names for the various series are reflective of the names of the Western discoverers or popularizers of the respective series.

Among his other contributions, Madhava discovered the solutions of some transcendental equations by a process of iteration, and found approximations for some transcendental numbers by continued fractions. In astronomy, he discovered a procedure to determine the positions of the Moon every 36 minutes, and methods to estimate the motions of the planets.

Manava



Manava (ca. 750 BC – 690 BC) is an author of the Indian geometric text of Sulba Sutras. The Manava Sulbasutra is not the oldest (the one by Baudhayana is older), nor is it one of the most important, there being at least three Sulbasutras which are considered more important. Historians place his lifetime at around 750 BC.

Manava would have not have been a mathematician in the sense that we would understand it today. Nor was he a scribe who simply copied manuscripts like Ahmes. He would certainly have been a man of very considerable learning but probably not interested in mathematics for its own sake, merely interested in using it for religious purposes. Undoubtedly he wrote the Sulbasutra to provide rules for religious rites and it would appear almost a certainty that Manava himself would be a Vedic priest. The mathematics given in the Sulbasutras is there to enable accurate construction of altars needed for sacrifices. It is clear from the writing that Manava, as well as being a priest, must have been a skilled craftsman.

Manava's Sulbasutra, like all the Sulbasutras, contained approximate constructions of circles from rectangles, and squares from circles, which can be thought of as giving approximate values of π. There appear therefore different values of π throughout the Sulbasutra, essentially every construction involving circles leads to a different such approximation. The paper of R.C. Gupta is concerned with an interpretation of verses 11.14 and 11.15 of Manava's work which give $\pi = 25/8 = 3.125$.

Charaka

Charak, sometimes spelled Charaka, was one of the principal contributors to the ancient art and science ofAyurveda, a system of medicine and lifestyle developed in Ancient India. He is sometimes dated to c. 800 BC as he worked on older treatise by Purnvasu Atreya (c.1000 BC) and Agnivesha Agnivesa, of whose work, the Agnivesha Tantra, was the basis of his Charaka Samhita Charaka is also referred to as the Father of Medicine.

The term Charaka is a label said to apply to "wandering scholars" or "wandering physicians". According to Charaka's translations, health and disease are not predetermined and life may be prolonged by human effort and attention to lifestyle. As per Indian heritage and science of Ayurvedic system, prevention of all types of diseases have a more prominent place than treatment, including restructuring of lifestyle to align with the course of nature and four seasons, which will guarantee complete wellness. He seems to have been an early proponent of prevention is better than cure doctrine. The following statement is attributed to Acharya Charaka:

> “ A physician who fails to enter the body of a patient with the lamp of knowledge and understanding can never treat diseases. He should first study all the factors, including environment, which influence a patient's disease, and then prescribe treatment. It is more important to prevent the occurrence of disease than to seek a cure. ”

These remarks may appear obvious today, though they were often not heeded to. Several other such remarks, which are held in reverence even today, were made by Charaka in his famous Ayurvedic treatise Charaka Samhita. Some of them pertain to the fields of physiology, etiology and embryology.

Sushruta

An ancient Indian surgeon dating back to almost 2500 years ago, Sushruta made numerous contributions to the field of surgery. Sushruta is regarded as the father of surgery. He authored the book Sushruta Samhita in which he described over 300 surgical procedures, 120 surgical instruments and classified human surgery in eight categories. He lived, taught and practised his art on the banks of the Ganges which can now be 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, etc. He also described removal of the prostate gland, urethral, hernia surgery, caesarian section. He classified details of the six types of dislocations, twelve varieties of fractures and classification of the bones and their reaction to the injuries. He has written about 76 signs of various eye diseases, symptoms, prognosis, medical/surgical interventions and cataract surgery. There is also description of method of stitching the intestines by using ant-heads as stitching material. He even introduced wine to minimize the pain of surgical incisions.

Sushruta details about 650 drugs of animal, plant, and mineral origin. Other chapters in Sushruta Samhita put emphasis on the well-being of children and expectant mothers. Sushruta has also detailed about 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.

Modern Indian Sciences

Atomic Energy

India has a flourishing and largely indigenous nuclear power program and expects to have 14,600 MWe nuclear capacity on line by 2020. It aims to supply 25% of electricity from nuclear power by 2050. India has uniquely been developing a nuclear fuel cycle to exploit its reserves of thorium. India has a vision of becoming a world leader in nuclear technology due to its expertise in fast reactors and thorium fuel cycle.

The main objective of India's nuclear energy programme is to use it for power generation, applications in agriculture, medicine, industry, research and other areas. India is today recognised as one of the most advanced countries in nuclear technology. Accelerators and research and nuclear power reactors are now designed and built indigenously. Currently, eight nuclear stations are producing eight billion kilowatt of electricity.

Nuclear power for civil use is well established in India. Since building the two small boiling water reactors at Tarapur in the 1960s, its civil nuclear strategy has been directed towards complete independence in the nuclear fuel cycle.

As a result, India's nuclear power program has proceeded largely without fuel or technological assistance from other countries. The pressurized heavy-water reactor (PHWR) design was adopted in 1964, since it required less natural uranium than the BWRs, needed no enrichment, and could be built with the country's engineering capacity at that time – pressure tubes rather than a heavy pressure vessel being involved. Its power reactors to the mid-1990s had some of the world's lowest capacity factors, reflecting the technical difficulties of the country's isolation, but rose impressively from 60% in 1995 to 85% in 2001-02.

India's nuclear energy self-sufficiency extended from uranium exploration and mining through fuel fabrication, heavy water production, reactor design and construction, to reprocessing and waste management. It has a small fast breeder reactor and is building a much larger one. It is also developing technology to utilise its abundant resources of thorium as a nuclear fuel.

The Atomic Energy Establishment was set up at Trombay, near Mumbai, in 1957 and renamed as Bhabha Atomic Research Centre (BARC) ten years later. Plans for building the first Pressurised Heavy Water Reactor (PHWR) were finalised in 1964, and this prototype – Rajasthan 1, which had Canada's Douglas Point reactor as a reference unit, was built as a collaborative venture between Atomic Energy of Canada Ltd (AECL) and NPCIL. It started up in 1972 and was duplicated Subsequent indigenous PHWR development has been based on these units, though several stages of evolution can be identified:

PHWRs with dousing and single containment at Rajasthan 1-2, PHWRs with suppression pool and partial double containment at Madras, and later standardized PHWRs from Narora onwards having double containment, suppression pool, and calandria filled with heavy water, housed in a water-filled calandria vault.

Title	No. of Units	Capacity (MWe)	Established Date
Tarapur Atomic Power Station (TAPS), Maharashtra	1	160	October 28, 1969
Tarapur Atomic Power Station (TAPS), Maharashtra	2	160	October 28, 1969
Tarapur Atomic Power Station (TAPS), Maharashtra	3	540	August 18, 2006
Tarapur Atomic Power Station (TAPS), Maharashtra	4	540	September 12, 2005
Rajasthan Atomic Power Station (RAPS), Rajasthan	1	100	December 16,1973
Rajasthan Atomic Power Station (RAPS), Rajasthan	2	200	April 1,1981
Rajasthan Atomic Power Station (RAPS), Rajasthan	3	220	June 1, 2000
Rajasthan Atomic Power Station (RAPS), Rajasthan	4	220	December 23, 2000
Rajasthan Atomic Power Station (RAPS), Rajasthan	5	220	February 4, 2010
Rajasthan Atomic Power Station (RAPS), Rajasthan	6	220	March 31, 2010
Madras Atomic Power Station (MAPS), Tamilnadu	1	220	January 27,1984
Madras Atomic Power Station (MAPS), Tamilnadu	2	220	March 21,1986
Kaiga Generating Station (KGS), Karnataka	1	220	November 16, 2000
Kaiga Generating Station (KGS), Karnataka	2	220	March 16, 2000
Kaiga Generating Station (KGS), Karnataka	3	220	May 6, 2007
Kaiga Generating Station (KGS), Karnataka	4	220	January 20, 2011
Kudankulam Atomic Power Project, Tamilnadu	1	1000	December 31, 2014
Narora Atomic Power Station (NAPS), Uttarpradesh	1	220	January 1,1991
Narora Atomic Power Station (NAPS), Uttarpradesh	2	220	July 1,1992
Kakrapar Atomic Power Station (KAPS), Gujarat	1	220	May 6, 1993
Kakrapar Atomic Power Station (KAPS), Gujarat	2	220	September 1,1995

Biotechnology

India has been the frontrunner among the developing countries in promoting multi- disciplinary 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 constituted in 1982. A 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.

Highlights

- 3rd biggest biotech industry in the Asia-Pacific region.
- No. 1 producer of Hepatitis B vaccine recombinant.
- India is amongst the top 12 biotech destinations in the world and ranks third in the Asia-Pacific region.
- India has the second-highest number of USFDA–approved plants, after the USA.
- India adopted the product patent regime in 2005.

Information Technology

PARAM 8000

After being denied Cray supercomputers as a result of a technology embargo, India started a program to develop indigenous supercomputers and supercomputing technologies. Supercomputers were considered a double edged weapon capable of assisting in the development of nuclear weapons.For the purpose of achieving self-sufficiency in the field, the Centre for Development of Advanced Computing (C-DAC) was set up in 1988 by the then Department of Electronics with Dr. Vijay Bhatkar as its Director. The project was given an initial run of 3 years and an initial funding of ₹ 300,000,000, the same amount of money and time that was usually expended to purchase a supercomputer from the US.In 1990, a prototype was produced and was benchmarked at the 1990 Zurich Supercomputering Show. It surpassed most other systems, placing India second after US.

Unveiled in 1991, PARAM 8000 used Inmos 8000 transputers. Transputers were a fairly new and innovative microprocessor architecture designed for parallel processing at the time. It distributed memory MIMD architecture with a reconfigurable interconnection network. It had 64 CPUs.

Param Yuva II

Param Yuva II was made by Centre for Development of Advanced Computing in a period of three months, at a cost of ₹16 crore (US$3 million), and was unveiled on 8 February 2013. It performs at a peak of 524 teraflops and consumes 35% less energy as compared to Param Yuva. It delivers sustained performance of 360.8 teraflops on the community standard Linpack benchmark, and would have been ranked 62 in the November 2012 ranking list of Top500. In terms of power efficiency, it would have been ranked 33rd in the November 2012 List of Top Green500 supercomputers of the world.It is the first Indian supercomputer achieving more than 500 teraflops.

Param Yuva II will be used for research in space, bioinformatics, weather forecasting, seismic data analysis, aeronautical engineering, scientific data processing and pharmaceutical development. Educational institutes like the Indian Institutes of Technology and National Institutes of Technology can be linked to the computer through the national knowledge network. This computer is a stepping stone towards building the future petaflop-range supercomputers in India.

EKA

Tata's supercomputer, EKA, is the 4th fastest computer in the world and the fastest in Asia at SC07, the International Conference for High Performance Computing, Networking, Storage, and Analysis at Reno, Nevada in the US. Read on to know what makes it so.

EKA, meaning 'one' is Sanskrit, is the supercomputer built at the Computational Research Laboratories (CRL) in Pune. The Tata Group's CRL has developed the EKA as a wholly indigenous high-performance computing solution that will be used for the government's scientific research and for the Tata Group's own product research and development.

The EKA made its way to the Top 500 list at the international conference in Reno – the first time an Indian entry has been ranked so high. The EKA is based on the Hewlett Packard Cluster Platform 3000 BL46Oc system. It has a peak performance of 170 teraflops (Trillion floating point operations per second) and uses nearly 1,800 computing nodes. Its sustained performance of 120 teraflops cleared the performance benchmarks laid down by the worldwide community that ranks computers.

The EKA was built using a circular dense data center layout, unlike the typical densely-packed supercomputers, making it the first time a site has used this kind of architecture. It has been designed-based on the CLOS architecture with off-the-shelf servers and Infiniband interconnect technologies with the Linux Operating System. CRL is the first site in the world to use the Dual Data Rate Infiniband with fiber-optic cable technology to achieve high-performance solutions.

Built with the support of Tata Consultancy Service and partners like HP, Intel, and Mellanox at a cost of US$ 30 million in about 20 months, the EKA is considered Tata's greatest contribution in placing India on the global IT map. The Tata Group retains the patent rights to develop the supercomputer. With this technology, the EKA can be used in the fields of drug discovery, nanotechnology, and automotive engineering.

The other less-talked-about entry from India is another supercomputer from the Indian Institute of Science, Bangalore. This too has found its place at number 58 in the Top 500 list. 7 other supercomputers from India too have found a place in the Top 500.

Top science centres in the country like Isro, IISc and select IITs have started work on a mission to build and run the fastest supercomputer that will work at exaflops per second, faster than the current Petaflops performanceworldwide. There is no exaflop supercomputer in the world yet and the first one is expected to emerge around 2019-2020, which is exactly when India has planned to launch its own.

India's proposed new supercomputer is set to work at 132 exaflops per second as against an 1 exaflops per second machine being built by Cray Incorporated, the iconic American computer company which has projected that its machine would be ready by 2020. The IISc-Isro project has the backing of the Centre which has set aside Rs 11,000 crore for its development (roughly $2 bn), apart from support to the other major initiative of having 100-150 supercomputers at the local, district and national levels under a national programme.

Prof N Balakrishnan, Professor at the Supercomputer Education and Research Centre (SERC) and Associate Director, IISc, told Deccan Herald: "The world does not have an exaflop supercomputer yet. The first one is to come up around 2019. Research work on exaflops is underway at IISC, Isro and a few IITs and C-DAC for India's own proposed exaflop supercomputer. It is a collective project and scientists from around the country are involved in it.

Oceanography

India has a coastline of more than 7600 km and 1250 islands. The Department of Ocean Development was established in 1981 to ensure optimum utilisation of living resources, exploitation of non-living resources such as hydrocarbons and minerals, and to produce ocean energy. Two research vessels, ORV Sagar Kanya and FROV Sagar Sampada, are assessing and evaluating the resource potential.

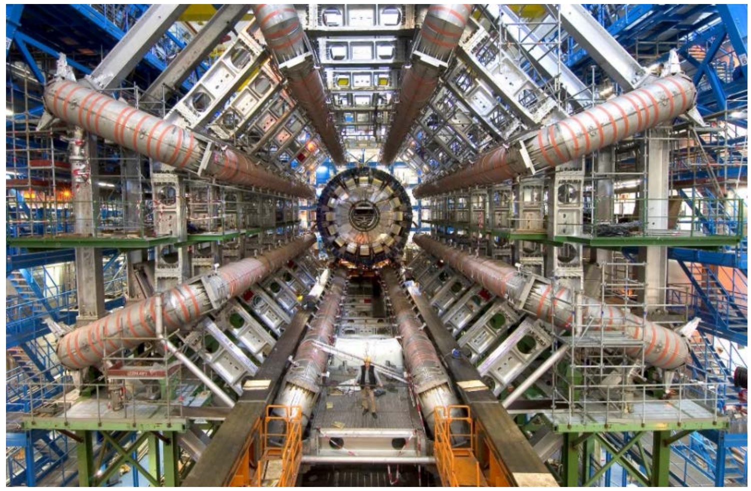
Survey and exploration efforts have been directed to assess sea bed topography, and concentration and quality of mineral nodules. India has sent 13 scientific research expeditions to Antarctica since 1981, and has established a permanently manned base, Dakshin Gangotri. A second permanent station, an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

A National Institute of Ocean Technology has been set up for the development of ocean- related technologies.

National Institute of Oceanography (NIO) holds about 50 patents, 60% of which has come from marine biotechnology studies. It has now been realized that organisms living in the marine environment carry a variety of molecules that could prove beneficial in developing new drugs and other products for healthcare. This is a new area of research that NIO's researchers are pursuing. Their studies have yielded not only research publications, but intellectual property for the institute. Another area of research that has generated patents for the institute is marine instrumentation. Some recent technologies developed by the institute include one for an Autonomous Underwater Vehicle (AUV).

Particle Physics

India at Large Hadron Collider (LHC)



The Standard Model is the widely accepted modern theory of elementary particles and their interactions. The model classifies the elementary particles into three broad groups—leptons or the light particles (such as electrons), hadrons or the heavier particles (such as protons and neutrons, that are formed from quarks) and bosons, the carriers of fundamental forces. Leptons and hadrons interact by exchanging bosons, each of which is responsible for a different fundamental force. Photons mediate the electromagnetic force, which affect all charged particles. Gluons mediate the strong nuclear force, which affects quarks. The weakons (intermediate vector bosons) mediate the weak nuclear force, responsible for the reactions that fuel the Sun and for the emission of beta particles from certain nuclei. The Standrad Model stipulates that all particles acquire mass through their interaction with Higgs boson (popularly referred to as God particle). The Standard Model takes into account 18 particles—six quarks (up, down, charm, top, strange, and bottom), six leptons (electron neutrino, muon, muon neutrino, tau and tau neutrino) and six mediator bosons (gluon, photon, W+, W-, Z0 and Higgs). The search for Higgs boson proved to be more difficult. The main objective of Large Hadron Collider (LHC) also called the Big Bang Experiment was to prove or disprove the existence of Higgs boson. The LHC is a multi-billion Euro research facility created by CERN (Counseil European pour la Recherche Nuclaire but later renamed as Organisation Europeenne pour la Recherche Nuclaire). In English it is called European Organisation for Nuclear Research. The total estimated cost of LHC is about 4.5 billion euro (the currency of European Union) and its annual operating budget is about 800 million euro.

The announcement that the LHC finally caught a glimpse of the elusive Higgs boson created world-wide excitement. The very name of the particle (Higgs boson) connects the name of India's best-known physicists Satyendra Nath Bose. The fundamental particles in the universe is divided into two groups—fermions (named after the Italian physicist Enrico Fermi) and bosons.

The LHC has proved that the Higgs boson, the existence of which was predicted for ensuring the correctness of the Standard Model, does exist. However, its pursuit does not end here. It will continue to delve into some other fundamental issues in particle physics like super symmetric particles, detailed structure of the top quark and heavy gauge bosons. It will also search for a new phase of strongly interacting matter at extremely high energy densities called the Quark Gluon Plasma (QGP) and also look for the constituents or the conditions which create dark matter in the universe.

India's participation in the Mega Science Pursuit that is LHC is very significant. Scientists from India have taken part in building the LHC machine and two of the four experiment set-ups or detectors namely, CMS (Compact Muon Selenoid) Detector and ALICE (A Large Ion Collider Experiment). It is the CMS Experiment which led to the discovery of the highly elusive Higgs boson. ALICE has been built to search for QGP. India has also contributed significantly in the development of the Worldwide LHC Computing Grid (WLCG).

India's collaboration with CERN began in the 1960s in the form of scientist-to-scientist and institutional collaboration. The first recognition of India's involvement with the LHC came up in 1980s when scientists from the Tata Institute of Fundamental Research (TIFR), Mumbai made significant contribution to the development of L3 detector. In 1991, the Department of Atomic Energy (DAE), Government of India and CERN signed an agreement of cooperation for a period of 10 years. Under this agreement the Raja Ramanna Centre for Advanced Technology, Indore, successfully supplied a few subsystems for the up gradation of Large Electron Positron (LEP) collider-200. This agreement made it possible for high energy physicists working in different DAE institutions and universities (Supported by DST as part of the agreement signed between DST and DAE) to take part in research in particle physics being carried out at CERN and to make important contributions in a frontier area of research. In March 1996, India joined the newly launched LHC project. This was made possible by a protocol signed between DAE and CERN. India agreed to provide in-kind contributions in terms of ideas, hardware and skilled manpower. Realising the significance of India's contributions, the CERN Governing Council accorded India the Observer Status. Soon India will become an Associate Member of the CERN, which will take India's collaboration to which will take India's collaboration to a new height. India has arrived at global mega science scene through its participation at LHC. India is also participating in the FAIR project in Germany and TMT project in USA. Several other international consortia have approached India for participation.

Today about 200 scientists and research students in India are involved with the LHC project. The collaboration with CERN has led to the convergence of national capacities. The community of high energy physicists has been charged with new challenges. The Indian industry has found new opportunities. The collaboration has created many spin-off technologies that include detectors, ultra-pure materials, silicon chip and high-vacuum technology. It has fired the imagination of young researchers involved in the project. The project clearly demonstrated team spirit among the participants.

The following institutions/universities of India are taking part or in the process of taking part in the LHC project: Aligarh Muslim University, Aligarh, Bhabha Atomic Research Centre, Mumbai, Bose Institute, Kolkata, Delhi University, Delhi, Guwahati University, Guwahati; Jammu University, Jammu; Indian Institute of Technology Bombay, Mumbai; Indira Gandhi Centre for Atomic Research, Kalapakkam; Institute of Physics, Bhubaneswar; Panjab University, Chandigarh; Raja Ramanna Centre for Advanced Technology, Indore; Rajasthan University, Jaipur; Saha Institute of Nuclear Physics, Kolkata; Tata Institute of Fundamental Research, Mumbai; Variable Energy Cyclotron Centre, Kolkata; Visva Bharati University, Shanti Niketan. In coming years more institutions/universities are expected to take part in the project.

A Nataraja statue was gifted to CERN by the Government of India as a symbol of India's long-standing relationship with CERN. Nataraja, the Cosmic Dancer, depicts a dancing Lord Shiva trampling ignorance. Speaking at the unveiling ceremony, Dr Anil Kakodkar, Chairman of the Indian Atomic Energy Commission and Secretary to the Government of India, expressed his satisfaction that "the Indian scientific community is part of the quest for understanding the Universe". India's involvement with CERN dates back to the early 1960s.

Space Sciences

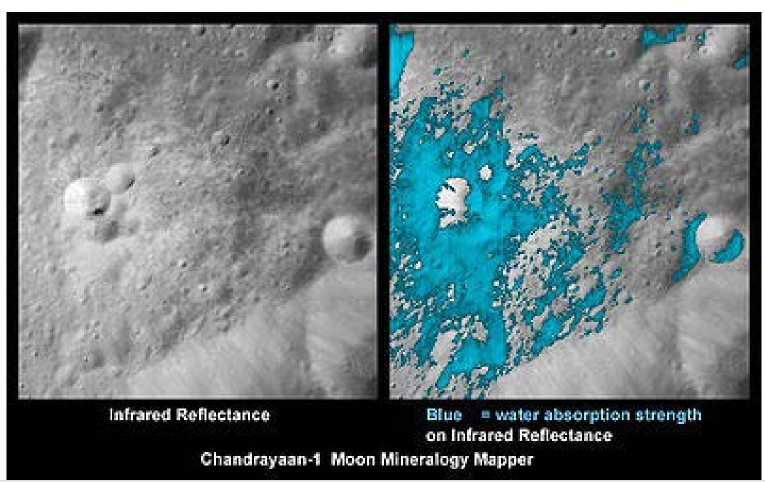
Chandrayaan Mission

India after having established capability to launch satellites into space decided to embark on undertaking an unmanned mission to the Moon. On 15 August 2003 (the 56th Independence Day) the then Prime Minister of India announced: "Our country is now ready to fly high in the field of science. I am pleased to announce that India will send her own spacecraft to the moon by 2008. It is being named Chandrayaan-I".

Chandrayaan-1 was launched by the Indian Space Research Organisation (ISRO) on 22 October 2008 at 6:22 AM IST from Satish Dhawan Space Centre. It was sent to the Moon in a series of orbit-increasing manoeuvres around the Earth over a period of 21 days instead of sending it on a direct trajectory of the Moon. The spacecraft was successfully inserted into lunar orbit on 8 November 2008. The Mission was expected to operate for two years. However, the communication with the spacecraft was suddenly lost on 29 August 2009. The Mission was a major boost for India's space programme. It proved India's capability in developing its own technology in exploring the Moon.

Some of the achievements of the Mission are:

- Detected water on Moon.
- Confirmed the magma ocean hypothesis that Moon was once a completely molten body.
- Recorded images of the landing sites of the US spacecraft.
- Provided high-resolution spectral data on the mineralogy of the Moon.
- Enabled scientists to study the interaction between the solar wind and the Moon, a planetary body without a magnetic field.
- Confirmed the presence of calcium and carried out most accurate measurement yet of magnesium, aluminium and iron on the lunar surface.
- Discovered a large cave below the lunar surface, an empty volcanic tube measuring about 2 kilometres in length and 360 meters in width. Japanese Lunar Orbiter, Kaguya (SELENE), had also discovered a cave on the Moon.



India's Mars Mission - Mangalyaan

"Astronomy and space science have always caught the imagination of youth world over. When Indian moon mission through Chandrayaan 1 succeeded, it is not only the Indian Space Community but also the youth of the country which got excited. This has encouraged the Indian Space Organisation (ISRO) to launch bolder and more ambitious deep missions. In August 2010, a specially-constituted task force met and concluded that India had the capability to launch and unmanned scientific mission to Mars. Preparedness of scientists and engineers at various ISRO centres to launch this unmanned flight scheduled is evident from their desire to plan the 'lift off' in October-November 2013. This Indian mission to the Red Planet, is basically targeted towards the youth of India. It would hopefully inspire youth to study science, technology and engineering and mathematic known as STEM."

T. Ramasami, Secretary, Department of Science and Technology in his Foreword to the book, Mars Beckons India: The Story of India's Mission to Mars by Srinivas Laxman, Vigyan Prasar, 2013.

After the successful completion of the Chandrayaan-1 mission ISRO launched another ambitious mission, the Mars Orbiter Mission (MOM) or the Manglayaan mission. The Government of India approved the project the project on 3 August 2012. The Mission was launched by ISRO by using a Polar Satellite Launch Vehicle at 2:38 PM IST on 5 November 2013.

The MOM is India's first interplanetary Mission. It is essentially a "Technology demonstration" project. One of the main objectives of India's Mars mission is to develop the technologies required for design, planning, management and operation of an interplanetary mission.

The technological and scientific objectives of the Mission are:

- Design and realization of Mars orbiter.
- Deep space communication, mission planning and management.
- Incorporation of autonomous features to handle contingency situation.
- Exploration of Mars surface features, morphology, mineralogy and Martian atmosphere by indigenous instruments.

The Mars Orbiter Mission has five scientific payloads to observe Martian surface and exosphere extending up to 80,000 km. They are:

- Mars Colour Camera (MCC) for optical imaging.
- Thermal Infrared Imaging Spectrometer (TIS) for mapping surface composition and mineralogy.
- Methane Sensor for Mars (MSM) for detecting the presence of methane.
- Mars Exospheric Neutral Composition Analyzer studying the neutral composition of Martian atmosphere.

- Lyman Alpha Photometer (LAP) for studying escape processes through upper atmosphere through deuterium/hydrogen.

Together the payloads had a weight of 15 kg.

Mangalyaan completed its six-month mission on March 24, but will remain operational even after its assignment duration expires. Indian Space Research Organisation says that the mission would technically end on March 24, 2015. The spacecraft will remain operational even after that as there is no fuel constraint. This will help us delve deeper into the seasons and climate on Mars. Mangalyaan was able to capture some beautiful images of Mars and have got ample data. Analysis of the data is being done and once this is final, it will be made public.

On September 24, 2014, India created history by becoming the first country to succeed on its first Mars mission when the Mars Orbiter Mission (MOM) slipped into the orbit of the Red Planet after a few nail-biting moments. The country joined the United States, European Space Agency and the former Soviet Union in the elite club of Martian explorers with the MOM. The five payloads on the spacecraft were scheduled to carry out experiments for six months. A lot would depend on the blackout period for Mars in June. The next challenge for the spacecraft will be in June next year when all three - Mars, Earth and Sun-will be in one line. There will be no communication (blackout period) with the spacecraft for nearly 14 days. The blackout would be experienced between June 8 and 22 as the Sun would come between Earth and Mars. During the blackout period, the spacecraft would be in fully autonomous mode and no data would be transmitted to or from it. ISRO is currently planning the launch of the fourth out of seven in the Indian Regional Navigational Satellite System (IRNSS) series of satellites after IRNSS-1A, IRNSS-1B and IRNSS-IC. These satellites would provide India's own navigational services.

Health Mission: Polio Eradication

India is now officially declared 'Polio Free' by the World Health Organisation. India is one of the 11 countries in the South East Asian region which have been certified as being free of the wild polio virus.

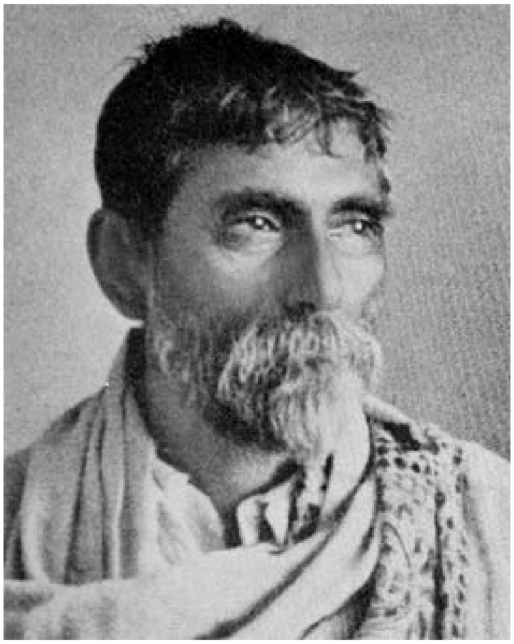
This achievement makes the South-East Asia Region, the fourth WHO Region to be certified as polio-free, after the Region of the Americas in 1994, the Western Pacific Region in 2000 and the European Region in 2002.

India has been polio free since January 2011. India embarked on the programme to eradicate polio 19 years ago in 1995, when the disease used to cripple more than 50,000 children in the country every year. This achievement has been possible with resolute will at the highest levels, technological innovations like the indigenous bivalent polio vaccine, adequate domestic financial resources and close monitoring of polio programme, with which immunization levels soared to 99 per cent coverage and India achieved polio eradication. A 2.3 million strong team of polio volunteers and 150,000 supervisors worked day and night to reach every child. A 2.3 million strong team of polio volunteers and 150,000 supervisors worked day and night to reach every child.

WHO, UNICEF, Rotary International, Bill and Melinda Gates Foundation and others stakeholders including the parents of the children, for their strong technical and operational supported to this grand achievement.

Modern Indian Scientists

Acharya Prafulla Chandra Ray—Founder of the Indian School of Modern Chemistry



"A more remarkable career than that of P. C. Ray could not well be chronicled", wrote Nature, the famous international scientific journal. He was a meticulous researcher. He published about 120 research papers mostly in research journals of international repute. Ray conducted systematic chemical analysis of a number of rare Indian minerals with the object of discovering in them some of the missing elements in Mendeleev's Periodic Table. In this process he isolated mercurous nitrite in 1896, which brought him international recognition, as it was a compound, which was not known then. Prafulla Chandra Ray was the founder of the Indian school of modern chemistry. He was a pioneer of chemical industries in India.

Ray was born on 2 August 1861 in a village in the district of Jessore (subsequently of Khulna), now in Bangladesh. Ray's early education was in his village school, founded by his father. He then studied at the metropolitan College (later named Vidyasagar College) in Kolkata. . He was a recipient of the prestigious Gilchrist Scholarship and studied at the Edinburgh University. In 1885, Ray obtained his BSc degree and in 1887 he was awarded the DSc degree of the Edinburgh University. After retiring from the Presidency College in 1916, Ray joined the University College of Science, Calcutta University at the invitation of Asutosh Mookerjee.

The first volume of Ray's celebrated work, The History of Indian Chemistry was published in 1902. The second volume was published in 1908. It was Marcellin Pierre Eugene Berthelot (1827-1907), who inspired to undertake this monumental work. Ray's Hindu Chemistry was immediately recognised as a unique contribution in annals of history of science.Ray died on 16 June 1942 in his living room in the University College of Science of the Calcutta University surrounded by his students (whom he loved most), friends and admirers.

Mercurous Nitrite and Related Compounds: In 1895 Prafulla Chandra reported the first synthesis of the hitherto unknown mercurous nitrite, HgzCN02)Z- This event was described by him in his autobiography as "the discovery of mercurous nitrite opened a new chapter in my life". It is relevant to mention here that stable mercury (I) complexes are sparse in literature, even today, owing to the instability of mercury (I) towards disproportionation to mercury (II) and metallic mercury in solution. Moreover, the nitrite ion is not very stable and can undergo facile decomposition. The compound, HgzCN02)2 is thus a fascinating example of a stable substance composed of two relatively unstable ions. The preparation of Hg2 (NO)2 was an accidental discovery. He wanted to prepare water soluble mercurous nitrate as an intermediate for the synthesis of calomel, Hg2 C12. Accordingly, dilute aqueous nitric acid (1 :4) was reacted with excess mercury. To his surprise this resulted in the formation of yellow crystalline HgzCN02)2' Hg (excess) + HN03 (dilute) (1). This result was first published in the Journal of Asiatic Society of Bengal which was immediately noticed by Nature. This was the beginning of a series of thorough investigations which resulted in many significant publications on this nitrite and its derivatives.

Ammonium Nitrite and Alkylammonium : Nitrites One of the very notable contributions ofPrafulla Chandra in the field of nitrite chemistry was the synthesis of ammonium nitrite in pure form via double displacement between ammonium chloride and silver nitrite, (2). (2) Ammonium nitrite, so formed, was sublimed at 32-33°C under reduced pressure to afford crystalline colourless needles. It had all along been believed that ammonium nitrite undergoes fast thermal decomposition yielding N2 and H20. (3) Prafulla Chandra established that this reaction is far less facile than thought. He carried out a series of experiments to show that pure ammonium nitrite is indeed stable and it can be sublimed without decomposition even at 60°C. The stability of this salt in its vapour state was firmly established by vapour density measurements. He presented the results in a meeting of the Chemical Society in London and the scientific audience including William Ramsay was greatly impressed. Nature (August 15, 1912) immediately highlighted the successful preparation of 'ammonium nitrite in tangible form' and the determination of the vapour density of 'this very fugitive salt'. The details of these experiments were published in the Journal of Chemical Society, London in the same year.

Organic Sulphur Compounds: In the College of Science, Prafulla Chandra made major contributions to the chemistry of organic sulphur compounds. He synthesised new compounds and studied their interactions with the salts of mercury. Moreover, ligating properties of some of these thio-compounds were investigated. Long-chain sulphur species, sulphur-containing condensed heterocycles and thioketones are some of the systems that he synthesised. For example, as a by-product of the synthesis of 1,4-dithian (Figure 4) from dithioethylene glycol and ethylene bromide, he isolated the long chain compound, BrC2HiSC2H4)48Br (5), which was 'the first instance of a crystalline organic sulphur compound of such high molecular weight as 3068'. Br-C2 H4 -Br + NaS-C2 H4 -SNa + Br-C2H4-Br + ... + NaS-C2H4- SNa + Br-C2H4 - Br ~BrC2H4(SC2H4)nBr + nNaBr (5) He also worked on the synthesis of condensed heterocyclic systems. Of these, the synthesis of triethylene tri- and tetrasulphides from simple reactions of ethylene dibromide and alcoholic KSH (6) are noteworthy. Potassiulll permanganate oxidation of the tetrasulphide to the corresponding sulphone compound (7) was also examined. A brief report of his work on the synthesis of thiocamphor and other cyclic thioketones was published in Nature in 1934.

Coordination Compounds: Prafulla Chandra made extensive contributions to the coordination chemistry of the heavier transition metal ions like platinum, iridium and gold. Particularly noteworthy are his studies on organic sulphides such as methyl sulphide, ethyl sulphide, diethyl sulphide and diethyl disulphide as ligands. Complexes of different types were isolated and their compositions were deduced based on elemental analysis and molar conductance. From the reaction of diethyl sulphide with iridium tetrachloride he isolated two isomers of composition IrCI3.3Et2S, one orange and another red. The orange compound is now known to have the pseudo octahedral meridional geometry and not the facial geometry (Figure 6b) assigned by Prafulla Chandra. This work indeed represents the isolation of the first mixed halide octahedral thioether compound of the generic type MX3 (R2S)3 which now has rich chemistry (M=lr(III), Rh(III), Os(lll) and Ru(III); X = Cl, Br, I) representing the efforts of many later workers in different countries. The first seed was however sown by Prafulla Chandra.

Dr.Anil Kakodkar

Dr Anil Kakodkar, the famous Indian nuclear scientist was born on 11 November 1943 in the village Barawani, 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 VJTI in Bombay University in 1963 to obtain a degree in Mechanical Engineering.

In the year 1964, Anil Kakodkar joined the Bhabha Atomic Research Centre (BARC).

He was 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 also was also in 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 the year 1996, Anil Kakodkar became the youngest Director of the BARC after Homi Bhabha himself. From the year 2000 onwards, he has been leading the Atomic Energy Commission of India. Dr Anil Kakodkar has been playing a crucial part 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.

Anna Modayil Mani (1918-2001)

Anna Modayil Mani (Commonly known as Anna Mani) is one of the most distinguished Indian scientists. She greatly contributed to India's self-sufficiency in meteorological instruments. On realising the potential of solar energy as an alternate source of energy for a tropical country like India she took upon herself the task of generating data on seasonal and geographical distribution of solar energy in India. She worked on a number of projects for harnessing wind energy. Much before the role of ozone in shielding all life forms on Earth was understood, Anna Mani started working on atmospheric ozone. In recognition of Anna Mani's phenomenal contribution to ozone studies, she was made a member of the International Ozone Commission.

Anna Mani was greatly influenced by the ideals of Mahatma Gandhi who led the India's freedom struggle. She wore Khadi all her life. She is regarded an early feminist. She did not marry and devoted her life to the pursuit of scientific studies.

Anna Mani was born on 23 August 1918 in a wealthy family in Peermedu in Kerala, then part of the State of Travancore. She was the seventh of eight children of her parents. She developed an avid interest in reading in her childhood.In 1939, she obtained her BSc (Honours) degree in Physics and Chemistry from the Madras Presidency College. She got a scholarship for graduate studies in the Indian Institute of Science (IISc) in Bengaluru (then Bangalore). Anna Mani started working for her PhD degree under the supervision of C. V. Raman at the IISC. She worked on the spectroscopy of diamonds and rubies.Anna Mani submitted her PhD dissertation to the Madras University, as in those days it was the Madras University which formally granted degrees to the research students working at the IISc. However, she never got the PhD degree as she did not qualify for PhD degree as she did not have an MSc degree.

After working for three years at Raman's Laboratory, Anna Mani won a scholarship for higher studies in England in 1945. She wanted to pursue her research interest in physics but the scholarship was meant for working in the area of development of meteorological instruments. In England she first worked at the Harrow laboratories of the Instruments Division of the British Meteorological Office. Here she studied the evolution of weather instruments, their calibration and standardisation procedures. She also got the opportunities to visit field observatories and manufacturers of meteorological instruments. She also worked for some time at the National Physical Laboratory at Teddington on standards and standardisation for different weather parameters.After spending three years in England Anna Mani, returned to India in 1948. She joined the Instruments Division of the India Meteorological Department (IMD) in Pune as Meteorologist. At the time Anna Mani joined, the Division was headed by S. P. Venkiteshwaran. Later in 1953 Anna Mani became Head of this Division. Venkiteshwaran had set up a workshop with the purpose of producing simple meteorological instruments like rain gauges, evaporimeters, thermometers, anemometers, wind vanes, and others. Anna Mani, who herself was a nationalist, was inspired by Venkiteshwaran to make India self-reliant in weather instruments. She decided to achieve this in shortest possible time by utilising her expertise gained in England.

The immediate problem was to find enough skilled people having the right kind of expertise to operate the machinery. Such people were not to be found in the country. In those days even simple meteorological instruments like barometers and thermometers were imported. Not much could be expected from private sector and almost everything had to be done in-house. So Anna Mani's first challenge was to train enough people to make them expert in design, manufacture, calibration, installation and observation. She also standardised and prepared detailed drawings and technical manuals for over 100 different instruments. She helped the Indian Standards Institution (ISI) to publish Indian standards for various weather instruments.

After making significant contribution towards attaining India's self-reliance in meteorological instruments she shifted her attention to solar energy. She realised that India being a tropical country solar energy could provide an alternate source of energy provided it was properly harnessed. To achieve proper harnessing of solar energy the first requirement was a sufficient knowledge of seasonal and geographic distribution of solar energy. Though there was a network of stations in the country for measuring solar radiation sufficient data on seasonal and geographic distribution of solar energy was not available. It was Anna Mani who took up the task of designing and manufacturing a whole range of solar radiation instruments in the country.

Anna Mani ensured that calibration and standardisation meet the world standards. The Instruments Division of IMD at Pune headed by Anna Mani was designated as the regional centre for Asia. As a mark of Anna Mani's notable contribution to radiation measurements in the tropics she was made Chairperson of the CIMO (The Commission for Instruments and Methods of Observations) Working Group on radiation instruments. She also became a Member of the International Radiation Commission.

In 1960, Anna Mani started studying atmospheric ozone at a time when the danger of destruction of atmospheric ozone by human-made activities was not yet appreciated. She undertook the task of ozonesonde in India. In this endeavour she got encouragement from K. R. Ramanathan. Ozonesonde is an apparatus for measuring ozone. Because of Anna Mani's dedicated effort India became one of the five countries to have its own ozonesondes. This made possible for India to generate reliable data on atmospheric ozone and the data generated over two decades helped to establish a clear picture of seasonal and geographical variation of upper atmospheric ozone over the tropics. The World Meteorological Organisation (WMO) took note of Anna Mani's significant contribution to ozone studies and she was made a Member of the International Ozone Commission. At the request of Vikram Sarabhai, the founder of India's space programme, Anna Mani took up the task of setting up a meteorological observatory and an instrumentation tower at the Thumba Rocket launching facility. She and her team completed the task successfully within the stipulated time. After her retirement from the IMD in 1976, Anna Mani worked in the Raman Research Institute in Bengaluru as a Visiting Professor. She helped to set up a millimetre-wave telescope at Nandi Hills. She prepared important publications on solar and wind energies. She established a small factory in the industrial suburbs of Bengaluru for manufacturing instruments for measuring wind speed and solar energy. She hoped that instruments produced in her factory would help to develop solar and wind energy.

Anna Mani died on 16 August 2001 at Thiruvananthapuram.

Asima Chatterjee (1917-2006)

"The endeavour of scientists, teachers, only the students but also the people at large, to understand the value of such pursuit. The facts of history and also the requirements of scientific progress will point to the supreme need for promoting the public understanding of science. The success of this effort will depend on our sincerity and zeal as also the depth of team spirit with which we would address ourselves this enlightened task."

Asima Chatterjee in her General Presidential address to Indian Science Congress (1975)

Asima Chatterjee was a pioneer woman scientist of India. She was the first woman to be awarded the Doctor of Science (DSc) degree by an Indian university in 1944 and the first woman scientist to occupy a Chair in an Indian University. She was the first woman General President of the Indian Science Congress (1975). Her research career spanned over five decades. She is best known for her significant work in the field of natural products, especially alkaloids, coumarins (a group of plant-derived olyphenolic compounds) and terpenoids (probably the most widespread group of natural products) derived from Indian medicinal plants. Her works have been widely quoted and some of her important works have become part of textbooks related to her fields of work. Her pioneering work on indole alkaloids made considerable impact on subsequent research in India and abroad. She established a school of natural products chemists in India.

Chatterjee also worked in mechanistic organic chemistry. She thoroughly investigated the mechanism of the acid-catalysed hydramine fission of phenylethanol. She developed a method for detecting and locating double bonds in organic compounds by using periodic acid (H_5IO_3). The method was a good alternative to ozonolysis. Chatterjee and her group developed the anti-epileptic drug, Ayush-56 and an antimalarial drug from Indian medicinal plants. The drugs were patented and they were developed by several companies. Ashima Chatterjee was born on 23 September 1917 in a middle class family of Bengal. She grew up in Kolkata. After completing her school education she entered the Scottish Church College of the Calcutta University in 1936. She obtained her MSc degree from Calcutta University in 1938, majoring in organic chemistry. She got her DSc degree from the Calcutta University in 1944.

In 1940, Chatterjee joined the Lady Brabourne College as the Founder Head of the Chemistry Department. In 1944, she was appointed as an Honorary Lecturer in Chemistry of the Calcutta University. In 1947, she went to USA where she first worked with L. M. Parks at the University of Wisconsin on naturally occurring glycosides and then with L. Zechmeister at the Californian Institute of Technology, Pasadena. At the California Institute of Technology she worked on carotenoids and pro-vitamins. In 1949 she went to the University of Zurich to work with the Nobel Laureate Paul Karrer and where she worked on biologically active alkaloids. She returned to India in 1950.

Chatterjee left Lady Brabourne College in 1954 to join the Department of Chemistry in the University College of Science, Calcutta University, where she worked till the end of her active academic career. She was appointed as Khaira Professor of Chemistry, one of the most prestigious and coveted chairs of Calcutta University. She occupied this Chair till 1982. Chatterjee revised, updated and edited Bharatiya Banashoudhi, a six volume treatise on Indian medicinal plants, published by Calcutta University during 1973-1977. The treatise was originally edited by K. P. Biswas. She was the Chief Editor of the six-volume Treatise on Medicinal Plants published Council of Scientific and Industrial Research (CSIR). The six-volume treatise described seven hundred medicinal plants.

Chatterjee played an instrumental role in establishing a Regional Research Institute for carrying out research on Indian medicinal plants for the development of Ayurvedic drugs. The Institute was established under the aegis of the Central Council for Research in Ayurveda and Sidha in Salt Lake, Kolkata through unique centre-state collaboration. An Ayurvedic Hospital was also established as part of the Institute for systematic clinical trials. Chatterjee was made Honorary Principal Co-ordinator and in this capacity she nurtured the Institute till her death.

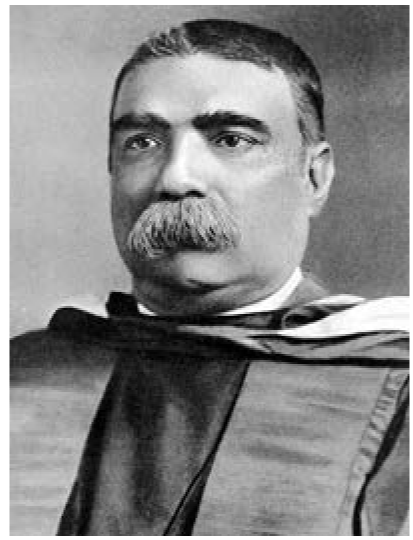
Like other scientists of her time Ashima Chatterjee had to struggle a lot to establish herself as a researcher. She was a highly dedicated teacher and researcher. She cared for the well-being of her students. She emphasised the importance of cultivating the scientific way of thinking or scientific temper among the common people of the country. She thought that the Indian Science Congress could and should play an effective role in this important task. In her Presidential Address to the Indian Science Congress, she said: "...scientific way of thinking, if properly cultivated, would help secure for the people of the country all the benefits of progress in science and technology. But dissemination of scientific knowledge must not be limited to urban areas. It should be extended also to people in villages in an effective manner. In this field

Indian Science Congress should pla y an effective role as well. More widespread and systematic dissemination of scientific information is sure to educate public opinion."

Chatterjee died on 23 November 2006 in Kolkata at the age of 89.

Chatterjee was nominated by the President of India as a Member of Rajya Sabha (Upper House of Indian Parliament) which she served from February 1982 till May 1990.

Asutosh Mookerjee (1864-1924)—Mathematician, Jurist, and Educationist



Asutosh Mookerjee was one of the pioneer architects of Modern India. He was a distinguished mathematician of his time. He published about 20 original research papers in mathematics in national and international journals. He wrote a book in mathematics titled Geometry of Conics. He established the Calcutta Mathematical Society in 1908 and directed its activities as its President till his death. He could become a mathematician of international repute if he had chosen to confine himself to the pursuit of mathematics alone. He pursued his mathematical studies even when he was busy as lawyer at the Court. He was one of the most eminent legal luminaries of pre-eminent legal luminaries of pre-independent India. He was a highly successful advocate. As Judge of the Calcutta High Court he passed judgement in nearly 2,000 cases and many of which are still quoted as masterpieces of judgment.

However, Mookerjee is mostly known for his pioneering role in broadening the scope of higher education in the country. As Vice Chancellor of Calcutta University he started postgraduate studies and research in the University. He changed the very direction of Calcutta University. He integrated teaching and research at the University level for the first time in India. Before Mookerjee became Vice Chancellor of Calcutta University, it was only an examining body. Mookerjee started a number of post-graduate departments in science. He also played an instrumental role in strengthening the teaching of arts subjects at post-graduate level.

Mookerjee presided over the first Indian Science Congress in 1914. He was elected President of the Asiatics Society four times, a record in the annals of the Society up to his time.

Asutosh was born in Kolkata (then Calcutta) on 28 June 1884 to Gangaprasad Mukhopadyhyay and Jagattarini Devi. His father was a well-known physician and his mother was known to be a woman of courage and considerable strength of character. Asutosh was fondly devoted to his mother. He never went against the wishes of his mother. Asutosh was personally nominated by the then Viceroy Lord Curzon as the representative of Calcutta citizens to attend the coronation of King Edward VII, However, his mother did not want his son to go abroad and so Asutosh declined the offer.

Asutosh studied at the South Suburban School and from where he passed the Matriculation Examination of Calcutta University in 1879. He then joined the Presidency College. He passed the FA examination in 1881 and joined the BA course. While an undergraduate student he published a research paper in mathematics in the Journal Messenger of Mathematics. The paper was titled "Some extension of a theorem of Salmons." In 1884, he passed the BA examination standing first in the University. The year in which he passed his BA examination, Mookerjee was elected a Member of the London Mathematical Society. The news of his election to the London Mathematical Society was reported in The Statesman on 12 February 1884: "We understand that Babu Asutosh Mookerjee, who stood first at the last BA examination, has been elected a member of the London Mathematical Society. He is the first Indian on whom the Society has conferred this honour." In 1885, Mookerjee passed his MA Examination in mathematics securing first position in order of merit. In 1886, Mookerjee got his MA degree in Natural Sciences. The same year he qualified in the special competitive examination for the award of the prestigious Premchand Roychand studentship. He also studied law from the City College and stood first in all the examinations of law. He started practising law at the Calcutta High Court in 1888 after obtaining a Bachelor of Law (B.L.) degree the same year. He obtained his Doctorate of Law (D.L.) degree in 1894. He was invited by Lord Curzon, the then Viceroy of Brtish India, to become a Judge of the Calcutta High Court. Mookerjee joined the High Court in 1904 after obtaining consent from his mother. For a brief period he also served as the Chief Justice of the Calcutta High Court.

It is not widely known that Mookerjee served as lecturer in mathematics and mathematical physics at the Indian Association for the Cultivation of Science from 1887 to 1889. He delivered lectures in optics, mathematical physics and pure mathematics. His lectures were of exceptional high standard.

Mookerjee's long association with Calcutta University started in 1889 as a Fellow and the same year he became a member of the Syndicate of the University at the age of 25. He served as President of the Board of Studies in Mathematics. In 1906, he was invited by Lord Minto, the Viceroy, to be Vice Chancellor of Calcutta University. He remained as Vice Chancellor for the four consecutive terms till 1914. He was again appointed as Vice Chancellor for another term in 1921. As Vice Chancellor his first priority was to establish post-graduate teaching departments, both in science and arts. His move was strongly opposed by the Government. He could not expect any additional financial support for his move. However, Mookerjee could achieve his goal because of the spontaneous support from Taraknath Palit and Rash Behari Ghosh. Taraknath Palit made an initial donation of Rs. 13.66 lakhs to the University for two Profesorrships, one each in physics and chemistry. Palit also donated to the University a plot of land and a residential building. The first Palit Professorship of Chemistry was offered to Acharya Prafulla Chandra Ray, who took up the assignment in 1916 after his retirement from the Presidency College. Mookerjee invited Chandra Sekhar Venkata Raman to become the first Palit Professorship of Physics. Raman accepted the offer in 1917. In 1914, Rash Behari Ghosh made an initial donation of Rs.10.46 lakhs, out of which four professorships were created one each in applied mathematics, physics, chemistry and botany. The first incumbents to these four Gosh Professorships were Ganesh Prasad, P. C. Mitter, and S. P. Agharkar. Mookerjee appointed Meghnad Saha, S. N. Bose and S. K. Mitra as lecturers in the Physics Department. Saha and Bose were first were first appointed in the Department of Applied Mathematics but they were later transferred to the Physics Department at the instance of Mookerjee.

The first Indian Science Congress was inaugurated by Asutosh Mookerjee. The Indian Science Congress was established with the initiatives undertaken by P. S. MacMohan and J. L. Simonsen, who worked jointly as Honorary General Secretaries of the Congress till 1921. The first Science Congress was held in January 1914 at Kolkata in the premises of the Asiatic Society of Bengal (later renamed as the Asiatic Society).

Asutosh Mookerjee died on 25 May 1924 in Patna. He had gone Patna in connection with his legal practices.

Remembering Asutosh Mookerjee, Michael Sadler (1861-1943), who was Chairman of Calcutta University Commission (The Sadler Commission) during 1917-1919, wrote: “In Asutosh Mookerjee India has lost one of her greatest men; the world one of its commanding personalities. He was might in battle. He could have ruled an empire. But he gave the best of his powers to education because he believed that in education rightly lies the secret of human welfare and the key to every empire’s moral strength.”

Atma Ram

A Pioneer of Glass Technology in India“All glass technologists can feel a glow of pleasure at the prominent place their subject has attained in India and will join in their appreciation of Dr. Atma Ram’s work.”

Prof. W. E. S. Turner, FRS, a doyen in the field of glass and ceramics technology

Atma Ram’s contributions cover fundamental and applied sciences as well as technology of production. His most significant achievement was the development and production of optical glass. In those days it was a vitally strategic material, the technology of production of which was a closely guarded secret of ten countries in the world.

Some of his work led to the development of entirely new industries in the country like the production of heat insulating materials from waste mica and foam glass for use in building, cold storage and refrigeration industries. Atma Ram’s work also made it possible to produce many articles indigenously, thus making import from European countries redundant. Some of the articles, which were produced using technologies developed by Atma Ram Are: chemical porcelain, glass electrode for pH meters, coloured glasses, sun-glare glasses, ceramic and vitreous enamel colours and stains, and special refractories. He held 23 patents relating to his industrial work. His work on the origin of colour in copper-red glasses was of fundamental importance. His work showed that the red colour was due to the formation of cuprous oxide colloid and not copper colloid as it used to be believed then, by scientists the world-over. Atma Ram’s findings helped the substitution of imported selenium for production of red bangles, which happens to be one of the biggest cottage industries in the country.

Atma Ram was a firm believer in the manufacture indigenous products for the progress of the nation. He believed that scientists and technologists had a social responsibility of utmost importance and that their activities should be related to the needs of the society, which supports them. Freedom and accountability must go hand in hand in their work. He believed that in a country like India, scientists must be extra careful in spending public funds.

Atma Ram was born on 12 October 1908 in a small village named Pilana in Bijnor District of western Uttar Pradesh. His parents belonged to a lower middle class family. He had early school education in his village where he studied Persian, Arabic and Urdu. After passing middle school examination he had to walk several kilometres to a school located in another village for higher classes. In 1924, he passed his matriculation examination securing first class from Banaras Hindu University, Varanasi, as a private student. He also passed his Intermediate Examination from the same university in 1926, but this time as a regular student.

He passed the BSc examination of the Agra University from DAV College, Kanpur in 1929. He then joined the Allahabad University for doing his MSc degree in chemistry. While studying at the Allahabad University he was much influenced by the celebrated Indian physicist Meghnad Saha,

Atma Ram passed his MSc examination in 1931, standing first in order of merit and the taught chemistry for a brief period at the Government College, Ajmer. After this he joined the research group of Nil Ratan Dhar at the Allahabad University for his PhD degree.

In 1936, Atma Ram joined the Indian Industrial Bureau at Alipore, Kolkata (then Calcutta). Later when the newly appointed Director of Scientific and Industrial Research, Shanti Swarup Bhatnagar shifted the Bureau to Delhi University, Atma Ram also moved there. Atma Ram became one of the important members of the nucleus, which in 1942, developed into the Council of Scientific and Industrial Research.

In 1945, Atma Ram was given the responsibility of setting up the Central Glass and Ceramic Research Institute (CGCRI) at Kolkata. During the initial days of CGCRI, the Indian glass and ceramic industry was at its infancy. The CGCRI played a major role in placing the industry on a sound footing. This was made possible by two major projects undertaken by the CGCRI. The first project was the comprehensive all-India survey of glass and ceramic raw materials with respect to their availability both quantitatively and qualitatively and their usefulness to the industry. This survey established the fact that high-grade raw materials were available in the country which could be used in place of imported ones. The second project was the detailed testing of the products manufactured and marketed by the industry to ascertain the basic defects in the manufacture of these products and it these could be rectified.

Atma Rama was deeply interested in applying science and technology to the welfare of the society. He was a great exponent of teaching science in the mother tongue. He displayed keen interest in propagating science in Hindi. The publication of “Bharat Ki Sampada” in several volumes was initiated by the CSIR, when Atma Ram was its Director General. He served as President of Vigyan Parishsad Prayag and encouraged many to undertake original science writing in Hindi. Recognising his contribution in popularising science Hindi, the Central Hindi Institute, Agra founded prizes after his name for encouraging science writing in Hindi.

Atma Ram died on 6 February 1983.

Birbal Sahni

The renowned paleobotanist, Birbal Sahni, was born on November 14, 1891 in Shahpur District, now in Pakistan. He was the third son of Ishwari Devi and Lala Ruchi Ram Sahani. He studied from the Government College, Lahore and Punjab University. He 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 some new genus of plants.

Birbal Sahni was not only botanist but also 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 age of 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. Besides, Sahni took a keen interest in archaeology. One of his investigations led to the discovery of coin moulds in Rohtak in 1936. For his studies on the technique of casting coins in ancient India he was awarded the Nelson Wright Medal of the Numismatic Society of India.

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

Chandrasekhara Venkata Raman—A Legend of Modern Indian Science

"I would like to tell the young men and women before me not to lose hope and courage. Success can only come to you by courageous devotion to the task lying in front of you and there is nothing worth in this world that can come without the sweat of our brow. I can assert without fear of contradiction that the quality of the Indian mind is equal to the quality of any Teutonic, Nordic or Anglo-saxon mind. What we lack is perhaps driving force which takes one anywhere. We have, I think, developed an inferioty complex. I think what is needed in India today is the destruction of that defeatist spirit. We need a spirit of victory, a spirit that would carry us to our rightful place under the sun, a spirit which will recognise that we, as inheritors of a proud civilisation, are entitled to a rightful place on this planet. If that indomitable spirit were to arise, nothing can hold us from achieving our rightful place."

Chandrasekhar Venkata Raman, popularly known as C. V. Raman, was the first Indian (and also the first Asian) Nobel Laureate in science. Raman deserves to be remembered not only for his towering scientific accomplishment but also for his indomitable spirit. He excelled under the most adverse circumstances. Raman was a staunch patriot and he had great faith in India's potential for progress.

Raman's celebrated discovery, the Raman Effect, experimentally demonstrated that the light-quanta and molecules do exchange energy which manifests itself as a change in the colour of the scattered light. This phenomenon was earlier predicted theoretically by Hendrik Anthony Kramers (1894-1952) and Werner Heisenberg (1901-1976). It was the most convincing proof of quantum theory of light. Albert Einstein (1879-1955) wrote: "C. V. Raman was the first to recognise and demonstrate that the energy of photon can undergo partial transformation with matter. I still recall vividly the deep impression that this discovery made on all of us…". Raman was awarded Nobel Prize in Physics in 1930 for his discovery.

Raman's interests in science were wide, from astronomy and meteorology to physiology. Raman published 475 research papers and wrote five remarkable monographs on topics so varied that one's mind boggles. Raman made many major scientific discoveries in acoustics, ultrasonic, optics, magnetism and crystal physics. Raman's work on the musical drums of India was epoch-making. C. V. Raman was born on 7 November1888 in his maternal grandfather's house, in a small village of Thiruvanaikaval near Tiruchirapalli (Triconopoly in those days), on the bank of Kaveri in Tamil Nadu. Raman's grandfather Saptarshi Sastri was a great Sanskrit scholar, who in his younger days travelled on foot to distant Bengal to learn navya naya (modern logic). Raman passed his matriculation examination at the age of 11 and he passed his F.A. examination (equivalent to today's intermediate) with a scholarship at 13. In 1903, Raman joined the Presidency College in Chennai (then Madras) from where he passed the B.A. (1904) and M.A. (1907) examinations. He stood first both in B.A. and M.A. examinations and won all the prizes available.

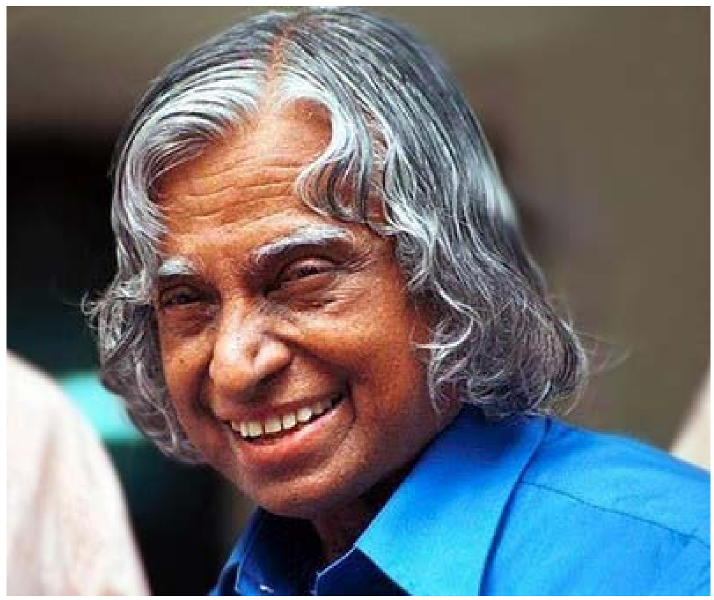
While Raman was a student he independently undertook investigations in acoustics and optics and published research papers in prestigious research journal. His first paper on ‘unsymmetrical diffraction bands due to a rectangular aperture’ was published in the Philosophical Magazine (London) in November 1906. This was the result Raman’s measuring the angles of a prism using an ordinary spectrum in his college. It was followed by a note in the same journal on a new experimental method of measuring surface tension. The Nobel Laureate Lord Rayleigh (1842-1919) took note of the papers published by Raman as a student.At the instance of his father, Raman took the Financial Civil Service Examination. He stood first the examination and in the middle of 1907 Raman proceeded to Kolkata to join the Indian Finance Department as Assistant Accountant General. His starting salary was Rs. 400 per month, a fabulous sum in those days. At that point of time nobody would have even dreamt that Raman would again venture into the pursuit of science. Raman’s prospects in the Government service were too lucrative and during those days opportunities for doing research were rare. One day while going office, Raman saw a signboard with the words ‘Indian Association for the Cultivation of Science’ written on it. On his way back he came to the Association where he first met am individual named Asutosh Dey (Ashu Babu), who was to be Raman’s assistant for 25 years. Ashu Babu took Raman to the Honorary Secretary of the Association, Amrit Lal Sircar, who was overjoyed when he came to know about Raman’s intention to do research at the Association’s laboratory. Amrit Lal had reason to be overjoyed because it was his uncle Mahendra Lal Sircar (1833-1904), a man of vision, who had established the Association.

The Association happens to be the first institute to be established in the country solely for carrying out scientific investigations. Mahendra Lal realised that ‘science would never strike a deep root in the country through the process of its introduction in the educational curriculum alone.’ To realise his dreams Mahendra Lal founded the Association. However, during Mahendra Lal’s lifetime nobody came forward to do research under the aegis of the Association. It was Raman who happened to be first to come forward to realise Mahendra Lal Sircar’s dream.

In 1817, Raman was invited by Asutosh Mookerjee (1864-1924), to be a professor in the newly established University College of Science. The salary of the professorship was about the half the amount that Raman was getting in the Finance Department. However, Raman happily accepted the offer and he joined the Calcutta University as Palit Professor in July 1917. Asutosh Mookerjee was touched by Raman’s total devotion to science and he said so on many occasions. Even after joining the Calcutta University, Raman was allowed to continue his work at the Association’s laboratories. In 1933, Raman left Kolkata to join the Indian Institute of Science (IISc), Bengaluru, as its Director. In fact he was first Indian to become its Director. He succeeded Sir Martin Forster, FRS. He served IISc as its Director (1933-1937) and Head of the Physics Department (1933-1948). After his retirement from the IISc he concentrated his attention in building an institute of his own, the Raman Research Institute.Raman died on 21 November 1970. As per his desire he was cremated in the gardens of his institute.Raman had a holistic view of science. He believed nature is the best teacher. He once observed: “What is science in the last analysis but the study and love of nature, displayed not in the form of abstract worship but in the practical form of seeking to understand nature?” Further he said: “One aspect of Indian culture was its profound understanding of Nature. Much of India’s philosophy related itself to the understanding of the rationale and the meaning of the phenomena of Nature.”

Raman scattering or the Raman Effect is the inelastic scattering of a photon. It was discovered by C. V. Raman and K. S. Krishnan in liquids, and by G. Landsberg and L. I. Mandelstam in crystals. The effect had been predicted theoretically by Adolf Smekal in 1923. When photons are scattered from an atom or molecule, most photons are elastically scattered (Rayleigh scattering), such that the scattered photons have the same energy (frequency and wavelength) as the incident photons. A small fraction of the scattered photons (approximately 1 in 10 million) are scattered by an excitation, with the scattered photons having a frequency different from, and usually lower than, that of the incident photons. In a gas, Raman scattering can occur with a change in energy of a molecule due to a transition Chemists are primarily concerned with the transitional Raman Effect.

Dr. A P J Abdul Kalam



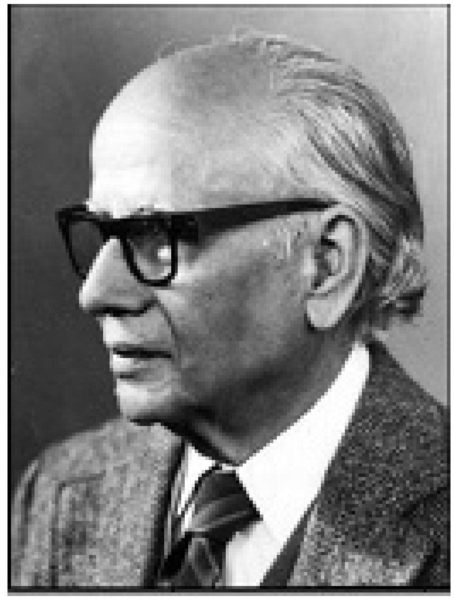
Born on October 15, 1931 at Rameswaram in Tamil Nadu, Dr Avul Pakir Jainulabdeen Abdul Kalam is a man of great distinction. Known as the Missile Man of India worldwide, he also became very popular as India's 11th President.

Kalam was inherited his parent's honesty and discipline which helped him in life. He specialized in Aeronautical Engineering from Madras Institute of Technology. Before becoming the President of India, he worked as an aerospace engineer with the Defence Research and Development Organisation (DRDO). Kalam's contribution in the development of ballistic missile 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 is currently a visiting professor at IIM, Ahmedabad, IIM, Indore, 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 injected 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. Dr Kalam's 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 is 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) and Padma Vibhushan (1990) and the highest civilian award Bharat Ratna (1997).

Dr. B. P. Pal



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

In 1929 Dr Pal qualified for the Masters degree in Botany at Rangoon University where he also won the Matthew Hunter Prize for topping among all science streams in the University. He was awarded a scholarship which permitted him to pursue his post-graduate education at Cambridge. Dr Pal worked with Sir Frank Engledow on hybrid vigour in wheat at the coveted 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 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 at its campus, which 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.Dr Pal was also a rose breeder of distinction and created several varieties. He was 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 a Fellow of the Royal Society in 1972 and received numerous awards including the Padma Vibhushan.

Dr. G Madhavan Nair

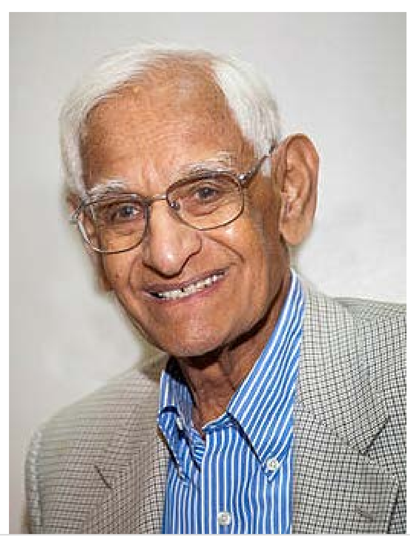
Dr G Madhavan Nair was born on October 31, 1943 in Thiruvananthapuram, Kerala. This former chairperson of the India Space Research Organisation (ISRO) is known as the man behind Chandrayaan, India's first unmanned mission to the moon.

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), Bombay. 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 telemedicine for meeting the needs of society at large. As a result, more than 31,000 classrooms have been connected under the EDUSAT network and telemedicine 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 ground water prospects and enable the farmers in taking important decisions based on their query.

In the international arena, Madhavan Nair has led the Indian delegations for bilateral cooperation and negotiations with many space agencies and countries, especially with France, Russia, Brazil, Israel, etc., and has been instrumental in working out mutually beneficial international cooperative agreements. Shri 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.

Dr. Har Govind Khurana



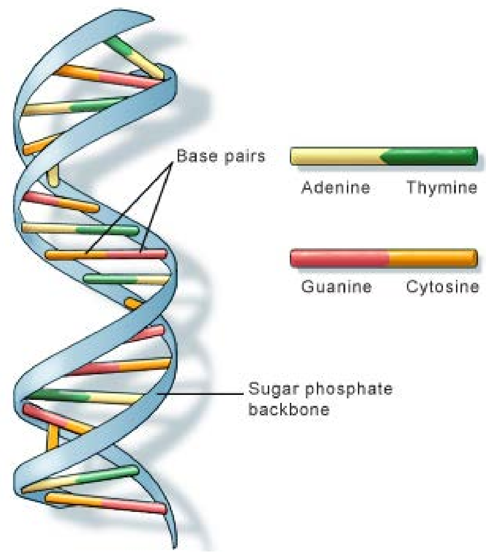
Dr Har Govind Khurana was born on January 9, 1922 in a small village called Raipur in Punjab (now in Pakistan) and was the youngest of five siblings. His father was a patwari, an agricultural taxation clerk in British India.

Khurana had his preliminary schooling at home. Later he joined the DAV High Multan High School. He graduated in Science from Punjab University, Lahore, in 1943 and went on to acquire his Masters degree in Science in 1945. He joined the University of Liverpool for his doctoral work and got his Doctorate in 1948. He did postdoctoral work at Switzerland's Federal Institute of Technology, where he met his

Swiss wife Elizabeth Sibler. Later he took up a job at the British Columbia Research Council in Vancouver and continued his pioneering work on proteins and nucleic acids.

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

Dr Khurana received the Nobel Prize in Physiology or Medicine in 1968 along with M W Nienberg 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 honored him with Padma Vibhushan in 1969.



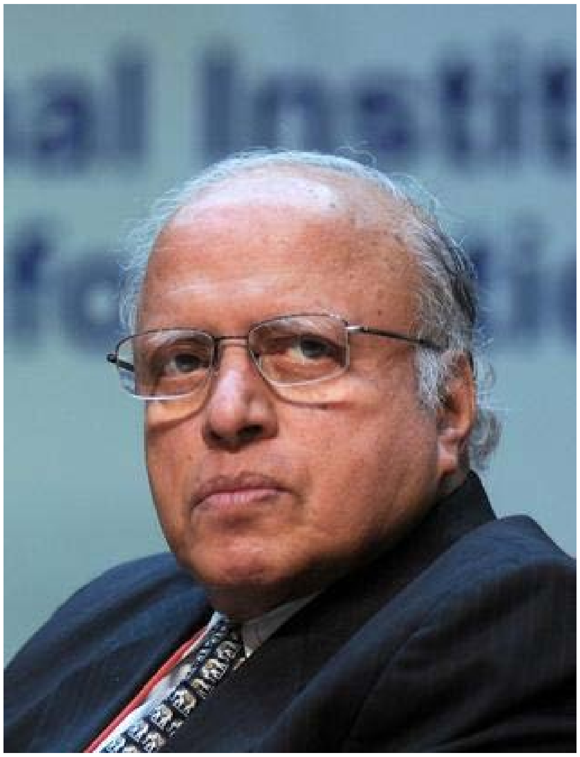
In the 1960s Khorana confirmed Nirenberg's findings that the way the four different types of nucleotides are arranged on the spiral "staircase" of the DNA molecule determines the chemical composition and function of a new cell. The 64 possible combinations of the nucleotides are read off along a strand of DNA as required to produce the desired amino acids, which are the building blocks of proteins. Khorana added details about which serial combinations of nucleotides form which specific amino acids. He also proved that the nucleotide code is always transmitted to the cell in groups of three, called codons. Khorana also determined that some of the codons prompt the cell to start or stop the manufacture of proteins. Khorana made another contribution to genetics in 1970, when he and his research team were able to synthesize the first artificial copy of a yeast gene.

By combining synthetic and enzymatic methods, Khorana was able to overcome many obstacles to the chemical synthesis of polyribonucleotides. Khorana's work provided unequivocal proof of codon assignments and defined some codons that had not been determined by other methods. Some triplets, which did not seem to code for any particular amino acid, were shown to serve as "punctuation marks" for beginning and ending the synthesis of polypeptide chains (long chains of amino acids). Khorana's investigations also provided direct evidence concerning other characteristics of the genetic code. For example, Khorana's work proved that three nucleotides specify an amino acid, provided proof of the direction in which the information in messenger RNA is read, demonstrated that punctuation between codons is unnecessary, and that the codons did not overlap. Moreover, construction of specific polyribonucleotides proved that an RNA intermediary is involved in translating the sequence of nucleotides in DNA into the sequence of amino acids in a protein. Summarizing the remarkable progress that had been made up to 1968 in polynucleotide synthesis and understanding the genetic code, Khorana remarked that the nature of the genetic code was fairly well established, at least for Escherichia coli.

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

In a note after winning the Nobel Prize, Dr Khurana 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 Khurana 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 Khurana died in a hospital in Concord, Massachusetts, on November 9, 1911

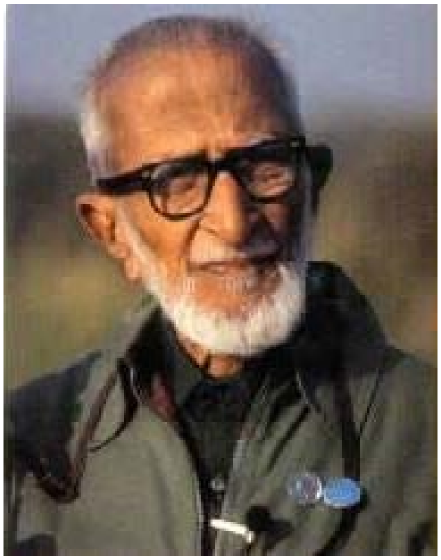
Dr. M S Swaminathan



Maankombu Sambasivan Swaminathan was born on August 7, 1925 in Kumbakonam, Tamil Nadu. This famous geneticist is known as the man behind India’s ‘Green Revolution’, a programme, which revolutionised 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 20th century. He is founder and Chairman of the M S Swaminathan Research Foundation.

His physician father was an ardent follower of Gandhiji 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, then did further studies at the Wisconsin University. There he turned down a professorship. He was clear about coming back to India and work 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 emphasizes on preservation of biodiversity. Swaminathan brought into India seeds developed in Mexico by 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 some 70 million tonnes of wheat a year, compared to 12 million tonnes in the early '60s. He served as the Director General of the Indian Council of Agricultural Research from 1972 to 1979 and became Union Minister for Agriculture from 1979 to 1980. He served as 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.

Dr. Salim Ali



Dr Salim Moizuddin Abdul Ali or Dr Salim Ali is synonymous with birds. The famous ornithologist-naturalist was born on November 12, 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 Bomaby 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 child's bird, 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 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 I983. He died at the age of 90, on June 20, 1987.

Dr 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 a lot of other path-breaking initiatives. Born on October 11, 1946 at Muramba, Akola, Maharashtra, Bhatkar obtained his Bachelor of Engineering degree 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 a Member of Scientific Advisory Committee to Cabinet of Government of India, Governing Council Member of CSIR, India and eGovernace Committee Chairman of 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. Other recognitions include Saint Dnyaneshwar World Peace Prize, Lokmanya Tilak Award, HK Firodia and Dataquest Lifetime Achievement Awards, and many others. He was a nominee for Petersburg Prize and is a Distinguished Alumni of IIT, Delhi.

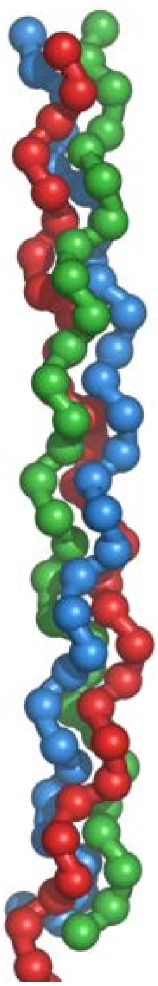
Dr Bhatkar has authored and edited 12 books and 80 research and technical papers. His current research interests include Exascale Supercomputing, AI, Brain-Mind- Consciousness, and Synthesis of Science and Spirituality.

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.

Gopalasamudram Narayana Ramachandran—Discoverer of the Triple Helix

Gopalasamudram Narayana Ramachandran, popularly known as G. N. Ramachandran (or simply GNR to those who knew him well) is one of those scientists who have made India proud by their research. He had many lucrative assignments for doing research in advanced countries but like his mentor C. V. Raman, he decided to work in India against all odds. He was one of the most brilliant Indian scientists of the 20th century.

Ramachandran worked in a number of fields in physics, chemistry and biology. He published more 250 research publications and several reviews in well-known international journals. His first major research contribution was the discovery of the triple helical structure of collagen. He was drawn to collagen by J. D. Bernal's remarks that structural proposals for collagen were unsatisfactory. Bernal made these remarks in a casual conversation during his visit to Chennai in 1952.



Triple Helix

The research paper proposing triple helical structure for collagen was published in 1955. Ramachandran co-authored this paper with Gopinath Kartha. Their concept of coiled-coil structure proved to be fundamental advance in the understanding of polypeptide structure. Ramachandran and his colleagues, V. Sasisekhara and C. Ramakrishnan laid the foundations for the conformational analysis of polypeptide chains. They introduced a two-dimensional map what is today known as in biochemical literature as the "Ramachandran phi-psi diagram" or simply "Ramachandran plot", which provided a rational basis for describing all stereo chemically possible structures of polypeptides. They reduced the 'structure space' of protein chains to two-dimensional with dihedral (torsion) angles as variables. This had a profound impact on stereo-chemistry and structural biology. The triple helical structure of collagen proposed by Ramachandran and his group is considered as an important milestone in molecular biology.

Ramachandran was born on 8 October 1922 in Ernakulam near Kochi (then Cochin) in Kerala. He had his early schooling in a government school in Ernakulum. After the Intermediate examination, Ramachandran joined the St. Joseph's College in Trichy in 1939. Here he enrolled himself in the BSc (Honours) degree in physics in spite of the fact that he had developed a deep interest in mathematics since his childhood.

Ramachandran's father, Narayana Iyer, wanted his son to take up the Indian Civil Service Examination but apparently he failed to persuade his son in doing so. He then sent Ramachandran to Delhi to take Indian Railway Engineering Service Examination. But even this was not liked by Ramachandran. It is said that he deliberately performed poorly in the entrance examination to ensure that he was not selected. After this digression Ramachandran joined the Electrical Engineering Department of the Indian

Institute of Science, Bengaluru, for his MSc degree. However, soon he switched over to the Physics Department headed by C. V. Raman.

Ramachandran obtained his MSc degree in 1944 and started working for his doctoral degree under the supervision of C. V. Raman. After obtaining his Doctor of Science degree in 1947 he planned to go to Cambridge in England to work in the Cavendish Laboratory, where Sir William Lawrence Bragg was the Director. He succeeded in getting a prestigious scholarship for higher studies in England provided by the Royal Commissioners of the 1851 Exhibition and which made possible for him to work in Cavendish Laboratory. After finishing his doctoral work in Cambridge, Ramachandran returned to India in June 1949 and he joined the Department of Physics of the Indian Institute of Science as Assistant Professor.

In 1952, Ramachandran joined the Madras University as the first Professor and Head of the Department of Physics. At the time, Ramachandran was 30 years old. The Department of Physics was started with two faculty members, Ramachandran in experimental physics and Alladi Ramakrishnan in theoretical physics. The Department was first located in a single room of the main building of the University. Ramachandran's research work carried out at the Madras University brought an unprecedented level of recognition to the University. In 1970, Ramachandran came back to the Indian Institute of Science. He was given the responsibility of starting a new department of molecular biophysics. The department which was formally started in 1971 grew into a major centre of structural biology.

Ramachandran Died on 7 April 2001.

Homi Jehangir Bhabha—Founder of India's atomic Programme

Homi Jehangir Bhabha is mostly known as the chief architect of India's atomic energy programme. However, his contribution to India's development goes far beyond the sphere of atomic energy.

Bhabha was born on 30 October 1909 in a wealthy Parsi family of Mumbai. He attended the Cathedral and John Cannon Schools in Mumbai. After passing Senior Cambridge Examination at the age of 15, Bhabha entered the Elphinstone College in Mumbai and later the Royal Institute of Science, also in Mumbai. In 1927, Bhabha went to Cambridge, England to study at the Gonville and Caius College, where he first studied the Mechanical Tripos. It may be noted that both his fathe and his uncle Sir Dorab J. Tata (who had married Bhabha's father's sister) wanted Bhabha to become an engineer with a view that ultimate he would join Tata and Iron Steel Company at Jamshedpur. However, at Cambridge Bhabha's interest gradually shifted to theoretical physics. In 1928, Bhabha in a letter to his father wrote:

"I seriously say to you that business or job as an engineer is not the thing for me. It is totally foreign to my nature and radically opposed to my temperament and opinions. Physics is my line. I know I shall do great things here. For, each man can do best and excel in only that thing of which he is passionately fond, in which he believes, as I do, that he has the ability to do it, that he is in fact born and destined to do it…I am burning with a desire to do physics. I will and must do it sometime. It is my only ambition. I have no desire to be a 'successful' man or the head of a big firm. There are intelligent people who like that and let them do it…It is no use saying to Beethoven 'You must be a scientist for it is a great thing' when he did not care two hoots for science; or to Socrates 'Be an engineer; it is work of intelligent man'. It is not in the nature of things. I therefore earnestly implore you to let me do physics."

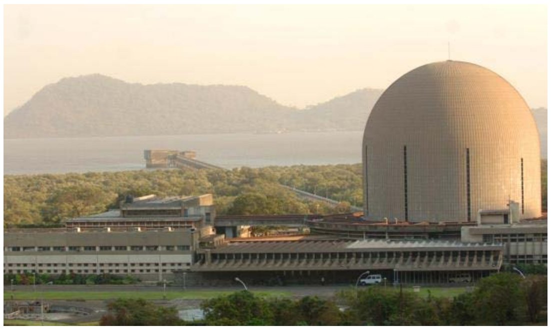
For studying physics Bhabha first wanted to do the Mathematics Tripos. Bhabha's father had to yield to his son's firm determination. But he put a condition. He told Homi that in case he could complete the Mechanical Tripos successfully he would allow him to stay in Cambridge to take up the Mathematics Tripos. So when Bhabha passed the Mechanical Tripos with first class, his father allowed his son to fulfill his wishes and two years later Bhabha passed the Mathematics Tripose again with first class. He then joined the Cavendish Laboratory from where he obtained his PhD in theoretical physics. His first research paper published in 1933 won him the Isaac Newton Studentship in 1934, which he held for three years and mostly worked in Cambridge except for a short period when he worked with Niels Bohr (1885-1962) at Copenhagen.

At Cambridge Bhabha's work was mostly related to cosmic rays. It may be noted here that the existence of penetrating radiations coming from outer space was detected towards the end of the 19th century by Charles Thomson Rees Wilson (1869-1963), the US physicist and Nobel Prize winner, gave the name of 'cosmic rays' to these radiations consisting of highly energetic charged particles. They consist of various types of nuclei but prominently of protons. Primary cosmic rays produce secondary's by interaction with the atmosphere. Bhabha jointly with W. Heitler explained the cosmic rays shower formation in a paper published in 1937. Before this the mechanism of shower formation was the subject of much speculation. The important contributions made by Bhabha while working at Cambridge have been summarised by G. Venkataraman (in his book, "Bhabha and His Magnificent Obsessions", Universities Press, Hyderabad, 1994) as:

- The explanation of relativistic exchange scattering (Bhabha scattering).
- The theory of production of electron and positron showers in cosmic rays (Bhabha-Heitler theory).
- Speculation about the Yukawa particle related to which was his suggestion of the name 'meson'.
- Prediction of relativistic time dilation effects in the theory of the meson.

In 1939, when the Second World War broke out, Bhabha was in India. He had come for a short holiday. However, the War changed his plan. Most of the scientists in England had to take part in war activities and there was no scope for doing basic research. So Bhabha had to abandon his plan to return to England to resume his research work at Cambridge. In 1940, Bhabha joined the Department of Physics of the Indian Institute of Science (IISc), Bengaluru, where a Readership in Theoretical Physics was specially created for him. At the time Bhabha joined the Physics Department of the IISc it was headed by C. V. Raman. At the IISc, Bhabha guided research on cosmic rays. He organised a group of young researchers in experimental and theoretical aspects of cosmic rays research.

On realising the fact that there was no Institute in the country which had the necessary facilities for original work in nuclear physics, cosmic rays, high energy physics, and other frontiers of knowledge in physics, Bhabha initiated steps to establish the Tata Institute of Fundamental Research (TIFR) in Mumbai. The institute was inaugurated in 1945. TIFR under the leadership played an important role in shaping India's atomic energy programme in its early years. Later Bhabha built a new laboratory entirely devoted to atomic energy research and development, which was later called Bhabha Atomic Research Centre (BARC). Bhabha was the first Chairman of the Atomic Energy Commission.



BARC

Bhabha was killed in a air-crash near the Mont Blanc peak of the Alps on 24 January 1966, while he was on his way to Vienna to attend a meeting of the Scientific Advisory Committee of the International Atomic Energy Agency.

Bhabha possessed sensitive and trained artistic gifts of the highest order. He loved music and dancing. He had considerable knowledge in Indian and western music. He painted and sketched. He designed the settings of dramatic productions. He was an architect of no mean ability. He was a true lover of trees and did everything to protect them.

Jagadish Chandra Bose—India's First Modern Physicist

Jagadish Chandra Bose, popularly known as J. C. Bose, occupies a unique position in the history of modern Indian science. He was the first Indian to make significant contribution to physics in 1895. His researches were concerned with electric waves and their interaction with matter. He devised his own instruments with great ingenuity and with such improved instruments he demonstrated various properties of radio waves like reflection, absorption, interference, double reflection and polarisation. He also generated radio waves which had wavelengths as small as 5 mm. Such waves are now called microwaves, and are used in radars, ground telecommunication, satellite communication, remote sensing and microwave ovens. Bose was the first to produce millimetre-length radio waves and study their properties. Bose also perfected the method of transmission and of reception of electromagnetic waves. In recent years there has been welcome news of proper credit being given to Bose for his pioneering work in the area of wireless telegraphy. The Institute of Electrical and Electronics Engineers in one of their publications wrote: "our investigative research into the origin and first major use of solid state diode detector devices led to the discovery that the first transatlantic wireless signal in Marconi's world famous experiment was received by Marconi using the iron-mercury-iron coherer with a telephone detector invented by Sir J. C. Bose."

JC Bose is considered as the first scientist from India under the Galilean Order. Bose was a pioneer in microwave optics technology. He was the first to show that semiconductor rectifiers could detect radio waves. Bose's galena receiver was amongst the earliest examples of a led sulphide photo conducting device.

Bose demonstrated that plant tissues under different kinds of stimuli like mechanical, application of heat, electric shock, chemicals and drugs, produce electric response similar to that produced by animal tissues. He also tries tried to demonstrate that similar electric response to stimulation could be noticed in certain inorganic systems. For his investigations Bose invented several novel and highly sensitive instruments. Among these the most important was the Crescograph, an instrument for measuring the growth of plant. It could record a growth as small as 1/100.000 inch per second. His theories about the relationship between living and non-living and plant's response to stimuli were not taken seriously in his time and even today some of his ideas have remained esoteric. However, it is now recognised that Bose had made very significant contributions to the field of chronobiology and circadian rhythms even before these two technical terms were coined.

60 GHz microwave apparatus

Jagadish Chandra was born on 30 November 1858 in Mymensingh (now in Bangladesh). His father Bagwan Chandra Bose served the British India government in various executive and magisterial positions. Though Bhagwan Chandra served the British government, he was a staunch nationalist and also a dreamer. He undertook, not always with success, many educational, agricultural and technical projects aiming to provide employment and promote opportunities to his less fortunate countrymen.

Jagadish Chandra started his education in a pathsala, a Bengali medium school. His father wanted his son to learn his mother tongue and know his own culture before he learned English and knew the foreign culture. Jagadish Chandra studied with the children of peasants, fishermen and workers. In their company young Jagadish Chandra imbibed a love for nature. Jagadish Chandra often attended yatras (folk plays) in village fairs and which inspired him to read the great epics, Ramayana and Mahabharata. The character of Karna in Mahabharata influenced him deeply. In later part of his life he wrote: "From his (Karna's) low caste came rejection, came every disadvantage; but he always played and fought fair! So his life, though a series of disappointments and defeats to the very end his slaying by Arjuna appealed to me as a boy the greatest of triumphs. I still think of the tournament where Arjuna had been victor, and then Karna coming as a stranger to challenge him. Questioned of name and birth, he replies, 'I am my own ancestor! You do not ask the mighty Ganges from which of its many springs it comes: its own flows justifies itself, so shall my deeds me!'" Further Bose wrote: "Like that of my boyhood hero's hero Karna, my life has been ever one of combat and must be to the last. It is not for man to complain of circumstances, but bravely to accept, to confront, and to dominate them."

In 1880, Bose sailed for England for studying medicine but he had to abandon his plan to study medicine because of the recurrence of a fever he had contracted earlier, and which exacerbated, by the odours of the dissecting rooms. After a year's study of medicine in London, Bose joined the Christ's College in Cambridge to study natural sciences. In 1884, Bose obtained a BA with a second class in natural sciences tripos and in the same year he also obtained a BSc from the London University.

In 1885, Bose joined the Calcutta Presidency College. Though Bose was given an appointment in the higher educational service but he was taken on temporary basis with one-half of the pay attached to an appointment in the higher educational service. Bose protested and he asked for the same salary as a European was entitled to get. When his protest was not entertained he refused to accept his salary. He continued his teaching assignment for three years without any salary. Finally both the Director of the Public Instruction and the Principal of the Presidency College fully realised the valu of Bose's skill in teaching and also his lofty character, As a result his appointment was made permanent with retrospective effect. He was given the full salary for the last three years in lumpsum, which he used for paying off his father's debt.

Bose was very much against in patenting his invention. He had resolved not to seek any personal advantage from his invention.

Bose died on 23 November 1937 at Giridih in Jharkhand .

Kalpana Chawla

Kalpana Chawla was born on July 1,1961 in Haryana's Karnal district. She was inspired by India's first pilot J R D Tata and 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 Master of Science degree in aerospace engineering from University of Texas in 1984, four years later, Dr Chawla earned a doctorate in aerospace engineering from 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 November 19, 1997 as part of a 6-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 killed in the Space Shuttle Columbia disaster in 2003.

Manali Kallat Vainu Bappu (1927-1982)—Doyen of Modern Indian Astronomy

Vainu Bappu is regarded as the 'main architect of revival of astronomical studies in India'. He played an instrumental role in establishing a number of astronomical institutions in India including the Indian Institute of Astrophysics in Bengaluru.

Vainu Bappu was born in Madras (now Chennai) on 10 August 1927. His father Sunanna Bappu was an astronomer at the Nizamiah Observatory, Hyderabad. His mother was Manali Kukuzhi. He was the only child of his parents. Influenced by his father, Bappu developed a keen interest in astronomy. Once he said: "I learnt my astronomy on the lap of my father." However, his interests were not limited to astronomy. He had wide ranging interests including painting, music, literature, gardening and architecture. He was eloquent speaker and he could hold an audience spellbound.

He became an accomplished amateur astronomer while still at school. In 1946, at the age of 19, he published two papers on astronomy in Current Science, a journal published by the Indian Academy of Sciences, Bengaluru. The papers were titled: "The effect of colour on the visual observations of long-period variable stars" and "On the visual light curve of LT Eridani".

He joined the Nizam College in 1946. While a student of the Nizam College he built a Spectrograph and which he used to obtain spectrograms of the airglow. In 1949, he obtained his MSc degree in physics from Madras University and then he went to join the Harvard Graduate School of Astronomy as a "Hyderabad state scholar for postgraduate studies in astronomy". At the time when Bappu joined the Harvard Astronomy School, its Faculty included such accomplished astronomers as Harlow Shapley, Donald Menzel, Bart J. Bok, Cecilia Payne-Gaposchkin, and Fred Whipple.

Within a few months of his arrival at Harvard, Bappu together with Bart J. Bok and Gordon A. Newkirk, Jr., discovered a comet. This purely accidental discovery was made on 2 July 1949. Perhaps Bappu is the only Indian who has discovered a comet. The comet was named Comet Bappu-Bok-Newkirk (C/1949 N1). Sometimes it is also referred to as Comet Bappu-Bok-Whipple.

Bappu obtained his PhD in 1952. After his PhD, he worked for a brief period as a Carnegie post-doctoral Fellow at the Mt. Wilson and Palomar Observatories where jointly with Olin C. Wilson he discovered an important phenomenon now called the Wilson-Bappu effect. It is the correlation between the measured width of the emission feature at the centre of the Ca II K line and the absolute visual magnitude of the star. This correlation is independent of spectral type and applicable to stars of G, K, and M.

Bappu returned to India in December 1952. One of the conditions of the Scholarship which had enabled him to go to Harvard University was that on return to India he would serve the Hyderabad state. However, the government could not offer him a suitable job and so by July 1953 he was told that he was free to try

In November 1954, Bappu joined the Uttar Pradesh State Observatory, Varanasi, as the Chief Astronomer. He convinced the then Chief Minister of Uttar Pradesh to promote astronomy in a big way and to shift the Observatory to a location better suited for observation. Thus the observatory was moved to Nainital in November 1955.

Vainu Bappu Observatory, Kavalur

In 1960, he took over as Director of the Kodaikanal Observatory in Tamil Nadu. The observatory had been originally established by the East India Company in the late eighteenth century "to promote the knowledge of astronomy, geography and navigation in India." It had a glorious past and accomplished astronomers like Norman Pogson (1829-1891) and John Evershed (1864-1956) had worked here. However, when Bappu took over its charge, the Observatory was in a very bad shape. Bappu transformed this old and outdated institution into an active centre of astronomical research. In early 1970s, Bappu established a new station at Kavalur and it produced results that could be compared to those of world's leading observatories. He conceived and steered a project to build a 2.36-m telescope. It was designed and fabricated indigenously. However, Bappu passed away before it became functional. Both the observatory and the telescope were named after Bappu.

Bappu was the first President of the Astronomical Society of India (1973-74). He served as Vice President (1967-1973) and President (1979) of the International Astronomical Union.

Vainu Bappu Observatory currently houses the largest telescope in the country

Bappu died on 19 August 1982 in Munich, Germany. At the time of his death he was just 55 years old.

Wilson–Bappu effect

The Ca II K line in cool stars is among the strongest absorption lines. A small emission, which originates in the chromosphere, is present in its core. In 1957, Olin C. Wilson and M. K. Vainu Bappu reported on the remarkable correlation between the measured width of the aforementioned emission line and the absolute visual magnitude of the star. This is known as the Wilson–Bappu effect. The correlation is independent of spectral type and applicable to stars of type G, K, and M. The wider the absorption, the brighter the star.

Meghnad Saha

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 started staying in a doctor's house near the school and had to work in that house to meet the cost of living. He ranked first in the Dhaka middle school test and got admitted into Dhaka Collegiate School.

He graduated from Presidency College with Mathematics major and got the second rank in the University of Calcutta whereas the first one was taken by Satyendra Nath Bose, another great scientist of India. In 1915, both S N Bose and Meghnad ranked first in MSc exam, 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 London's Royal Society.Saha got interested in Nuclear Physics. In 1947, he established Institute of Nuclear Physics which later was named after him as Saha Institute of Nuclear Physics. Other than being a scientist, he was also elected as the Member of Parliament. Besides, Saha's work relating to reform of 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 effort 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 ionization equation: The Saha ionization equation, also known as the Saha–Langmuir equation, is an expression that relates the ionization state of an element to the temperature and pressure. The equation is a result of combining ideas of quantum mechanics and statistical mechanics and is used to explain the spectral classification of stars. The expression was developed by the Indian astrophysicist Meghnad Saha in 1920, and later (1923) by Irving Langmuir.

$$\frac{n_{i+1}n_e}{n_i} = \frac{2}{\Lambda^3}\frac{g_{i+1}}{g_i}\exp\left[-\frac{(\epsilon_{i+1}-\epsilon_i)}{k_BT}\right]$$

Saha ionization equation is also utilized for determining the time & transmission frequencies variations & possible com dropouts, at blackout interval because of plasma trails, during space shuttle re-entry to our atmosphere.

Mokshagundam Visvesvaraya

Sir Mokshagundam Visvesvaraya , KCIE (popularly known as Sir MV; 15 September 1860– 14 April 1962 was a otable Indian engineer, scholar, statesman and the Diwan of Mysore from 1912 to 1918. He is a recipient of the Indian Republic's highest honour, the Bharat Ratna, in 1955. He was knighted as a Knight Commander of the British Indian Empire (KCIE) by King George V for his contributions to the public good. Every year, on his birthday, 15 September is celebrated as Engineer's Day in India in his memory. He is held in high regard as a pre-eminent engineer of India. He was the chief designer of the flood protection system for the city of Hyderabad in Telangana, as well as the chief engineer responsible for the construction of the Krishna Raja Sagara dam in Mandya.

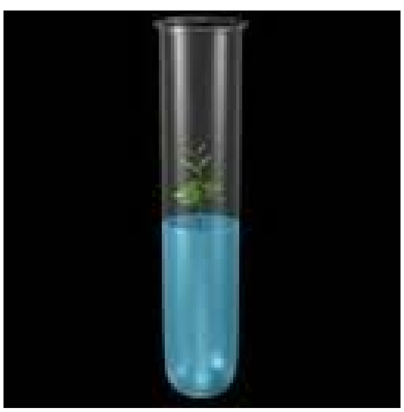
Upon graduating as an engineer, Visvesvaraya took up a job with the Public Works Department (PWD) of Mumbai and was later invited to join the Indian Irrigation Commission. He implemented an extremely intricate system of irrigation in the Deccan area. He also designed and patented a system of automatic weir water floodgates that were first installed in 1903 at the Khadakvasla Reservoir near Pune. These gates were employed to raise the flood supply level of storage in the reservoir to the highest level likely to be attained by a flood without causing any damage to the dam. Based on the success of these gates, the same system was installed at the Tigra Dam in Gwalior and the Krishna Raja Sagara (KRS) Dam in Mandya/ Mysore,Karnataka. In 1906–07, the Government of India sent him to Aden to study water supply and drainage system and the project prepared by him was implemented in Aden successfully. Visvesvaraya achieved celebrity status when he designed a flood protection system for the city of Hyderabad. He was instrumental in developing a system to protectVisakhapatnam port from sea erosion. Visvesvaraya supervised the construction of the KRS Dam across the Kaveri River from concept to inauguration. This dam created the biggest reservoir in Asia when it was built. He was rightly called the "Father of modern Mysore state" (now Karnataka): During his period of service with the Government of Mysore state, he was responsible for the founding of, (under the Patronage of Mysore Government), the Mysore Soap Factory, the Parasitoide Laboratory, the Mysore Iron & Steel Works (now known as Visvesvaraya Iron and Steel Limited) in Bhadravathi, the Sri Jayachamarajendra Polytechnic Institute, the Bangalore Agricultural University, the State Bank of Mysore, The Century Club, Mysore Chambers of Commerce, University Visvesvaraya college of Engineering, Bangalore and numerous other industrial ventures. He encouraged private investment in industry during his tenure as Diwan of Mysore. He was instrumental in charting out the plan for road construction between Tirumala and Tirupati. He was known for sincerity, time management and dedication to a cause.

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 fertilisation of angiosperms. Till then no one thought that flowering plants could be fertilised in test-tubes. Maheshwari's technique immediately opened up new avenues in plant embryology and has applications in economic and applied botany. Cross-breeding of many flowering plants which cannot crossbreed naturally can be done now. The technique is proving to be of immense help to plant breeders. His 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 replied that "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 at University of Delhi as an important center of research in embryology and tissue culture. The department was recognised by University Grants Commission as Centre of Advanced Study in Botany.



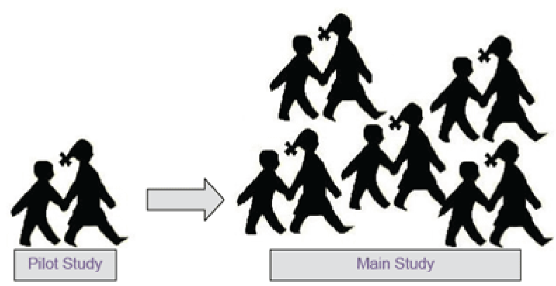
Maheshwari was assisted by his wife in preparation of slides in addition to her household duties. Way back in 1950 he talked of contacts between embryology, physiology and genetics. He also emphasized the need of initiation of work on artificial culture of immature embryos. These days tissue culture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

P C Mahalanobis

A well-known Indian statistician and scientist, Mahalanobis is greatly popular for introducing new methods of sampling. Mahalanobis is remembered by Indians as an Indian scientist and as an applied statistician. His most significant contribution in the field of statistics was the Mahalanobis Distance. Besides these 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 in 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. Then he enrolled himself into Presidency College and got a BSc degree with specialization in Physics. In the year 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 realised 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 and were formally registered on April 28, 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 and he had also corrected some of the errors of the census methodology in India. Besides statistics, Mahalanobis also had a cultural bent of mind. He had worked as a secretary to Rabindranath Tagore particularly during the foreign visits of the great poet and also worked in the Vishwa Bharati University. Mahalanobis was honoured with the second highest civilian award of the country, Padma Vibhushan, for his immense contribution to the field of science.

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

Ronald Ross

Ronald Ross was born in India in 1857 at Almora district in Uttarakhand. His father was a general in the British Army in India. Ross lived in India until he was eight. 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.

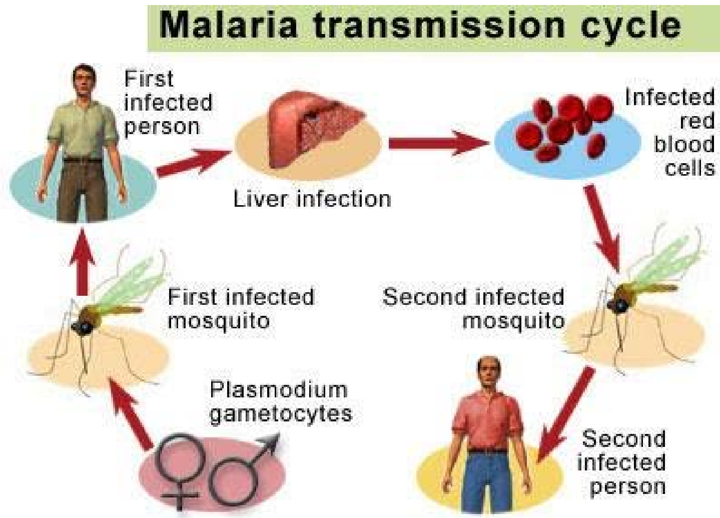
While posted in Ooty, he fell ill with malaria. After this, he was transferred to the medical school in Osmania University, Secunderabad. He discovered the presence of the malarial parasite within a specific species of mosquito, of the genus Anopheles. He initially called them dapple-wings.

Ross made his crucial discovery while dissecting the stomach of a mosquito fed on the blood 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 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 service. The building where he worked and actually discovered the malarial 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.

Having won the Nobel Prize for Physiology or Medicine in 1902, Ronald Ross is famous for his work concerning malaria. He was the one who discovered that the malaria parasite resided in the

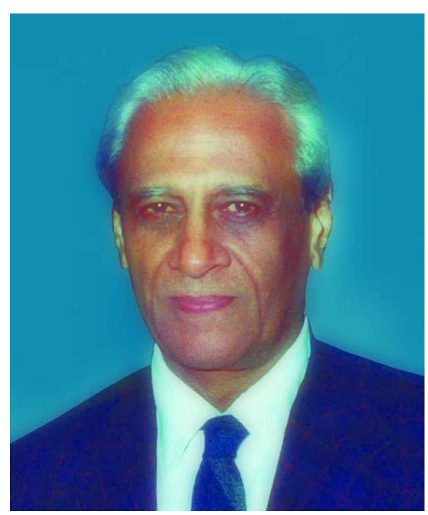


gastrointestinal tracts of mosquitos. Because of this, other scientists and doctors were able to deduce that mosquitoes spread the diseases and discovered ways to counter malaria. Because of his contribution as well as experience concerning malaria and other tropical diseases, he became the Director-in-Chief of the Ross Institute and Hospital for Tropical Diseases—an institute established to honor his works.

It was in 1894 when he set his mind on determining how mosquitoes propagated malaria. It wasn't easy for him because for two and a half years, he failed but after that, he was able to successfully demonstrate how the malaria bacteria resided in the mosquitoes' gastrointestinal tract—this was what helped him establish Laveran and Manson's hypothesis as a fact. His research started while he was at Presidency General Hospital where he studied in his own bungalow at the Mahanad village. From time to time, he went around the village to collect mosquitoes with the help of the Indian scientist Kishori Mohan Bandyopadhyay. In 1883, Ross became the Acting Garrison Surgeon of Bangalore and it was then when he realized how they can control mosquitoes and the propagation of malaria by countering their means of propagation and limiting the mosquitoes' access to water.

Interestingly, Ross was assigned to work at Sigur Ghat which was near Ooty, a hill station. Three days after he arrived, he had malaria and made the observation that there was a mosquito on the wall which had a strange posture. This mosquito was what he called as the "dappled wings" kind of mosquito. He was transferred to Secunderabad, and it was there he was able to culture some 20 brown mosquitoes which he later on infected from a patient's blood. After the blood feeding, he then dissected the mosquitoes and this was where he was able to discover the presence of the malaria bacteria which stayed in the gastrointestinal tract of infected mosquitoes.

Satish Dhawan (1920-2002)—A Scientist with a Social Commitment



Satish Dhawan shaped India's space programme by translating Vikram Sarabhai's dream into reality. His role in shaping the country's space programme is enough to make him one of the most influential personalities in post-Independence India. However, Dhawan's pre-eminent role in the development of science and technology in the country goes much beyond the confines of India's space programme. He made very significant but multi-dimensional contribution to scientific research, science education, development and training of S&T manpower, S&T policy formulation and implementation and building of S&T institutions and transforming the existing ones. He did all this with a deep sense of social commitment and keen awareness of present and future requirements of the country. He was widely regarded as the conscience of the scientific community. He was a great inspirer of people.

Dhawan was one of the most eminent researchers in the field of fluid mechanics--turbulence and boundary layers. He carried out pioneering experiments in rural education, remote sensing and satellite communication. His efforts led to the development of operational systems like INSAT, India's telecommunication satellite system, the Indian Remote Sensing Satellites (IRS), and the Polar Satellite Launch Vehicle (PSLV). Dhawan advocated the need of accurate weather prediction, which, he believed could substantially improve India's economy. It is said that perhaps 'Dhawan was India's first champion of numerical weather prediction.'

Dhawan was the longest serving Director of the Indian Institute of Science (1962-1981), one of the premier scientific research and educational institutions in the country. He was the Chairman of the Indian Space Research Organisation (ISRO) from 1972 to 1995 and Chairman of the Indian Space Commission from 1972 to 2002. It was because of Dhawan, who took great pains to establish close interfaces with the multiple users, that the Indian space programme has attained the importance status in the country's development.

Dhawan was a great inspiring leader. He readily took the responsibility of failures of people working under him and allowed them to take the credit when there were successes. It was not that he was not disappointed at failures, but he would not show it to others. Every time he would analyse the causes for the failure in depth so that it did not repeat again. He considered the institution more important than the individual and always endeavoured to create collective decision-making structures. He was an original thinker. He had a deep sense of humour. He was a deeply compassionate human being. He avoided publicity.

Dhawan's most important contribution was as a teacher. In fact, he primarily considered himself a teacher. His role as a teacher was not confined to his class rooms. APJ Abdul Kalam, the former President of India and an important contributor to India's space programme, who worked closely with Dhawan wrote: "The unique feature of his teaching was that he created a spirit of research and inquiry in me, taught me how to design without giving me the design. He enriched my design capability by following through implementation and test phase, just by asking more and more questions and making me find the answers from them. This enriched my self-confidence in taking up future design problems."

Satish Dhawan was born on 25 September 1920 in Srinagar, Jammu & Kashmir. His father was a civil servant and retired as Resettlement Commissioner of the Government of India. He studied at the Punjab University in Lahore (now in Pakistan). He had a combination of academic degrees. From Punjab University, Lahore he obtained BA in Mathematics and Physics and MA in English Literature. In 1943, he moved to the USA where he first attended the University of Minnesota, Minneapolis and completed a Bachelor of Engineering degree in Mechanical Engineering in 1945. In 1947 he obtained a Master of Science in Aerospace Engineering and Aeronautical Engineer's degree from the California Institute of Technology (Caltech). From Caltech he also obtained a double PhD in Mathematics and Aerospace Engineering under the supervision of Hans W. Liepmann (1914-2009), an American engineer known for his numerous contributions in fluid mechanics covering a wide range of problem areas.

In 1951, Dhawan joined the Department of Aeronautical Engineering of the Indian Institute of Science, Bengaluru (then Bangalore). His initial appointment was as Senior Scientific Officer but within four years he became Professor and Head of the Department and in 1962, at the age of 42, he became the youngest

Director of the Institute. He transformed the Institute and brought in young faculty both from within the country and abroad, started new departments and encouraged to initiate work in newer areas, for example in atmospheric sciences. Dhawan was a star attraction in the campus right from the day he joined the Institute.

After the sudden death of Vikram Sarabhai in December 1971, Smt. Indira Gandhi, the then Prime Minister of India, invited Dhawan to head the India's space programme. At the time the offer was made, Dhawan was in USA on a sabbatical leave and he was teaching a course at Caltech. After finishing the course he came back to India and met the Prime Minister. He told the Prime Minister that he would be willing to take up the assignment but he would like to put up the following two conditions: (i) He should be allowed to continue as Director of IISc, and (ii) the headquarters of India's space programme should be located in Bengaluru. The Prime Minister accepted both the conditions and Dhawan took up charge of India's space programme in September 1972. He became Chairman of the newly established Space Commission, Secretary to the Department of Space and Chairman of ISRO. It may be noted that the space Commission and the Department of Space were established on 1 June 1972. Since the time of Dhawan all the three posts are simultaneously held by a single person.

Mr. Dhawan has set up the country's first supersonic wind tunnel at IISc. A supersonic wind tunnel is a wind tunnel that produces supersonic speeds ($1.2<M<5$) The Mach number and flow are determined by the nozzle geometry. The Reynolds number is varied by changing the density level (pressure in the settling chamber). Therefore a high pressure ratio is required (for a supersonic regime at $M=4$, this ratio is of the order of 10). Apart from that, condensation of moisture or even gas liquefaction can occur if the static temperature becomes cold enough. This means that a supersonic wind tunnel usually needs a drying or a pre-heating facility. A supersonic wind tunnel has a large power demand, so that most are designed for intermittent instead of continuous operation.

Dhawan had a deep sense of social commitment. For him the mere economic benefit accruing from science and technology was not enough. He expressed his concern for the entire segment of the society. His comments on ISRO's effort in identifying and delineating 13 types of wasteland in the country as pointed out by K. Kasturirangan, former Chairman of ISRO, are worth quoting. When Kasturirangan showed him the maps prepared for reclaiming the lands for agricultural and other uses, Dhawan said: "…this is all very good and these maps are very useful to develop this country. But do you know that wastelands in our country are not a waste? There are tribals and others who depend on the produce of these so-called wastelands. If you start water recharging and improve the water availability in these lands to improve the vegetative cover, the whole place may look very promising to prospective developers. Then these tribals will be disturbed and there will be no system to protect them." For him a technology had no use if it did not serve the common person (aam admi). He strongly believed that the chief objective of science and technology should be to serve the country and its people.

Dhawan's fascination for nature was contagious. Natural phenomena around him always made him curious. Like a true scientist in the tradition of Archimedes, Galileo, Newton, Raman and many others, he had an inner urge to unravel or to understand the mysteries of nature. He was fascinated with birds and birds' flight.

Dhawan died on 3 January 2002 at the age of 81.

Satyendra Nath Bose

Satyendra Nath Bose has been in the news of late 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 his name as Boson.

Satyendranath Bose was born on January 1, 1894 in Kolkata. His father Surendranath Bose was employed in the Engineering Department of the East India Railway. Satyendranath was the eldest of his seven children.

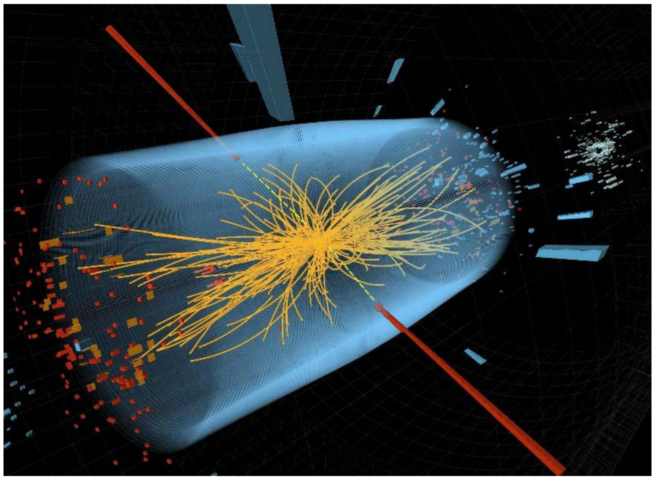
Satyendra Nath Bose did his schooling from Hindu High School in Kolkata. He was a brilliant student and did his college from the Presidency College, Kolkata with Mathematics as his major. He topped the university in BSc and MSc.

In 1916, the Calcutta University started MSc classes in Modern Mathematics and Modern Physics. S N Bose started his career in 1916 as a Lecturer in Physics in Calcutta University. He served here 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. Einstein 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 the scientists. It became famous to the scientists as '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, Satyendranath Bose was elected Chairman of the Physics of the Indian Science Congress and in 1944 elected full chairman of the Congress. In 1945, he was appointed as Khaira Professor of Physics in Calcutta University. He retired from Calcutta University in 1956. The University honored him on his retirement by appointing him as Emeritus Professor. Later he became the Vice Chancellor of the Viswabharati University. In 1958, he was made a Fellow of the Royal Society, London.

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

In quantum mechanics, a boson is a particle that follows Bose–Einstein statistics. Bosons make up one of the two classes of particles, the other being fermions. The name boson was coined by Paul Dirac to commemorate the contribution of the Indian physicist Satyendra Nath Bose in developing, with Einstein, Bose–Einstein statistics—which theorizes the characteristics of elementary particles. Examples of bosons include fundamental particles such as photons, gluons, and W and Z bosons (the four force-carrying gauge bosons of the Standard Model), the Higgs boson, and the still-theoretical graviton of quantum gravity; composite particles (e.g. mesons and stable nuclei of even mass number such as deuterium (with one proton and one neutron, mass number = 2), helium-4, or lead-208); and some quasiparticles (e.g. Cooper pairs, plasmons, andphonons).



An important characteristic of bosons is that their statistics do not restrict the number of them that occupy the same quantum state. This property is exemplified by helium-4 when it is cooled to become a superfluid. Unlike bosons, two identical fermions cannot occupy the same quantum space. Whereas the elementary particles that make up matter (i.e. leptons and quarks) are fermions, the elementary bosons are force carriers that function as the 'glue' holding matter together. This property holds for all particles with integer spin (s = 0, 1, 2 etc.) as a consequence of the spin–statistics theorem.

Shanti Swarup Bhatnagar — Builder of a Chain of Laboratories in India

"As a young boy, my classmates used to teach me for being a day-dreamer. I used to think of great things which Science could do for India and the part I, myself, should play in it with the rest of friends. The improbabilities of my dream coming true used to be the principal subject of jokes when I was a student. If I had not possessed a sense of humour and had taken those jests seriously I should have been a physical wreck. But, God be thanked, I have survived to see some of my dreams fulfilled. Failures have been many and successes few, but with an inborn optimism and faith in my country's future I pursue on."

Shanti Swarup Bhatnagar was one of the builders of scientific and industrial foundations of modern India. Bhatnagar along with Homi Jehangir Bhabha, Prasanta Chandra Mahalanobis, Vikram Ambalal Sarabahi and others played a significant part in building of post-independent S&T infrastructure and in the formulation of India's science and technology policies.

Bhatnagar's position in the annals of Indian science is truly unique. He was a highly accomplished scientist, an able science manager and an administrator, a great creator of institutions and a staunch patriot. He was a great leader of men. He was an effective communicator and he urged his fellow scientists to develop an effective communication skill.

Shanti Swarup Bhatnagar was born on 21 February, 1894 at Bhera, district Shapur, Punjab (now in Pakistan). Bhatnagar had his early schooling in a Maktab (a Persian word meaning primary school). The medium of instruction in the Maktab was Urdu. He also studied at Anglo-Vernacular High School, Sikanderbad and Dayal Singh High School, Lahore. Bhatnagar passed the intermediate Examination of the Punjab University and joined the Forman Christian College for the BSc degree. After completing his bachelor's degree in 1916, Bhatnagar took up his first formal employment as Demonstrator in the Physics and Chemistry Department of the Forman Christian College. Later he became the Senior Demonstrator in the Dayal Singh College. Though Bhatnagar was employed he did not give up his idea of pursuing higher studies. He joined the MSc course of the Punjab University. He obtained his MSc degree in 1919. After MSc, Bhatnagar moved to England for higher studies. This became possible because of the initiative taken by Ruchi Ram Sahni. Bhatnagar was awarded a scholarship by the Dyal Singh College Trust for higher studies abroad.Bhatnagar in his childhood took delight in conducting scientific experiments. While in school he even created a "laboratory" of his own for conducting experiments.

Bhatnagar was a university professor for 19 years (1921-40), first at the Banaras Hindu University (BHU), Varanasi and then Punjab University, Lahore. He had a reputation of a very inspiring teacher. Bhatnagar's research contributions in the areas of magneto chemistry and physical chemistry of emulsions were widely recognised. Bhatnagar developed accurate and simple methods for measuring small changes occurring in magnetic properties of materials. His methods have been used to solve many complex problems connected with colloids, alloys and atomicity of mercury, iodine and selenium under different conditions. He also did considerable work in applied chemistry and he could earn a large amount of money from his applied research. As an unprecedented magnanimous act Bhatnagar donated his earnings from his applied research to the Punjab University, Lahore where he was working.

Bhatnagar was instrumental in setting up of the Council of Scientific and Industrial Research (CSIR). He was its Founder Director (a post later re-designated as Director General). This became a major agency for scientific and industrial research in independent India. At the time of his death a a number of national laboratories were fully functional. Today the CSIR has grown into chain of about forty laboratories with a total scientific and technical staff strength of about 10,000. The CSIR laboratories cover a large spectrum of science and technology. The major activities of CSIR can be grouped under three sections namely, Missions and National Programmes, CSIR Thrust Areas and Capability Development.

Council of Scientific & Industrial Research

Bhatnagar played an instrumental role in the establishment of the National Research and Development Corporation (NRDC), which was visualised to bridge the gap between research and development. Bhatnagar was responsible for the initiation of the industrial research movement in India. The Government of India, being persuaded by the efforts made by Bhatnagar, set up an industrial Research Utilisation Committee for translating science and technology into industrial applications. Bhatnagar constituted the one man Commission in 1951 to negotiate with oil companies for starting refineries and this ultimately led to establishment of many oil refineries in different parts of the country.Bhatnagar exhibited a high poetic talent particularly in Urdu. After his wife's death Bhatnagar published a collection of his Urdu poems, titled Lajwawanti (after his wife's name). During his stay Banaras Hindu University, Varanasi, Bhatnagar composed the 'Kulgeet' (university song) of the university. Bhatnagar died on 1 January 1955.

Bhatnagar's life was of a true "Karma Yogi". Bhatnagar had shown what an individual could do with a greater sense of devotion to duty. He believed that the greatest asset of a nation was its people. Bhatnagar worshipped science. He had an abiding faith in the scientific and technological potential of India. He never lost faith in his own abilities and he worked for the betterment of the society and not for his own benefit.

Subramanyan Chandrasekhar

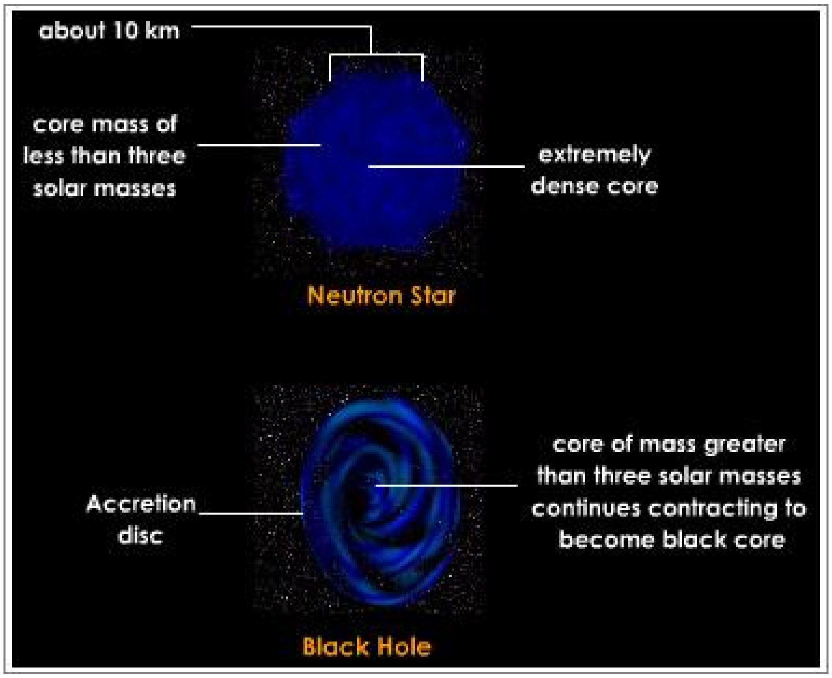
Subrahmanyan Chandrasekhar was born on October 19, 1910 in Lahore. His father, Chandrasekhara Subrahmanya Iyar was an officer in Indian Audits and Accounts Department. His mother Sitalakshmi was a woman of high intellectual attainments. Sir C V Raman, the first Indian to get Nobel Prize in science, was his paternal uncle. Till the age of 12, Subramanyan Chandrasekhar had his education at home under his parents and private tutors. In 1922, at the age of 12, he attended the Hindu High School. He joined the Madras Presidency College in 1925. Subrahmanyan Chandrashekhar passed his Bachelor's degree, BSc (Hon), 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 degree at Cambridge in the summer of 1933. In October 1933, Chandrasekhar was elected to a Prize Fellowship at Trinity College for the period 1933-37. In 1936, while on a short visit to Harvard University, Subrahmanyan Chandrasekhar was offered a position as a Research Associate at the University of Chicago and remained there ever since. In September 1936, Subrahmanyan Chandrashekhar married Lomita 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. 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 discovery of Chandrasekhar Limit, major work done by Subrahmanyan Chandrasekhar includes: theory of Brownian motion (1938-1943); theory of the illumination and the polarization of the sunlit sky (1943-1950); the equilibrium and the stability of ellipsoidal figures of equilibrium, partly in collaboration with Norman R Lebovitz (1961-1968); the general theory of relativity and relativistic astrophysics (1962-1971); and the mathematical theory of black holes (1974- 1983).

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



The **Chandrasekhar limit** is the maximum mass of a stable white dwarf star. The limit was first indicated in papers published by Wilhelm Anderson and E. C. Stoner, and was named after Subrahmanyan Chandrasekhar, the Indian-American astrophysicist who independently discovered and improved upon the accuracy of the calculation in 1930, at the age of 19. This limit was initially ignored by the community of scientists because such a limit would logically require the existence of black holes, which were considered a scientific impossibility at the time. White dwarfs, unlike main sequence stars, resist gravitational collapse primarily through electron degeneracy pressure, rather than thermal pressure. The Chandrasekhar limit is the mass above which electron degeneracy pressure in the star's core is insufficient to balance the star's own gravitational self-attraction. Consequently, white dwarfs with masses greater than the limit would be subject to further gravitational collapse, evolving into a different type of stellar remnant, such as a neutron star or black hole. (However, white dwarfs generally avoid this fate by exploding before they undergo collapse.) Those with masses under the limit remain stable as white dwarfs.

The currently accepted value of the limit is about 1.39 (2.765 × 1030 kg).

The **Chandra X-ray Observatory (CXO)**, is a space observatory launched on STS-93 by NASA on July 23, 1999. Chandra is sensitive to X-ray sources 100 times fainter than any previous X-ray telescope, enabled by the high angular resolution of its mirrors. Since the Earth's atmosphere absorbs the vast majority of X-rays, they are not detectable from Earth-based telescopes; therefore space-based telescopes are required to make these observations. Chandra is an Earth satellite in a 64-hour orbit, and its mission is ongoing as of 2014.Chandra is one of the Great Observatories, along with the Hubble Space Telescope, Compton Gamma Ray Observatory (1991–2000), and the Spitzer Space Telescope. The telescope is named after Subrahmanyan Chandrasekhar.

Sunita Williams Pandya

Sunita Williams Pandya is the second woman of Indian origin to have gone on a NASA space mission after Kalpana Chawla. Born on 19 September 1965 to Dr Deepak and Bonnie Pandya at Ohio in the US, she holds three records for female space Travelers, longest space flight (195 days) number of space walks (four) and total time spent on space walks (29 hours and 17 minutes). As of November 2012, Williams has made seven spacewalks totaling 50 hours and 40 minutes putting her in No. 5 on the list of most experienced spacewalkers.

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. As for her education, Williams attended Needham High School in Needham, Massachusetts, graduating in 1983. She went on to receive a Bachelor of Science degree in Physical science from the United States Naval Academy in 1987, and a Master of Science degree in Engineering Management from Florida Institute of Technology in 1995. The 46-year-old Williams is all set for her next expedition to space in July 2012. She will be a flight engineer on the station's Expedition 32 crew and will become 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. She is a devotee of Hindu God Ganesha. She took with her a copy of Bhagavad Gita and an idol of Ganesha when she visited the International Space Station on her record- breaking space flight.

Thiruvenkata Rajendra Seshadri

"Money and materials alone do not secure good research; they are only adjuncts and it is the human element behind them that does. Leadership in this context is of utmost importance. Not only in war, not only in big business and industry, but also in research there is what is known as "strategy". We have all appreciated great generals, who with small armies and limited weapons have overpowered large and better equipped adversaries. Similarly with small resources great men have built up large industries. We can ignore leadership in the field of scientific research only at the cost of the nation's security and prosperity."

T. R. Seshadri in his Presidential Address to the Indian Science Congress, 1967

Thiruvenkata Rajendra Seshadri was one of the most accomplished chemists of India. He built up one of the finest schools on chemistry of natural products. His own research contributions to chemistry were very significant. The work of Seshadri and his group on natural products can be groupd into four areas, namely, structure elucidations, synthesis and synthetic methods, stereochemistry, and biogenetic theory. Seshadri trained 160 PhD students and published more than 1000 research papers. Among the compounds whose structures were elucidated were: Gossytrin and related pigments of cotton and hibiscus flowers, pedicinin, pedicellic acid and related compounds, mangiferin, dalbergin, latifolin, ferreirin and homoferreirin, pongamol, karanjin, auranetin prudomestin, neptitrin, pedaliin, cupressulflavone, theleporic acid, virensic acid, tingenone, enhydrin, santalin, and alpha terthienyl methanol. The synthetic methods developed by Seshadri and his group include: selective O-methylation and demythylation, C-mythylation, C-prenylation, nuclear oxidation (removal of a hydroxyl group), and nuclear reduction. They also carried out the total synthesis of the following compounds: gossypetin, quecetagetin, khellin, pterocarpin, rotenoids, cyanomaclurin, pedaletin, damanacanthal and related anthraquinones.

Seshadri was born on 3 February 1900 in Kulitalai, a small town situated on the banks of the river Kaveri near Tiruchirapalli. His father was a teacher in a local school. Seshadri received his school education in the temple towns of Srirangam and Tiruchirapalli. In school, he was much influenced by his teachers, who instilled in him "…a sense of duty, obligation to society, love of humanity and thirst for knowledge."

In 1917, Seshadri joined the Madras Presidency College to study the BSc (Honours) course in chemistry. After obtaining the Honourse degree in chemistry of the University of Madras, Seshadri worked for the Ramakrishna Mission for a year. Later he started doing research in the Chemistry Department of Presidency College as a University research scholar. His research supervisor was B. B. Dey, the then Head of the Department. Seshadri's work with Dey on the synthesis of quinolino-pyrones earned him two prizes from the Madras University—the Sir William Wedderburn Prize and the Curzon Prize.

In 1927, Seshadri was selected for a scholarship awarded by the Government of Madras for studying abroad. The scholarship enabled him to visit England, where he worked with Sir Robert Robinson at

Manchester University on new antimalarial drugs and synthesis of anthocyanins. Based on his research work he obtained his PhD degree of the Manchester University in 1929.

Seshadri returned to India in 1930. He first joined the Madras University as a Research Fellow. But after some months he joined The Agricultural College and Research Institute as a soil analyst. There was little scope for undertaking fundamental research in this institute. After three years working as a soil analyst, Shesadri joined Andhra University at Waltair as a senior lecturer and head of the newly created Chemistry Department. The task before him was to build a university department from scratch. He had to build new laboratories and equip them. Courses of study had to be framed. While he was busy building up his laboratories he continued his research. It was not easy. He had to rush on a bicycle to the Biochemistry Department of the Andhra Medical College at Visakhapatnam, located about 5 kilometres away. In 1934, he was appointed Reader. In 1937, Seshadri became Professor and was also given the responsibility of looking after the University Department of Chemical Technology. In the same year Seshadri laid the foundation of the Department of Pharmaceutical Sciences of the Andhra University.

In 1949, Seshadri was invited to head the Chemistry Department of the Delhi University by its Vice Chancellor Sir Maurice Gwyer. It was a difficult decision because by then he had built up an active school of teaching and research at Waltair. However, finally he decided to take up the new challenge. In Delhi Seshadri started an active research centre on natural products.

Seshadri was a great teacher. He inspired many young researchers. He felt deeply about the duties of a scientist. He died on 27 September 1975.

Venkataraman Ramakrishnan

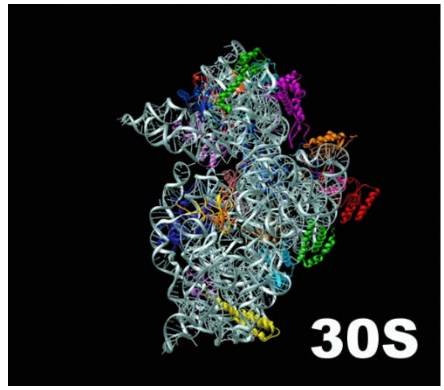
Venkataraman Ramakrishnan was born in Chidambaram, a small town in Cuddalore district in Tamil Nadu in 1952. His parents C V Ramakrishnan and Rajlakshmi were lecturers of biochemistry at Maharaj Sayajirao University in Baroda, Gujarat.

Venky, as he is popularly known, did his schooling from the Covent of Jesus and Marry 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 MRC Laboratory of Molecular Biology, Cambridge. It was there he cracked the complex functions and structures of Ribosome, which fetched him Nobel Prize for Chemistry in 2009, along with Thomas E Steitz and Ada E Yonath. He became the fourth scientist of Indian origin to win a Nobel Prize after Sir C V Raman, Har Gobind Khurana and Subramanyan Chandrasekhar.

Venkataraman Ramakrishnan began his career as a postdoctoral fellow with Peter Moore at Yale University, where he worked on ribosome. 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 University of Utah to work as a professor of Biochemistry. He worked here 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.

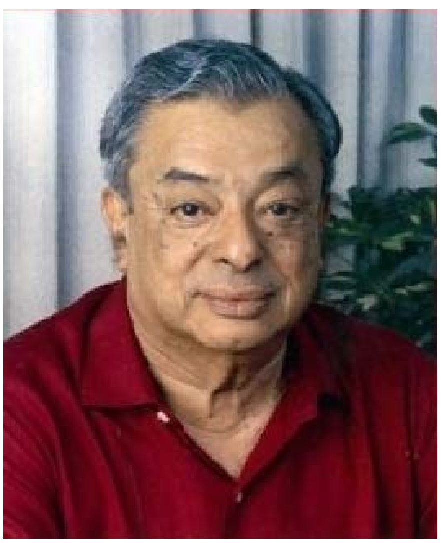


In 1999, along with his fellow mates, he published a 5.5 angstrom resolution structure of 30s subunit of ribosome. In the subsequent year, Venkataraman submitted a complete structure of 30s subunit of ribosome and it created a sensation in structural biology.

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.

Verghese Kurien



Fondly called the 'Milk Man of India', Verghese 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 Master of Science 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 modernise 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 Co- operative Milk Marketing Federation, the cooperative organization that manages the Amul food brand. Amul is a global standard truly 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 is milk with a difference – pasteurized, packaged, branded, owned by farmers.

Vikram Ambalal Sarabhai—Founder of India's Space Programme

"Like a magician creating flowers by rubbing his hands together, Dr. Sarabhai could, and did set up a large number of different organisations. Like a modern Sankara, Dr. Sarabhai has left his footprints from Kashmir to Kanyakumari in the form of various institutions and organisations dedicated to science and learning."

S. P. Pandya, an early associate of Sarabhai and who also served as Director of PRL

Sarabhai's name will remain inseparable from India's space programme. It was Sarabhai, who put India on the international map in the field of space research. He also made pioneering contributions to other fields incessantly till the last moment of his life.

The most striking aspect of Sarabhai's personality was the range and breadth of his interests and the way he transformed his ideas into institutions. He was one of the most versatile personalities of his time. Sarabhai was a creative scientist, a successful and forward looking industrialist, an innovator of the highest order, a great institution builder, an educationist with a difference, a connoisseur of arts, an entrepreneur of social change, a pioneering management educator and more. However, the most important aspect about his personality is that besides being all that he was a very warm human being with tremendous compassion for others. He was a man who could charm and win the hearts of all those with whom he interacted. This was possible because he could convey a sense of respect and trustfulness to them and also a sense of his own trustworthiness.

We are told that anybody, irrespective of his/her position in the organisation, could meet Sarabhai without any fear or feeling inferiority and Sarabhai would always offer him/her a seat and make him/her relax and talk on equal terms. He believed in an individual's dignity and tried hard to preserve it. He was always in search of a better and efficient way of doing things. Whatever he did, he did it creatively. He displayed extreme care and concern for the younger people. He was always ready to provide opportunities and freedom to them.

He was a dreamer with a seemingly unmatched capacity for hard work. He was a visionary, who could not only see opportunities but created some where none could apparently exist. To him the object of life was, as Pierre Curie (1859-1906), the French physicist who was co-discoverer with his wife Marie curie (1867-1934) of polonium and radium, had observed, "to make life a dream and to turn the dream into reality."

Sarabhai was a man who could look far ahead of his times. The success of India's space programme is a testimony to his farsightedness.

A large part of his time was taken up by his research and he continued to supervise research till his untimely death. Nineteen people did their PhD work under his supervision. Sarabhai independently and in association with his colleagues published eighty-six research papers in national and international journal.

Vikram Ambalal Sarabhai was born on 12 August 1919 in a wealthy family at Ahmedabad. His early education was in the family school started by his mother Sarladevi on the lines propounded by Maria Montessori. After completing his Intermediate Science examination from Gujarat College, he went to Cambridge in 1937 and from where he obtained his Tripos in Natural Sciences in 1940.

At the outbreak of the Second World War he returned to India and joined the Indian Institute of Science at Bengaluru where he took up research in cosmic rays under the supervision of C. V. Raman. Sarabhai started work on cosmic ray intensity variations which later him into studies of interplanetary space, solar-terrestrial relationships and geomagnetism of interplanetary space. He published his first research paper entitled, "Time Distribution of Cosmic Rays" in the Proceedings of Indian Academy of Sciences in 1942. In 1945, he went back to Cambridge to work for his PhD degree. In 1947, he was awarded PhD by the Cambridge University for his thesis entitled "Cosmic Ray investigations in Tropical Latitudes". After getting his PhD, he returned to India.

Soon after his return from Cambridge, Sarabhai established the Physical Research Laboratory at Ahmedabad. K. R. Ramanathan, a student of C. V. Raman, joined as its first Director. Sarabhai remained associated with the Physical Research Laboratory throughout his life, in spite of his many and varied responsibilities, first as a Professor of Cosmic Ray Physics and later as Director. At the Physical Research Laboratory, Sarabhai started an extensive series on cosmic ray time variations. He set up a group which was undoubtedly the best in this field and which earned international recognition.

Sarabhai spearheaded the country's rocket technology. His Physical Research Laboratory pioneered research in space science and technology. In 1961, the Government of India placed space research and peaceful use of outer space under the jurisdiction of the Department of Atomic Energy. The Indian National Committee for Space Research (INCONSPAR) was constituted in 1962 under the Chairmanship of Vikram Sarabhai to oversee all aspects of space research in the country. India's space programme started with the setting up of a station to launch sounding rockets. These rockets are so named because they 'sound' the atmosphere or in other words measure various atmospheric parameters during their flight. The United Nations Committee on the Peaceful Use of Space in its resolution recommended the creation and use of sounding rocket facilities especially in the equatorial region and the southern hemisphere. Sarabhai sieged this opportunity as he saw it as a means to realise his own dreams. So agreements were signed with the National Aeronautics and Space Administration (NASA) of USA for training in assembling and launching imported sounding rockets and help in establishing the launching station. An agreement was also signed with the French Space Agency. Sarabhai recruited a small group of young men and sent them to USA for training at the NASA's Goddard Space Flight Centre. These people after returning from USA formed the core group for creating the Thumba Equatorial Rocket Launching Station.

In 1965, the Government of India established the space Science and Technology Centre (SSTC) at Thiruvananthapuram. Its objectives were to design, develop and construct rocket and satellite payloads, instrumentation and to promote research in space science and technology. The Thumba Equatorial Rocket

Launching Station was formally dedicated to the United Nations (UN) on 2 February 1968 by the then Prime minister Indira Gandhi. The UN recognised the Station as an International Equatorial Research Facility.

Sarabhai had recognised very clearly the practical benefits of space applications for a developing country like India. He identified three specific applications—remote sensing, communication and meteorology. Sarabhai had realised that if space research programme was to contribute effectively to national development, it had no alternative other than to develop an indigenous satellite launching capability ranging from low-orbiting to synchronous level. With the realisation he set in motion a project on satellite fabrication and the development of the launching vehicles. That Sarabhai's dedicated efforts had prepared a strong base for ushering India in the space age was validated by the fact that India launched its first satellite into space only three and half years after Sarabhai's untimely death.

Sarabhai established or helped to establish more than 25 institutions in diverse fields. After the sudden and tragic death of Bhabha, Sarabhai was made Chairman of the Atomic Energy Commission. He was at the helm of both atomic energy and space research programmes in India from May 1966 till his death.

His greatest contribution was yet to come and it was the founding of the Indian Space Research Organization (ISRO). Jawaharlal Nehru was the Prime Minister and Dr. Homi Jehangir Bhabha, his principal scientific consultant, and Vikram was able to convince both of them the significance of India entering into a space program, especially in the light of the successful launching of satellites by the then USSR and the USA. There is an off-quoted statement of Vikram on this: "There are some who question the relevance of space activities in a developing nation. To us, there is no ambiguity of purpose. We do not have the fantasy of competing with the economically advanced nations in the exploration of the moon or the planets or manned space-flight." The first step towards this was the setting up of Indian National Committee for Space Research (INCOSPAR) of which Dr. Vikram was made the chairman. Then he brought up the idea of setting up of India's first rocket launching station. Dr. Bhabha accompanied by Dr. Vikram inspected several places to locate India's first rocket launching station and finally both of them decided to locate it at Thumpa, a coastal hamlet near Trivandrum, the capital of Kerala state. The significance of the place was that the magnetic equator of the planet passed through that area, and this would facilitate atmospheric, and space studies. Thus was set up the Thumpa Equatorial Rocket Launching Station (TERLS). The first rocket launching in India took place from TERLS in November 1963. It was a U.S-made rocket. But India wanted to achieve self-reliance in this field and a series of installations such as Space Science and Technology Center (SSTC), Rocket Fabrication Facility (RFF) and Propellant Fuel complex came up in Thumpa. The present Vikram Sarabhai Space Center (VSSC), ISRO's premier and the largest unit is the combination of all these installations. The first India-made rocket, styled Rohini, was launched from a pad in Thumpa in November 1967. The credit for the founding of India's satellite launching station at Shreeharikotta also goes to Dr. Vikram. When Dr. Bhabha, the father of India's nuclear research and development, died in an aircraft crash in 1966, Dr. Vikram was appointed chairman of India's Atomic Energy Commission.

Dr. Vikram Sarabhai, the son of a fabulously rich family of industrialists, is responsible for the founding in 1947 of the Ahmedabad Textile Industries Research Association (ATIRA), which paved the way for the modernization of India's textile industry. In 1962 he took the initiative to set up Indian Institute of Management in Ahmedabad. After three years he set up Community Science Center in the same city. The nuclear reactor in Kalpakkam, the cyclotron project in Calcutta, the Electronic Corporation ofIndia (ECIL) in Hyderabad, and the Uranium Corporation of India (UCIL) in Jaduguda, Bihar are just some of the other famous institutions Dr. Vikram gave leadership to establish.

Sarabhai died on 30 December 1971 at Kovalam, Thiruvanathapuram, Kerala.

Yellapragada Subba Rao—The Man Who Made Miracle Drugs

"You've probably never heard of Dr. Yellapragada Subba Rao

. Yet, because he lived, you may be alive and well today. Because he lived you may live longer."

Doron Antrim, a US news reporter in 1950 in "Argosy", a magazine published from New York till 1978.

In every generation, a few individuals toil and struggle to achieve seemingly impossible feats. Some of them rise against all odds, even when their own survival is not assured. Some give up lucrative positions in society to achieve something unique. Some even after being despised and persecuted by society for their bold initiatives do not give up, or accept defeat. These are the ones who inspire and beckon people from successive generations to take up challenges, to rise above drab mediocrity, and to excel. Life of every such individual is unique even though there may be some commonalities in the circumstances from which such individuals rise. No society can progress without role models. Precedents of successes from extremely harsh conditions motivate many who have given up the struggle. For some Charlie Chaplin is the role model, for some it is Srinivasa Ramanujan and yet for others it is Tenzing Norgay and so it goes. What is important is that stories of the lives of such individuals should be told and retold. Unfortunately even though some achieved so much for fellow human beings, they have remained largely unknown. Yellapragada SubbaRow is one such name. Many of us may have never even heard his name.

Yellapragada SubbaRow was the man behind the development of many wonderful antibiotics such as tetracycline, antifolate cancer drugs, antifilarial drugs, antimalarial drugs and so on. He worked on some fundamental concepts in biochemistry. SubbaRow jointly with Cyrus Hartwell Fiske, developed a simple, accurate calorimetric method for the determination of inorganic as well as organic phosphorus. The procedure is usually known as Fiske-SubbaRow procedure is widely used even today for the determination of phosphorus. SubbaRow while working with Fiske discovered adenosine triphosphate and its role as a source of energy in muscle.

SubbaRow was responsible for many historic and far-reaching discoveries made in biological chemistry and medicine during 1924-1948. The unprecedented significance SubbaRow's multi-faceted contributions has been beautifully described by Pushpa Mitra Bhargava in his article, "Dr. Yellapragada SubbaRow; he Transformed Science; Changed Lives" published in the Journal of Indian Academy of Clinical Medicine. Bhargava wrote: "Rarely, extremely rarely, a person comes on the world scene and transforms science and our lives by making a large number of major discoveries in—and otherwise makes contributions to—more than one basic field and does not only get a Nobel Prize but does not get to be known by name to most people, including scientists around the world. I am referring to Yellapragada SubbaRow. Such an individual is perhaps born in a thousand years or more. I do not believe there is any other person in the documented history of biology and medicine over the 5,000 years who made such a large number of basic discoveries that are applied so widely."

SubbaRow's interest was not confined to scientific research alone. He was a great adventurer. He was enthusiastic about sports too and his interests embraced boxing, tennis, golf, archery, swimming, and horseback riding. He got his Private Pilot's License on 15 October 1947, just less than a year before his death. His greatest quality was his leadership ability, which was reflected in the loyalty he could command from his colleagues. His zeal for achieving something worthwhile bordered on the fanatical.

Yellapragada SubbaRow was born on 12 January 1895 in Bhimavaram in the West Godavari district of Andhra Pradesh, then part of the Madras Presidency. After passing his matriculation examination in three attempts, SubbaRow joined the Presidency College for the intermediate course. After passing the intermediate examination he joined Madras Presidency College. During this time he was much influenced by the ideals of Ramakrishna Mission. It is said that he took up medicine at the instance of the Mission though he did not formally join the Mission. He developed a passion for medical research. His economic condition was precarious during his medical studies at Chennai.

SubbaRow tried to enter the Madras Medical Service without success. He then took up the job as Lecturer in Anatomy and Physiology at Dr. Laksmi Pathi's Madras Ayurvedic College—one of the earliest attempts in India at putting Ayurveda on a modern footing to meet the challenge of the western medicine. The College traced its origin to a school started by the trustees of Chennapuri Kanyaka Parmeswari Devasthanam for training vaidyas. SubbaRow started taking a genuine interest in Ayurveda. He made an attempt "…to place the innumerable Indian herbs on a standardised basis so that they will of use to practitioners of all systems of medicine." He began to compose (with the help of students) a volume on "properties of vegetable drugs in northern India as described by Charaka, Drudhabala, Vrudha, Susrata and Vagabhata (both the Elder and the Younger)." However, he felt that the conditions at the college and also the objectives of its founder are not conducive to true research in Ayurveda and he decided to go to USA.

SubbaRow was awarded the Diploma of the Harvard University School of Tropical Medicine on 1 June 1924. After completing the Diploma SubbaRow became interested in biochemistry and started working with Cyrus Hartwell Fiske. He got his PhD degree in 1930. He continued to work in the Harvard Medical School till 1940 when he moved to Lederle Laboratories where he directed research and did work in the development of drugs till his death in August 1948.

As Gopalpur Nagendrappa wrote (Resonance, June 2012): “As long as the medical fraternity uses chemotherapy to treat several cancers, needs to administer folic acid (Vitamin B9) to cure pernicious anaemia and tropical sprue patients, prescribes hetrazine to rid the pain and deformity of people afflicted diseases, both doctors and patients should be grateful to Yellapragada SubbaRow who made all this possible.”

Folic Acid came out of Yellapragada SubbaRow's search of 18 long years for APAF the anti-pernicious anaemia factor.It is really the antidote for tropical sprue which had taken him to the jaws of death and carried away brother Purushottam-not for pernicious anaemia. Its failure to tackle the neurological abnormality in pernicious anaemia caused him to resume the APAF search in liver. He succeeded but lost publication priority to a rival team which isolated what is known as Vitamin B12 from a microbial source. Folic Acid and B12 supplement each other in the treatment of a wide range of megaloblastic anaemias including pernicious anaemia and tropical sprue.One of the observations Dr SubbaRow made while testing the phosphorus method seemed to provide a clue to the mystery what happens to blood sugar when insulin is administered. Biochemists began investigating the problem when Frederick Banting showed that injections of insulin, the pancreatic hormone, keeps blood sugar under control and keeps diabetics alive.

SubbaRow worked for 18 months on the problem, often dieting and starving along with animals used in experiments. But the initial observations were finally shown to be neither significant nor unique and the project had to be scrapped in September 1926.

Out of the ashes of this project however arose another project that provided the key to the ancient mystery of muscular contraction. Living organisms resist degeneration and destruction with the help of muscles, and biochemists had long believed that a hypothetical inogen provided the energy required for the flexing of muscles at work.

Two researchers at Cambridge University in United Kingdom confirmed that lactic acid is formed when muscles contract and Otto Meyerhof of Germany showed that this lactic acid is a breakdown product of glycogen, the animal starch stored all over the body, particularly in liver, kidneys and muscles. When Professor Archibald Hill of the University College of London demonstrated that conversion of glycogen to lactic acid partly accounts for heat produced during muscle contraction everybody assumed that glycogen was the inogen. And, the 1922 Nobel Prize for medicine and physiology was divided between Hill and Meyerhof.

The search SubbaRow directed at Lederle Laboratories for antibiotics with wider range of cures than the then available penicillin and streptomycin led to the discovery of polymyxin, widely used even today in cattle-feed, and Aureomycin, the first of tetracycline antibiotics which all of us have had some time or the other in our lives. Tetracyclines have saved millions of lives over the last 50 years.

Aureomycin was presented to medicine in 1948, the year SubbaRow died. It was the first broad-spectrum antibiotic, that is, one effective against both gram-positive and gram-negative germs. It was thus more powerful than either Fleming's penicillin or Waksman's streptomycin.

When SubbaRow's centenary year began in 1994, tetracyclines --especially Doxycycline -- helped confine and then eradicate the plague epidemic that broke out in Gujarat and Maharashtra. It was a debt SubbaRow paid to his motherland almost half a century after death which claimed him soon after the unveiling of Aureomycin before a medical gathering at the New York Academy of Sciences.

Modern S&T Centres of India

IIT & IIS

1. Indian Institute Of Technology (IIT), Chennai, Tamil Nadu
2. Indian Institute Of Technology (IIT), Bhubaneswar, Orissa
3. Indian Institute Of Technology (IIT), Delhi, Delhi
4. Indian Institute Of Technology (IIT), Gandhinagar, Gujarat
5. Indian Institute Of Technology (IIT), Guwahati,Assam
6. Indian Institute Of Technology (IIT), Hyderabad Andhra Pradesh
7. Indian Institute Of Technology (IIT), Indore, Madhya Pradesh
8. Indian Institute Of Technology (IIT), Kanpur, Uttar Pradesh
9. Indian Institute Of Technology (IIT), Kharagpur, West Bengal
10. Indian Institute Of Technology (IIT), Mandi, Himachal Pradesh
11. Indian Institute Of Technology (IIT), Mumbai, Maharashtra
12. Indian Institute Of Technology (IIT), Patna, Bihar
13. Indian Institute Of Technology (IIT), Punjab, Punjab
14. Indian Institute Of Technology (IIT), Jodhpur, Rajasthan
15. Indian Institute Of Technology (IIT), Roorke, Uttarakhand
16. Institute Of Technology (IIT), Varanasi, Uttar Pradesh
17. Indian Institute of Science, Bangalore

AIIMS

1. AIIMS Delhi, Ansari Nagar East, New Delhi
2. AIIMS Odisa: Sijua, Patrapada, Bhubaneswar
3. AIIMS Patna(Bihar):Phulwari sharif patna,bihar
4. AIIMS Raipur: Tatibandh, G E Road, Raipur, Chhattisgarh
5. AIIMS Rishikesh: Virbhadra Road, Rishikesh, Uttarakhand
6. AIIMS Bhopal:, Saket Nagar, Bhopal, MP

CSIR S&T Centres

1. Central Building Research Institute (CBRI), Roorkee (Uttaranchal)

Providing S&T back-up to the problems of buildings and construction industries in the areas of housing, building materials, geotechnical & structural engineering, building physics and fire research & testing.

2. Centre for Cellular and Molecular Biology (CCMB), Hyderabad, (AP)

In basic research, the areas are-Biotechnology & Biomedicine, Genetics, Molecular Biology, Biochemistry & Biophysics, Genomics, bioinformatics. Under socially relevant research, the areas are: DNA Fingerprinting, Conservation of endangered animals (wildlife), Molecular Diagnosis (Chromosome & DNA), and Genetic diversity in tribal population of India.

3. Central Drug Research Institute (CDRI), Lucknow (UP)

The Institute's basic objective is discovery and development of new drugs and contraceptive agents, and development of innovative, economic and environment friendly process technologies for known drugs and drug intermediates. The thrust of research is on tropical diseases (tuberculosis, malaria, and leishmaniasis), cardiovascular disorders (dementia, stress), metabolic diseases (diabetes, obesity) and some other problems (ulcers). Synthetic routes as well as natural products are explored to obtain drugs. Natural products explored include terrestrial plants, including Indian traditional remedies, and marine flora and fauna for search of novel molecules for drug development. The institute is equipped with latest facilities, infrastructure and expertise to utilize both conventional approaches of drug research as well as target-based molecular approaches utilizing inputs of molecular and structural biology, genomics, proteomics, bioinformatics, etc. and by utilizing high throughput technologies.

4. Central Electrochemical Research Institute (CECRI), Karaikudi (TN)

Fundamentals and Applied Research in the field of electrochemical power systems comprising batteries & fuel cells, corrosion science and engineering, electrochemicals, electrochemical material science electrochemical instrumentations, electrodics and biosensors, industrial metal finishing and electrochemical pollution control. Development of advanced eco-friendly technologies in the above fields. Undertaking sponsored projects, consultancies, testing & evaluation and human resources development through industry oriented technology courses and B.Tech programme on chemical and electrochemical engineering.

5. Central Electronics Engineering Research Institute, (CEERI) Pilani (Rajasthan)

Microelectromechanical Systems (MEMS) andSensors, Photonic Components and Sub-system, Special Electron Tubes, Electronics for Society Environment and Industry, Nano-Electronics.

6. Central Fuel Research Institute (CFRI), Dhanbad (Jharkhand)

Coal Preparation (from laboratory to continuous pilot plant scale), Coal Carbonization for assessing coking characteristics of coal for different metallurgical application and formulation of coal blends for the steel industry, development of various processed fuels, development of pollution control measures for coal based industries, waste utilization, Biorestoration of waste land, characterization of coals, lignite, cokes and related products, process engineering for coal conversion technologies, Power coal development, Coal combustion, Coal chemicals and Coal hydrogenation.

7. Central Food Technological Research Institute (CFTRI), Mysore (Karnataka)

Development of food products and processes for optimal utilization of country's agricultural produce; Value added convenience products; upgradation of traditional food technology & development of appropriate technologies for reducing/eliminating post-harvest losses and shelf-life studies, biotechnology; basic research related to food additives, flavours, Colorants, pre and probiotics, Physical properties of foods, micronutrients, food toxicity and safety, food microbiology, food chemistry, enzymatic and molecular biology, bioactive materials, food packaging, GM food analysis and nutrigenomics.

8. Central Glass & Ceramic Research Institute (CGCRI), Kolkata (WB)

Development of different varieties of specialty glasses including optical glass, optical materials, electronic materials, engineering and high temperature materials, ceramics for health care, ceramics for energy and environment, ceramic membrane technology, composites, low-cost building materials and traditional ceramics.

9. Central Institute of Medicinal & Aromatic Plants (CIMAP), Lucknow (UP)

Conservation and utilization of genetic resources of medicinal and aromatic plants (National Gene Bank); Bioprospection and development of technologies for therapeutic, nutraceutical, agrichemical and health care products; Transforming R&D leads to technologies and products; Bio-village approach for mission programme on technology dissemination in geranium, rose, mints, rosemary and Cymbopogon grasses; Development of improved varieties and their agrotechnologies for priority plants. Development and up-scaling of processing technologies for in-demand and value added products; Plant genomics and biotechnological improvement in Catharanthus, Withania and Mentha species; Plant tissue culture technology for developing high throughput regeneration and secondary metabolite production; Integrated nutrient and pest management strategies leading to near organic forming; Basic research in selected medicinal and aromatic plants for future exploitation. State of art research facility for Biotechnology, quality and analytical testing.

10. Central Leather Research TDS control in leather processing, value Addition and Institute (CLRI),

Chennai (TN)

cost control, Eco Benign leather processing, Material optimization, standardization and productivity enhancement studies, IT Enabled solutions for the leather products sector, New materials with improved properties –product development and adaptation studies, Design, Trend forecasting and industrialization of traditional art based products. Technological application for management of solid wastes from tanneries and effluent treatment plants and bioenergy generation. Study on econometric on environmental compliance of SMEs. Development of new methodologies and routes for organic synthesis and studies on better utilization of natural products. Development of newer tanning systems and leather processing methodologies. Biomaterials development and testing. IPR Management and tools and techniques for in-house IP acquisition & business processing, Tools and techniques for in-house applications of project management, Academic education and vocational training programmes in capacity building, Innovation & design of new training programmes. Also CSIR network programmes Technology Standardization of Bioresources for & from leather, Envinronment Freiendly Leather Processing, Development of speciality polymers Leather Composites, Industrial Waste Minimization and cleanup – Parchment like leather material from chrome shavings.

11. Central Mechanical Engineering Research Institute (CMERI), Durgapur (WB)

Robotics and Mechatronics, Advanced Manufacturing Technology, Rapid Prototyping and Tooling, Energy and Process Plants, Farm Machinery and Post Harvest Technology, Life Assessment Studies.

12. CSIR Centre for Mathematical Modelling and Computer Simulation (CCMMACS), Bangalore (Karantaka)

Mathematical Modelling for Climate, Environmental and Engineering Problems, Long-range MonsoonForecasting, Advance Forecasting of Cyclones, Multiscale Environmental Modelling Ocean Primary Productivity and Chemistry, Global Ocean Modelling, Earthquake Hazard Monitoring and Modelling, GPS Measurements, Computational Structural Mechanics, Industrial Fluid Flow, Modelling and Analysis of Complex, Physical and Industrial Systems, Network Security and High Performance Computing

13. Central Mining Research Institute (CMRI), Dhanbad (Jharkhand)

Development of mining technology for the exploitation of complex coal deposits; total packages for optimal exploitation of mineral deposits using improved technologies; numerical modeling of rock excavations and computer application in mine planning and designing from stability and safety points of view; and underground space technology. In addition, work has been done on prediction of ground stability; parameters contributing to air pollution in mines; ergonomics in mining operations; corrosion in mines; physical modeling of coal mining systems; development of communication systems for mines, methods for ventilation and safety in mines, mining machinery and equipment.

14. Central Road Research Institute (CRRI), New Delhi

Characterisation and development of pavement materials, Pavement design and analysis, Pavement performance and maintenance management, Geotechnical investigation and ground improvement, Use of waste and marginal materials, Natural hazard management (landslide), High performance materials for roads and bridges, Bridges design and evaluation (including prestressed and cable stayed), Corrosion studies for bridges, Instrumented monitoring of bridges, Bridge maintenance management system, Bridge inspection and rehabilitation, Highway planning and asset management, Rural road network planning, GIS and remote sensing applications to highway planning and traffic engineering, Travel demand analysis and modeling, Road traffic safety and capacity, Transport economics and project appraisal, Social and environmental impact assessment, Intelligent transport system, Air quality modelling and source apportionment, GHG emission inventory and analysis, Development of instrumentation for highways and bridges.

15. Central Scientific Instruments Organisation (CSIO), Chandigarh

Instrumentation for Strategic and Defence Applications; Optics and Opto-Electronics (including Coherent Optics); Agri-Electronic Instrumentation; Instrumentation for Geo-Science & Disaster Mitigation; Medical Instrumentation; Micro Electro Mechanical Systems (MEMS) and Sensors for Diverse Applications; Instrumentation for Energy Management, Condition Monitoring and Quality Control; Biomolecular Electronics & Nanotechnology; Environmental Monitoring Instrumentation; Analytical Instrumentation; Plant & Machinery for Railway Safety; Services (Services & Maintenance of Instruments, Special Manpower Training, Testing & Calibration of Instruments/Components, Energy Audit, etc.); Networked Programmes for CSIR including Electronics for Societal Purposes; Development of Key Technologies for Photonics and Opto-Electronics; Custom Tailored Special Materials etc.

16. Central Salt & Marine Chemicals Research Institute (CSMCRI), Bhavnagar (Gujarat)

Inorganic chemicals: (i) Development of technologies for recovery of common salt, industrial salt, iodized salt, low sodium salt, and marine chemicals like potash, bromine, and magnesium chemicals. Design and lay out of salt farm including salt engineering. Proto type device for improvement and quality control of salt. (ii) Development of technologies for specialty siliceous chemicals, zeolites, clays waste utilization for value added products, recovery of metals from solid wastes .Polymer and Membrane Science: Preparation of reverse osmosis and electrodialysis membrane for safe drinking water. Devices for domestic water purification, concentrating aqueous herbal extracts, animal powdered desalination units. Development of spiral elements for large-scale sewage water treatment plants. Developments of resins for brine purifications, resins for nitrate, arsenic and fluoride removal. Bio-salinity. Identification and cultivation of commercially important seaweeds, development of an innovative techniques for simultaneous preparation of carrageenam and liquid fertilizer, quality agarose, bacteriological grade agar, Cphycocyanin (Bio-pigment). Studies on environmental audit and marine impact assessment for scheduled Industry. Restoration of ecology of wastelands and saline lands. Basic research on plant physiology, biochemistry, molecular biology, agriculture chemistry and genetics. Assessment and performance of desert economic and halophytes plants.

17. Institute of Genomics & Integrative Biology (IGIB), Delhi

Allergy and Infectious Diseases, Genomics and Molecular Medicine, Gene Expression Profiling & Comparative Genomics, Genome Informatics, Proteomics and Structural Biology, Environmental Biotechnology, Bioactive molecules and Technology Development Unit, Design and Synthesis of Nucleic Acid and Peptides.

18. Institute of Himalayan Bioresource Technology (IHBT), Palampur (HP)

Floriculture tea sciences, biotechnologies and natural plant product Conservation Biology Cell and Tissue Culture, Genomics, Proteomics, Natural Products Chemistry, Agro-Chemicals, Chemical Engineering, Plant Virology, Pesticide Residues, Diagnostics.

19. Indian Institute of Chemical Biology (IICB), Kolkata (WB)

Natural products of medicinal, biological and industrial value and synthetic duplication of products of interest; development of innovative immunoassay techniques; gene regulation of hormones and their actions, genetic polymorphisms in pathology in Indian population, understanding the basis of parasitism and development of biotechnologies applicable to the diagnosis and chemotherapy of visceral leishmaniasis; investigation of the molecule basis of pathogenicity of Vibrio cholerae and development of novel approaches towards fertility control and regulation; delineation of the cellular and molecular basis of brain development and genesis and therapy of neurological diseases; investigation of gastric physiology; development of tissue-targeted drugdelivery systems; investigation of the molecular mechanism of biocatalysis; studies on carbohydrates, development of radiopharmaceuticals for myocardial imaging and renal and hepatobiliary studies; protein engineering models for self organizational phenomena in living systems, bioinformatics, molecular modelling and development of novel herbal medicines for common diseases.

20. Indian Institute of Chemical Technology, (IICT) Hyderabad (AP)

Development of technologies for Pesticides, Drugs, Pharmaceuticals, Organic Intermediates, Speciality and Fine Chemicals, Fluoro Organics. The major areas of interest to IICT are Natural Products Chemistry, Integrated Pest Management, Coal and Energy, Bioinformatics, Biology and Biotechnology, Gas-based Technologies. Nanotechnologies, Molecular Modelling and Combinatorial Chemistry, Lipid Sciences and Technologies, Organic Coatings and Polymers, Supramolecular Chemistry, Peptidomimetics, Nonviral gene Delivery Systems, Bio-chemical and Environmental Engineering Sciences, Biotransformations, Chemical and Engineering Sciences, Mechanical Engineering and Design, Chemical and Bio-evaluation, Simulation, Optimization and Control, Hazard and Risk Analysis Studies, Inorganic and Physical Chemistry, Pharmacology, Chemical and Instrumental Analysis, Catalysis and Material Sciences, Clean and Green Technologies with excellent infrastructure facilities, instrumental facilities, Pilot Plant facilities and Computer Centre.

21. Indian Institute of Petroleum (IIP), Dehra Dun (Uttaranchal)

Petroleum Refining technology, development of separation processes, conversion processes, petroleum products applications, development of chemicals and biotechnology.

22. Institute of Microbial Technology (IMT), Chandigarh

Molecular biology and Microbial Genetics; protein science and engineering; Fermentation technology including applied microbiology; cell biology and immunology; Operation and maintenance of Microbial Type Culture Collection and Gene Bank – International Depositary Authority, National facilities on Biochemical Engineering Research and Process Development Centre and Bioinformatics Centre on Protein Engineering.

23. Indian Toxicology Research Centre (ITRC), Lucknow- (UP)

Neurotoxicology, environmental health, ecotoxicology, phototoxicology, epidemiology, immunotoxicology, developmental toxicology, cardiovascular toxicology, pulmonary toxicology, environmental carcinogenesis, environmental monitoring and environmental biotechnology heavy metals, industrial dusts and fibres, plastics and polymers, hydrocarbons, pesticides, detergents, dyes and food additives.

24. National Aerospace Laboratories (NAL), Bangalore (Karnataka)

High Speed Combusion Civil Aircraft Design and Development Wind Energy Systems including Design of Large Wind Turbines Surface Modification Technologies Fuel Cells.

25. National Botanical Research Institute (NBRI), Lucknow (UP)

Conservation and conversion of non-crop plant genetic resources into economic wealth with appropriate S&T intervention. Development of value added products. Plant-based Herbal Formulations, Pharmacognosy, Ethnopharmacology, Nutraceuticals, Plant Biotechnology Plant Molecular Biology & Genetic Engineering Environmental Sciences Biofuel Eco-Restoration, Tree Biology, Biomass Biology,Biodiversity, Biofertilizer, Rehabilitation of degraded soils, mined sites, Agrotechnologies for economically important plants wasteland utilization, Conservation Biology, Floriculture, Medicinal Plants, Eco-education, Bioinformatics, Taxonomy, Biology of Lower Plants Environmental Monitoring, Phytochemistry, Entomology, Genetics.

26. National Chemical Laboratory (NCL), Pune- (Maharashtra)

Catalysis, biotechnology, organic chemical technology, and polymers and other high performance materials. Basic research in chemistry and biochemistry.

27. National Environmental Engineering Research Institute (NEERI), Nagpur (Maharashtra)

Pollution monitoring & mitigation systems and devices; Industrial waste minimization and cleanup; Developing green technologies for environment; Environmental impact and risk assessment and audit; Molecular environmental nanotechnology; Environmental nanotechnology; Genomics enabled environmental biotechnology; Predictive modeling of multimedia environmental quality; Quantification of environmental complexity; Vulnerability of water resources.

28. National Geophysical Research Institute (NGRI), Hyderabad (AP)

Seismology, lithosphere, earth's interior and environment, groundwater, geophysical exploration and geophysical instrumentation.

29. National Institute of Oceanography (NIO), Dona Paula, Goa

International Geosphere-Biosphere Programme, surveys for polymetallic nodules, oceanographic studies of the Antarctic waters, island development programme, coastal zone management, resources and parameters mapping of the EEZ of India, air-sea interaction studies, drugs from the sea, marine biotechnology, biofouling and corrosion studies, technologies for rural development, development of marine instruments, and development of acoustic and remote sensing techniques for monitoring the oceans.

30. National Institute of Science Communication and Information Resources (NISCAIR), New Delhi

Three major Network Programmes- Traditional Knowledge Digital Library to protect against biopiracy, National Science Digital Library to provide on-line S&T curriculam books to college students and E-Journals Consortia to provide research journals at the scientists desk in all CSIR laboratories; Dissemination of S & T information to Scientific Community; Popularization of Science amongst school children and general public; Spreading IT literacy; Information Resources; Information Products and Services; Training Programs.

31 National Institute of Science Technology and Development Studies (NISTADS), New Delhi

IPR: IPR & development studies; ITBT: Information technology and biotechnology: Policy matters and ethical concerns; InnP: Innovation policy; INKS: Innovation & knowledge society; TIARA: Technology & integrated assistance to rural artisans;. SD: Sustainable development STEVS: Science-technology-education valuation studies; HPS: History & philosophy of science/Public awareness of science.

32 National Metallurgical Laboratory (NML), Jamshedpur (Jharkhand)

Minerals & Metals: Bio-mineral processing for extraction of metal values from ores/concentrates/wastes, Developing capabilities in Advanced Manufacturing Technologies, Processing of Polymetallic sea nodules for recovery of valuable metals, Development of an eco-friendly cokeless cupola, Peritectic transformation in multi component iron based alloys during continuous casting, Coal characterization and resource quality assessment,Indigenous technology for optimizing Blast Furnace performance, Mechanical activation in improving theblended cement processing, Developing novel cements based on mechanically activated slag, fuelcells based on hydrogen, innovative technology fortitanium extraction, and development of titanium alloys .Materials: Development of coatings for improved corrosion resistance of steel reinforcement barsFabrication of oxidation & wear coating by spray technique for aerospace application, ceramic cereamic/metalbrazing alloys, nano-structure for novel electronics, magnetic and optical applications, Fabrication of super hard coatings, Bio-mimetic synthesis for bio material for implants and superparamagnetic particles for diagnostic applications, Ecology and Environment: Comprehensive assessment of water quality, Reduction in green house emission in metallurgical sector, Development of cleaner processes/technologies for metallurgical industries.

33. National Physical Laboratory (NPL), New Delhi

Measurements, standards and calibration, electronic & engineering materials, radio and atmospheric physics, cryogenics and superconductivity, applied projects like thin films, optical coatings, xeroradiography, high-pressure metal forming & high-powered ultrasonic systems, and underwater acoustic devices, non-conventional energy devices, and theoretical condensed matter physics.

34 Regional Research Laboratory (RRL), Bhopal- (MP)

Design and development of light alloys, metal matrix & polymetric composites; Sisal Fibre based technologies for eco-friendly wood substitutes; Industrial waste utilization technologies; Water resource exploration, assessment and management; CAE-CAD-CAM, Integration and Intelligent processing of engineering components; Disaster/Accident related materials and modeling; Development and Characterisation of low cost building materials/components; Micro fluidics & fuel cells; Mineral processing & equipment design.

35. Regional Research Laboratory (RRL) Bhubaneswar (Orissa)

Mineral Processing Technology, Extractive Metallurgy, preparation of Special Materials and alloys, Design & Project engineering, preparation of Inorganic and Organic chemicals, Energy & Environment management, Cultivation & Utilization of aromatic, medicinal and other economic plants; and development of new analytical methods.

36. Regional Research Laboratory (RRL), Jammu-Tawi (J&K)

Agrotechnology of medicinal & aromatic plants, identification /authentication of medicinal plants, synthetic (chiral) and natural product chemistry, herbal drugs, selected biological screening, bioprospecting microbial biodiversity for industrially useful enzymes, molecular biology & gene cloning, fermentation technology, quality control and standardization of herbal drugs, establishment of gene bank, bioinformatics, pharmacology phytochemicals/herbal drugs/ nutraceuticals research. Chemical Engineering & Design backup for packaging of technologies.

37. Regional Research Laboratory (RRL), Jorhat, (Assam.)

Medicinal Chemistry, Natural Products Chemistry, Synthetic Organic Chemistry, Biotechnology, Medicinal, Aromatic & Economic Plants, Geosciences, petroleum & Natural Gas, Material Science, Coal, Applied Civil Engineering, Chemical Engineering, Cellulose Pulp & Paper and Utilization of Mineral Resources.

38. Regional Research Laboratory (RRL), Thiruvananthapuram (Kerala)

Chemistry of Natural products, agroprocessing and speciality agrochemicals related to spices and oil seeds, Bioactive compounds from natural sources, Biochemicals and related products through enzyme engineering, materials processing for value addition of clays and beach sand minerals, oxide fine ceramics, metal alloys and composites, simulation of processes, photochemical systems including solar energy conversion, low cost building materials from agro and industrial wastes, calibration of procedures for analysis of toxic pollutants and waste water technology.

39. Structural Engineering Research Centre, (SERC), Chennai (TN)

Structural dynamics, including studies on vibration,blast and impact, earthquake engineering, bridge engineering, steel structures, experimental mechanics, wind engineering, computer-aided analysis and design of structures, fatigue and fracture, structural concretes and concrete composites, towers and towerlike structures, health monitoring and safety audit, and repair, retrofit and rehabilitation of structures.

Other R&D Centres

1. Acharya Tulsi Regional Cancer Institute and Research Centre, Bikaner, Rajasthan, India	2. Advanced Numerical Research and Analysis Group,Hyderabad,AP
3. Advanced Research Centre for Bamboo and Rattan, Aizawl, Mizoram, India	4. Aerial Delivery Research and Development Establishment,Agra UP
5. Aeronautical Development Establishment, New Thippasandra, Bengaluru, Karnataka	6. Agharkar Research Institute, Pune, Maharashtra
7. Agumbe Rainforest Research Station, Agumbe, Karnataka	8. AISSMS College of Pharmacy,pune maharastra
9. Akhil Bharatiya Itihas Sankalan Yojana,deshbandu gupta marg,new delhi	10. All India Institute of Speech and Hearing,Mysore karnataka

11. Anna University K B Chandrashekar Research Centre,Chennai tamilnadu	12. Anthropological Survey of India,Kolkata,west bengal
13. ANURIB, Kolkata,India	14. Arid Forest Research Institute,jodhpur rajasthan
15. Arignar Anna Memorial Cancer Hospital & Research Institute, Karapettai tamilnadu	16. Armament Research and Development Establishment,pune maharastra
17. Aryabhatta Research Institute of Observational Sciences, Nainital	18. Automotive Research Association of India,pune maharastra
19. Bhabha Atomic Research Centre, Pune	20. Bhandarkar Oriental Research Institute,pune maharastra
21. Bhaskaracharya Pratishthana, Erandwane pune maharastra	22. Birbal Sahni Institute of Palaeobotany,lucknow up
23. Bose Institute, Kolkata	24. C-DAC Ahmedabad
25. C-DAC Hyderabad	26. C-DAC Thiruvananthapuram
27. Camel Research Farm, Bikaner	28. Cancer Hospital & Research Centre, Gwalior
29. Center for Excellence in Basic Sciences, Mumbai	30. Center for Military Airworthiness and Certification,Bangalore karnataka
31. Center For Stem Cell Science, Hyderabad	32. Central Arid Zone Research Institute, Jodhpur, Rajasthan
33. Central Avian Research Institute,Bareilly UP	34. Central Drug Research Institute, Kaisarbagh, Lucknow UP
35. Central Electro Chemical Research Institute, Karaikudi tamilnadu	36. Central Electronics Engineering Research Institute, Pilani, Rajasthan
37. Central Food Technological Research Institute, Mysore, Karnataka	38. Central Glass and Ceramic Research Institute,Kolkata west bengal
39. Central Institute for Cotton Research maharastra	40. Central Institute of Brackish Water Aquaculture, Chennai, Tamil Nadu
41. Central Institute of Fisheries kerala, Technology, pune	42. Central Institute of Road Transport
43. Central Marine Fisheries Research Institute,kochi kerala	44. Central Rice Research Institute, Cuttack orissa
45. Central Road Research Institute, mathura road ,delhi	46. Institute of Himalayan Bioresource Technology, Himachal Pradesh
47. Central Salt and Marine Chemicals Research Institute,Bhavnagar gujarat	48. Central Tool Room & Training Centre, Bhubaneshwar orissa
49. Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala	50. Centre for Air Power Studies (India), Subroto Park, New Delhi
51. Centre for Airborne Systems, Bengaluru, Karnatak	52. Centre for Artificial Intelligence and Robotics, Bengaluru, Karnataka
53. Centre for Cellular and Molecular Biology, Hyderabad, Telangana	54. Centre for Development Studies, Thiruvananthapuram, Kerala

55. Centre for DNA Fingerprinting and Diagnostics, Hyderabad	56. Centre for Earth Science Studies, Thiruvananthapuram, Kerala
57. Centre For Electronics Design And Technology, Bengaluru, Karnataka	58. Centre for Fire, Explosive and Environment Safety, Timarpur, New Delhi
59. Centre for Forest Based Livelihood and Extension,agartala,Tripura	60. Centre for Forestry Research and Human Resource Development, Madhya Pradesh
61. Centre for Internet and Society (India), Bengaluru, Karnataka	62. Centre for Land Warfare Studies, Delhi Cantonment, New Delhi
63. Centre for Marine Living Resources & Ecology,cochin,kerala	64. Centre for Mathematical Sciences (Kerala)
65. Centre for Research on Energy Security, New Delhi	66. Centre for Rural Management,kottyam,kerala
67. Centre for Social Forestry and Eco-Rehabilitation,Allahabad,UP	68. Chennai Mathematical Institute, Chennai, Tamil Nadu
69. Combat Vehicles Research and Development Establishment,Chennai tamilnadu	70. Central Building Research Institute, Roorkee uttrakhand
71. CR Rao Advanced Institute of Mathematics, Statistics and Computer Science, Hyderabad, Telangana	72. CRIUM, Hyderabad
73. Crocodile Rehabilitation and Research Centre,kerala	74. CSIR Centre for Mathematical Modelling and Computer Simulation,Bengaluru,karnataka
75. Thapar Centre for Industrial Research & Development, Patiala	76. Defence Avionics Research Establishment, Bengaluru, Karnataka
77. Defence Electronics Application Laboratory, Dehradun, Uttarakhand	78. Defence Electronics Research Laboratory,hyderabad
79. Defence Institute of Advanced Technology, Girinagar, Maharashtra	80. Defence Materials and Stores Research and Development Establishment, Kanpur, Uttar Pradesh
81. Defence Metallurgical Research Laboratory, Hyderabad, Telangana	82. Defence Scientific Information and Documentation Centre,delhi
83. Defence Terrain Research Laboratory,Delhi	84. Desert Medicine Research Centre,jodhpur rajasthan
85. Directorate of Rice Research,hyderabad	86. Electronics and Radar Development Establishment,Bengaluru karnataka
87. IRADe,Malviya nagar,delhi	88. Environmental Protection Training and Research Institute, Hyderabad, Telangana
89. ERNET,Delhi	90. Fish research institutions in the Maharashtra
91. Fisheries College and Research Institute, Thoothukudi, Tamil Nadu	92. Forest Research Institute (India), , Dehradun, Uttarakhand

93. Forest Survey of India, Dehradun, Uttarakhand	94. Gas Turbine Research Establishment,Bangalore karnataka
95. Gau Vigyan Anusandhan Kendra, Nagpur	96. Gokhale Institute of Politics and Economics, Pune, Maharashtra
97. Govind Ballabh Pant Social Science Institute, Allahabad, Uttar Pradesh	98. Gujarat Cancer Research Institute, Ahmedabad, Gujarat
99. Haffkine Institute,Mumbai maharastra	100. Harish-Chandra Research Institute, Allahabad, Uttar Pradesh
101. High Energy Materials Research Laboratory, Pune, Maharashtra	102. Himalayan Forest Research Institute, Shimla, Himachal Pradesh
103. Homi Bhabha Centre for Science Education, Mumbai, Maharashtra	104. Homi Bhabha National Institute, Mumbai, Maharashtra
105. IBM India Research Laboratory,Delhi	106. Indian Academy of Sciences,bengaluru
107. Indian Association for the Cultivation of Science, Kolkata, West Bengal	108. Indian Centre for Space Physics,kolkatta west bengal
109. Directorate of Medicinal and Aromatic Plants Research, Boriyavi, Gujarat	110. Indian Council of Forestry Research and Education
111. Indian Council of Medical Research, Ansari Nagar, New Delhi,	112. Indian Council of Social Science Research,new delhi
113. Indian Diamond Institute,surat Gujrat	114. Indian Institute of Chemical Biology, Kolkata, West Bengal
115. Indian Institute of Crop Processing Technology, Thanjavur, Tamil Nadu	116. Indian Institute of Horticultural Research,Bengaluru
117. Indian Institute of Petroleum,Dehradun,uttrakhand	118. Indian Institute of Plantation Management, Malathalli, Bangalore
119. Indian Institute of Pulses Research,Kanpur uttar pradesh	120. Indian Institute of Remote Sensing, Dehradun, Uttarakhand
121. Indian Institute of Nano Science & Technology, Bengaluru, Karnataka	122. Indian Institute of Science, Bengaluru, Karnataka
123. Indian Institute of Science Education and Research, Bhopal	124. Indian Institute of Science Education and Research, Kolkata
125. Indian Institute of Science Education,kerala and Research, Mohali	126. Indian Institute of Science Education and Research, Pune
127. Indian Institute of Science Education and Research, Thiruvananthapuram	128. Indian Institute of Space Science and Technology, Thiruvananthapuram, Kerala
129. Indian Institute of Toxicology Research, Lucknow UP	130. Indian Institute of Tropical Meteorology, Pune
131. Indian Social Institute, New Delhi, Delhi	132. Indian Society of International Law, New Delhi
133. Indian Veterinary Research Institute, Bareilly, Uttar Pradesh	134. Tata Institute of Fundamental Research, Mumbai, Maharashtra

135. Indira Gandhi Centre for Atomic Research, Kalpakkam, Tamilnadu	136. Indira Gandhi Institute of Development Research,Mumbai maharastra
137. Indraprastha Institute of Information Technology,Govind puri New Delhi	138. Institute for Defence Studies and Analyses, Tula Ram Marg New Delhi
139. Institute for Plasma Research, Gandhinagar, Gujarat	140. Institute for Social and Economic Change, Bengaluru, Karnataka
141. Institute for Stem Cell Biology and Regenerative Medicine,Bangalore karnataka	142. Institute for Studies in Industrial Development, New Delhi
143. Institute of Development Studies, Kolkata	144. Institute of Forest Biodiversity, Hyderabad, Telangana
145. Institute of Forest Productivity,ranchi jharkhand	146. Institute of Life Sciences, Bhubaneshwar, Odisha
147. Institute of Mathematical Sciences, Chennai	148. Institute of Mathematics and Applications, Bhubaneswar
149. Institute of Minerals and Materials Technology Bhubaneswar, Odisha	150. Institute of Peace and Conflict Studies,new delhi
151. Institute of Physics, Bhubaneswar	152. Institute of Social Sciences, New Delhi
153. Institute of Wood Science and Technology, Bengaluru, Karnataka	154. Instruments Research and Development Establishment,Dehradun uttrakhand
155. Inter-University Centre for Astronomy and Astrophysics, Pune	156. International Centre for Automotive Technology,Haryana India
157. International Centre for Theoretical Sciences,bengalure karnataka	158. International Crops Research Institute for the Semi-Arid Tropics,hyderabad
159. International Institute of Information Technology, Hyderabad	160. ISRO Propulsion Complex, Mahendragiri Tirunelveli Tamil Nadu
161. Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore	162. K. Banerjee Centre of Atmospheric and Ocean Studies,Allahabad,up
163. Kabru super computer,Chennai,tamilnadu	164. Kaivalyadhama Health and Yoga Research Center, Lonavla, Maharashtra
165. Kamarupa Anusandhan Samiti,Assam	166. Kerala Forest Research Institute,kerala
167. Kerala School of Mathematics, Kozhikode	168. Kidwai Memorial Institute of Oncology,Bangalore,karnataka
169. Krishi Vigyan Kendra Kannur,kannur	170. Laser Science and Technology Centre, New Delhi
171. Liquid Propulsion Systems Centre,kerala	172. List of forest research
173. M. P. Birla Institute of Fundamental Research, Bangalore	174. Madras Institute of Development Studies,Chennai tamil nadu
175. Major Atmospheric Cerenkov Experiment Telescope,ladakh india	176. Mathematical Sciences Foundation,delhi

177. Microwave Tube Research and Development Center,bengaluru	178. The National Academy of Sciences, India,Allahabad UP
179. National Aerospace Laboratories,karnataka	180. National Atmospheric Research Laboratory, Chittoor, Andhra Pradesh
181. National Botanical Research Institute,lucknow,UP	182. National Brain Research Centre, Gurgaon, Haryana
183. National Centre for Antarctic and Ocean Research, Vasco-da-Gama, Goa	184. National Centre for Biological Sciences, Bengaluru, Karnataka
185. National Centre for Cell Science, Pune	186. National Centre for Disease Control,New Delhi
187. National Centre for Radio Astrophysics, Pune, Maharashtra	188. National Chemical Laboratory,pune,maharastra
189. National Council of Applied Economic Research, IP Estate, New Delhi	190. National Council of Educational Research and Training,New Delhi
191. National Dairy Research Institute,karnal haryana	192. National Environmental Engineering Research Institute, Nagpur, Maharashtra
193. National Geophysical Research Institute,Hyderabad	194. National Institute for Interdisciplinary Science and Technology, Thiruvananthapuram, Kerala
195. National Institute for Research in Reproductive Health, Mumbai, Maharashtra	196. National Institute for Research in Tuberculosis, Chennai
197. National Institute of Advanced Studies, Bengaluru, Karnataka	198. National Institute of Animal Biotechnology, Hyderabad, Telangana
199. Centre for Advanced Technogy, Indore	200. Central Coffee Research Institute, Bangalore
201. Gandhi Institute of Technology and Management, Visakhapatnam	202. Indian Institute of Astrophysics, Bangalore
203. Inter-University Accelerator Centre, New Delhi	204. Raman Research Institute, Bangalore
205. Saha Institute of Nuclear Physics, Kolkata	206. Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram

Arab Sciences

Golden Age Arab Sciences

Science in the medieval Arab world is the science developed and practiced in the medieval Arab world during the Arab Golden Age (8th century CE –c. 1258 CE, sometimes considered to have extended to the 15th or 16th century). During this time, Indian, Assyrian, Iranian and Greek knowledge was translated into Arabic. These translations became a wellspring for scientific advances, by scientists from the Muslim ruled areas, during the Middle Ages. The roots of Arab science drew primarily upon Arab, Persian, Indian and Greek learning. The extent of Arab scientific achievement is not as yet fully understood, but it is extremely vast.

These achievements encompass a wide range of subject areas; most notably

- Mathematics
- Astronomy
- Medicine

Other notable areas, and specialized subjects, of scientific inquiry include

- Physics
- Alchemy and chemistry
- Cosmology
- Ophthalmology
- Geography and cartography
- Sociology
- Psychology

Mathematics

The history of mathematics during the Golden Age, especially during the 9th and 10th centuries, building on Greek mathematics (Euclid, Archimedes, Apollonius) and Indian mathematics (Aryabhata, Brahmagupta), saw important developments, such as the full development of the decimal place-value system to include decimal fractions, the first systematised study of algebra (named for the work of scholar Al-Kwarizmi), and advances in geometry and trigonometry. Arabic works also played an important role in the transmission of mathematics to Europe during the 10th to 12th centuries.

Astronomy

Arab astronomy comprises the astronomical developments made in the Arab world, particularly during the Arab Golden Age (8th–15th centuries), and mostly written in the Arabic language. These developments mostly took place in theMiddle East, Central Asia, Al-Andalus, and North Africa, and later in the Far East and India. It closely parallels the genesis of other Arab sciences in its assimilation of foreign material and the amalgamation of the disparate elements of that material to create a science with Arab characteristics. These included Greek, Sassanid, and Indian works in particular, which were translated and built upon. In turn, Arab astronomy later had a significant influence on Byzantine and European astronomy (see Latin translations of the 12th century) as well as Chinese astronomy and Malian astronomy.

A significant number of stars in the sky, such as Aldebaran and Altair, and astronomical terms such as alidade, azimuth, andalmucantar, are still referred to by their Arabic names. A large corpus of literature from Arab astronomy remains today, numbering approximately 10,000 manuscripts scattered throughout the world, many of which have not been read or catalogued. Even so, a reasonably accurate picture of Arab activity in the field of astronomy can be reconstructed.

Medicine

In the history of medicine, **Arab medicine**, **Arabic medicine**, **Greco-Arabic** and **Greco-Arab** refer to medicine developed in the Arab Golden Age, and written in Arabic, the lingua franca of Arab civilization. The emergence of Arab medicine came about through the interactions of the indigenous Arab tradition with foreign influences. Translation of earlier texts was a fundamental building block in the formation of Arab medicine and the tradition that has been passed down.

Latin translations of Arabic medical works had a significant influence on the development of medicine in the high Middle Ages and early Renaissance, as did Arabic texts which translated the medical works of earlier cultures.

The mind-body connection is inherent to Arab medicine, whose foundations are Imaan (faith) and Tawakkul (trust). According to the Arab prophet, Muhammad: "There is no disease that Allah has created, except that He also has created its remedy". Indeed, this lay the foundations for early medical science, for "the Prophet not only instructed sick people to take medicine, but he himself invited expert physicians for this purpose". Around the ninth century, the Arab medical community began to develop and utilize a system of medicine based on scientific analysis. The importance of the health sciences to society was emphasized, and the early Muslim medical community strived to find ways to care for the health of the human body. Medieval Arabs developed hospitals, expanded the practice of surgery. Important medical thinkers and physicians of this time were Al-Razi (Rhazes) and Ibn Sina (Avicenna). Their knowledge on medicine was recorded in books that were influential in medical schools throughout Muslim world and

Europe, and Ibn Sina in particular (under his Latinized name Avicenna) was also influential on the physicians of later medieval Europe. Throughout the medieval Arab world, medicine was included under the umbrella of natural philosophy, due to the continued influence of the Hippocratic Corpus and the ideas of Aristotle and Galen. The Hippocratic Corpus was a collection of medical treatises attributed to the famous Greek physician Hippocrates of Cos (although it was actually composed by different generations of authors). The Corpus included a number of treatises which greatly influenced medieval Arab medical literature.

Physics

The natural sciences saw various advancements (from roughly the mid 8th to the mid 13th centuries, adding a number of innovations to the Transmission of the Classics (such as Aristotle, Ptolemy, Euclid, and Neoplatonism). Thinkers from this period included Al-Farabi, Abu Bishr Matta, Ibn Sina, al-Hassan Ibn al-Haytham and Ibn Bajjah. These works and the important commentaries on them were the wellspring of science during the medieval period. They were translated into Arabic, the lingua franca of this period.

Arabs had inherited Aristotelian physics from the Greeks and during the Golden Age developed it further. However the Arab world had a greater respect for knowledge gained from empirical observation, and believed that the universe is governed by a single set of laws. Their use of empirical observation led to the formation of crude forms of the scientific method. The study of physics in the Arab world started in Iraq and Egypt. Fields of physics studied in this period include optics, mechanics (including statics, dynamics, kinematics and motion), and astronomy.

Golden Age Arab Scientists

Abbas Ibn Firnas

Abbas Ibn Firnas (810-887) was polymath—an inventor, physician, engineer, musician and poet. He is also also known as Abbas Abu Al-Qasim Ibn Firnas Ibn Wirdas al-Takurini. He was born in Izn-Rand Onda, Al-Andalus (today's Ronda, Spain). He lived in Emirate of Cordoba. He devised a chain of rings that enabled to simulate the motions of the planets and stars and a means of manufacturing colourless ; designed a water clock called Al-Maqata; invented various glass planispheres; and made corrective lenses. He also developed a process for cutting rock crystals. Apparently he had designed a room in his house in which spectators could witness stars, clouds, thunder, and lightning. The mechanisms which produced these were located in a basement laboratory. He also devised 'some sort of metronome' , an instrument with an inverted pendulum that can be set to beat so many times a minute, the loud ticking giving the right speed of performance for a piece of music.

Al Idrisi

Abu Abd Allah Muhammad al-Idrisi al-Hasani al-Sabti or simply Al Idrisi (1099–1165 or 1166) was born in the city of Ceuta then belonging to Moroccan Almoravids. He lived Sicily and served in the court of King Roger II. He was a geographer, cartographer, and Egyptologist. Al-Idrisi is best known for his map, Tabula Rogeriana. It was prepared for King Roger II. Al-Idrisi's work exerted strong influence on geographers like Ibn Battuta, Ibn Khaldum and Piri Reis. He also inspired Christopher Columbus and Vasco Da Gama.

Al-Idrisi produced a compendium of geographical information titled Kitab nuzhat al-mushtaq fi'khtiraq al-'afaq (The book of pleasant journeys into faraway lands or The pleasure of him who longs to cross the horizons. His book Nuzhatul Mushtaq was also often cited.

Al-Battani

Abu Abd Allah Muhammad ibn Jabir ibn Sinan al-Raqqi al-Harrani al-Sabi al-Battani (c.858-c.929) was born in Harran near Urfa in Upper Mesopoamia (now in Turkey). He lived and worked in the city of Ar-Raqqah in north central Syria. In Latin literature he is referred to as Albategnius, Albategni or Albatenius. He was an astronomer, astrologer and mathematician. He extended a number of trigonometric relations which were transmitted from India and Greco-Rome. His book, Kitab az-Zij was frequently quoted by many medieval European astronomers including by Copernicus.

Al-Battani refined the existing values for the length of the year as 365 days, 5 hours, 46 minutes and 24 seconds against Ptolemy's 365 days, 5 hours, 55 minutes and 12 seconds. Based on his observations he compiled new tables of the Sun and Moon and indoing so he corrected some of Ptomey's results. In mathematics al-Battānī produced a number of trigonometrical relationships; discovered the reciprocal functions of secant and cosecant, and produced the first table of cosecants.

Alhazen

Abu al-Hasan ibn al-Hasan al-Haytham (c. 965-c.1040), often referred to as ibn al-Haytham was an Arab polymath. He is also known as by his Latinised name Alhazen or Alhacen. He was born in Basra, then part of Buyid emirate. He lived mainly in Cairo, Egypt.

He made significant contributions to the priciples of optics, astronomy, mathematics, meteorology, visual perception and scientific method. He is regarded as father of modern optics, ophthalmology, experimental physics and scientific methodology. He is also regarded as the first theoretical physicist.

In medieval Europe, he was nicknamed Ptolemaeus Secundus ("Ptolemy the Second") or simply called "The Physicist".

Alhazen made significant improvements in optics, physical science, and the scientific method. Alhazen's work on optics is credited with contributing a new emphasis on experiment.Jim Al-Khalili, a British-Iraqi terms Alhazen as be the "first true scientist" based on Alhazen's pioneering work on scientific method.

Alhazen's most famous work was his seven-volume treatise on optics titled Kitab al-Manazir (Book of Optics). Its Latin version was published in 1572 with the title Opticae thesaurus: Alhazeni Arabis libri septem, nuncprimum editi; Eiusdem liber De Crepusculis et nubium ascensionibus.

Scientific method

The duty of the man who investigates the writings of scientists, if learning the truth is his goal, is to make himself an enemy of all he reads, and… attack it from every side. He should also suspect himself as he performs his critical examination of it, so that he may avoid falling into either prejudice or leniency. Alhazen is often regarded as founder of experimental psychology and also founder of psychophysics.

Abu al-Qasim Khalaf ibn al-Abbas Al-Zahrawi

Abu al-Qasim Khalaf ibn al-Abbas Al-Zahrawi (936–1013), was an Arab Muslim physician. He is also known as Albucasis. He was born in the city El-Zahra, Andalusia. He lived most of his life in Córdoba. He is considered the greatest medieval surgeon. Many regard him as the father of modern surgery. His greates work on medicine was a thirty-volume encyclopedia of medical practices titled Kitan al-Tasrif. He made pioneering contributions to the field of surgical procedures and instruments and some of his discoveries are still applied in medicine to this day.

He was the first physician to describe an ectotopic pregnancy. He was also first to identify the hereditary nature of haemophilia. He was the first to draw hooks with a double tip for use in surgery. He illustrated various cannuale for the first time and treated wart with an iron and caustic metal as a boring instrument. He used and described over 200 surgical instruments and he used foreceps in vaginal deliveries. He pioneered the preparation of medicines by sublimation and distillation. His works were translated into Latin. It has been said that Al-Zahrawi was the "most frequently cited surgical authority of the Middle Ages".

Abu Ishak Ibrahim ibn Yahya al-Naqqash al-Zarqali

Abu Ishak Ibrahim ibn Yahya al-Naqqash al-Zarqali (1029-1087) was one of the leading astronomers of his time. He was also an instrument maker and astrologer. Although he is usually called as al-Zarqālī but his correct name was al-Zaqalluh. In Latin he is referred to as Arzachel or Arsechieles. He was born in born in a village near the outskirts of Toledo, then the capital of the Taifa of Toledo. He was trained as metalsmith.

He was well-versed in geometry and astronomy. In fact he was the one of the foremost astronomers of his time. He was an inventor and his works helped Toledo to become an intellectual centre of Al-andalus. He is also referred to in the works of Chaucer, as 'Arsechieles'.

Al-Zarqali's works were translated into Latin in the 12th century. In his "De Revolutionibus Orbium Coelestium", Nicolaud Copernicus quotes the works of al-Zarqali.

Al-Zarqālī wrote two works on the construction of an instruments.He also invented a perfected kind of astrolabe known as "the tablet of the al-Zarqālī" (al-ṣafīḥā al-zarqāliyya). This became famous in Europe under the name Saphaea.

Abu Mūsā Jābir ibn Hayyān

Abu Mūsā Jābir ibn Hayyān (fl.c.721–c.815) was a prominent Muslim polymath. In Europe, Jabir was known as Geber (Latinised version of Jabir).He has been entitled differently as al-Azdi al-barigi or al-Kufi or al-Tusi or al-Sufi. An anonymous European writer produced alchemical and metallurgical writings under the pen-name 'Geber' (referred to as pseudo-Geber) in the 13th century. It is generally believed that Jabir was born in Tus, Khorasan in Iran (then Persia) and later moved to Kufa. However, some suggest that he was of Syrian origin and later lived in Persia and Iraq.

The seeds of the modern classification of elements into metals and non-metals could be seen in Jabir's chemical classification where he proposed the following three categories:

- "Spirits" which vaporise on heating, like camphor, sulphur and ammonium chloride.
- "Metals" like gold, silver, lead, tin copper and iron and khar-sini (Chinese iron).
- Non-malleable substances that can be converted into powders such as stones.

He made use of over twenty types of now-basic chemical laboratory equipment, such as the alembic and retort, and described many chemical processes like crystallisation and distillation. He described many substances like citric acid, acetic acid, tartaric acid, arsenic, antimony, bismuth, sulphur and mercury.

Jabir was a foremost alchemist of his time. He paved the way for most of the later Muslim alchemists, who lived in the 9th–13th centuries. As Max Meyerhoff observed Jabir's influence may also be traced throughout the entire historic course of European alchemy and chemistry. Jabir's treatises on alchemy were translated into Latin and became standard texts for European alchemists. In fact according to Erick John Holmyard, a historian of chemistry, Jabir developed alchemy into an experimental science and his influence is equal to that of Robert Boyle and Antoine Lavoisier.

The **Banu Musa brothers** namely Abu Ja'far, Muhammad ibn Musa Ibn Shakir, Abu al-Qasim Ahmad ibn Musa ibn Shakir and Al-Hasan ibn Musa ibn Shakir were three 9th-century scholars of Baghdad.

They made many observations and contributions to the field of astronomy, writing nearly a dozen publications over their astronomical research. They made many observations on the sun and the moon. Al-Ma'mun had them go to a desert in Mesopotamia to measure the length of a degree. They also measured the length of a year to be 365 days and 6 hours

The Banu Musa wrote almost 20 books the majority of which are now lost. Some of their important works were:

- The Book of Ingenious Devices. It describes 100 inventions.
- Qarasṭūn, a treatise on weight balance.
- On Mechanical Devices, a work on pneumatic devices, written by Ahmad.
- A Book on the Description of the Instrument Which Sounds by Itself, about musical theory.

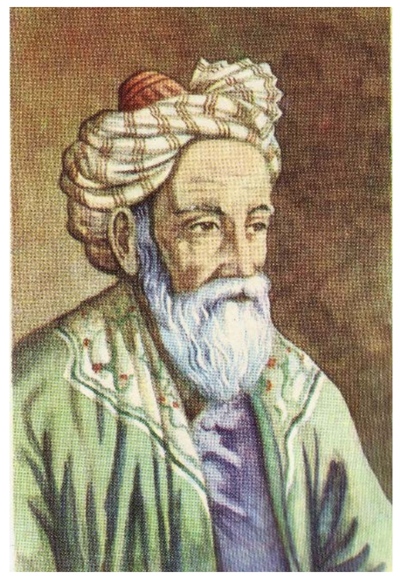
Ibn al-Nafis

Ala-al-din abu Al-Hassan Ali ibn Abi-Hazm al-Qarshi al-Dimashqi,(1231-1288) was an Arab physician. He is also called Ibn al-Nafis. He was born in Damascus. He is mostly known for being the first to describe the pulmonary circulation of the blood. He made original contributions to ophthalmology. His book Kitab al-Mukhtarfi al-Aghdhiya describes his studies on the effects of diet on health. He was an expert on the Shafi School of jurisprudence. He planned a 300-volume encyclopedia titled Al-Shamil fi al-Tibb but he could not complete it. His Al-Risalah al-Kamiliyyah fil Siera al-Nabawiyyah translated in Latin under the title Theologus Autodidactus is regarded as by some as the first theological novel and the first science fiction novel.

Al-Sabi Thabit ibn Qurra al-Harrani

Al-Sabi Thabit ibn Qurra al-Harrani (826-901) lived in Baghdad. He was born in Harran in Higher Mesopotamia/Assyria (Modern-day Turkey). He was a mathematician, physician, astronomer and translator. He made significant contributions to algebra, geometry, and astronomy. He was one of the first persons to reform the Ptolemaic system. He published his own observations of the Sun. He is regarded as a founder of statics in mechanics. Among his discoveries in mathematics was an equation for determining amicable numbers. He transformed mathematics by introducing the use of numbers to describe the ratios between geometrical quantities. He described a Pythaforas theorem. He also worked out the solution to chessboard problem which involved an exponential series. He translated many Greek works into Arabic including those of Apollonius, Archimedes, Euclid and Ptolemy.

Omar Khayyam



Ghiyath ad-Din Abu'l Fath Umar ibn Ibrahim al-Khayyam Nishapuri (1048 – 1131) was one of the major mathematicians and astronomers of the medieval period. He is popularly known Omar Khayyam. He was born in Nishapur in North Eastern Iran. After studying at Samarkand he moved Bukhara. He was a polymath—philosopher, mathematician, astronomer and poet. He also studied mechanics, geography, mineralogy, music and Islamic theology.

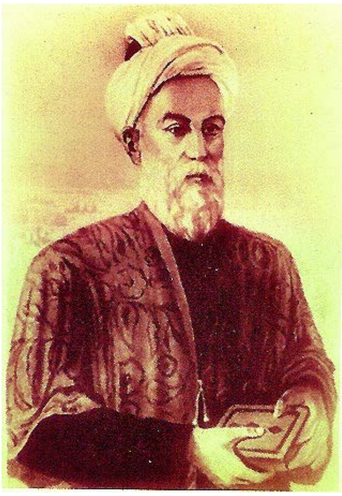
His book on algebra, the Treatise on Demonstration of Problems of Algebra, was a major contribution. It described geometric method for solving cubic equations by intersecting a hyperbola with a circle. He is also famous as a poet and he is best known for Rubaiyat of Omar Khayyam.

Hunayn ibn Ishaq

Hunayn ibn Ishaq (809–873) was a famous scholar, physician and scientist. He was born in al-Hira in southern Iraq and worked in Baghdad. In Latin he is known as Johannitis. He is sometimes referred to as Hunain or Hunein. He is known for his translation of Greek scientific and medical works into Arabic and Syriac, his method of translation and his contributions to medicine. He was arguably the chief translator of his time. He translated 116 works including Plato's Timaeus, Aristotle's Metaphysics and the Old Testament into Syriac and Arabic. Among the Arabs he was call "Sheikh of the translators". His method of translation was followed by later translators. Ḥunayn ibn Isḥaq was the most productive translator of Greek medical and scientific treatises in his day. He studied Greek and became known among the Arabs as the "Sheikh of the translators." He mastered four languages: Arabic, Syriac, Greek and Persian. His translations did not require corrections. Hunayn's method was widely followed by later translators. He himself wrote about 26 original treatises most of which were related to medicine. He laid the foundations of the Arabic medicine.

Hunayn ibn Ishaq enriched the field of ophthalmology. His developments in the study of the human eye can be traced through his innovative book, "Ten Treatises on Ophthalmology." This textbook is the first known systematic treatment of this field and was most likely used in medical schools at the time.

Ibn Sina



Ibn Sina (c. 980 – 1037) also known as Pur Sina or Abu Ali al-Husayn ibn Abd Allah ibn Al-Hasanibn Ali ibn Sina. Ibn Sina, whose Latinised name is Avicenna, was a Persian polymath. Regarded as the most famous and influential polymath of Golden Age, Ibn Sina wrote on mathematics, physics, medicine, philosophy, astronomy, alchemy, geology, psychology, logic, theology and poetry. He wrote almost 450 works on a variety of subjects, of which around 240 have survived. His most famous works are The Book of Healing and The Canon of Medicine. The Canon of Medicine was a standard medical text at many medieval universities.

Tūsī

Khawaja Muhammad ibn Muhammad ibn Hasan Tūsī (1201– 1274) was born in the city of Tus in mediaval Khorasan (in north-eastern Iran). In the west he is usually known as Nasir al-Din or simply as Tusi. He was a plymath---astromer, biologist, chemist, mathematician, philosopher, physician, physicist and theologian.

Tusi is considered as one of the most eminent astronomers of his time. Based on his observations made at Rasad Khaneh Observatory Tusi made very accurate tables of planetary movements and which were presented in his book Zij –I ilkhani (Ilkhanic Tables) . This book contains astronomical tables for calculating the positions of the planets and the names of the stars. The model for the planetary system developed by Tusi was the most advanced of his time. It was used extensively until the development of the heliocentric model. For preparing his planetary models he introduced a geometrical technique called Tusi-couple.

Tusi proposed a theory of evolution of species in his book, Akhlaq-i-Nasri. He discussed how organisma were able to adapt to their environment. He recognized three types of living things: plants, animals, and humans and attempted to explain how humans evolved from advanced animals.

He wrote a book on trigonometry independently of astronomy and he was the first person to do so. In his Treatise on the Quadrilateral, Al-Tusi presented an extensive exposition of spherical trigonometry distinct from astronomy. It was Al-Tusi who developed trigonometry as an independent branch of pure mathematics distinct from astronomy.

He was the first to list the six distinct cases of a right triangle in spherical trigonometry. He also stated the law of sines for spherical triangles.

Mohhammad ibn Zakariya al-Razi

Mohhammad ibn Zakariya al-Razi (854-925/935), in Latin he is known as Rhazes or Rasis. He was a plymath—physician, alchemist, chemist and philosopher. He occupies an important place in history of medicine. He is regarded as the discoverer of alcohol and vitriol (sulphuric acid).

Rhazes made fundamental contributions to various fields of science. He wrote over 200 manuscripts. He is known for his contribution which led to numerous advances. He was an early advocate of experimental medicine. He was one of the first persons to use Humoralism to distinguish one contagious disease from another. He is regarded as the father of paediatrics and a pioneer of ophthalmology. In his important book about smallpox and measles Rhazes described clinical characterisation. His numerous medical works were translated into Latin. Edward Granville Browne termed hin as "probably the greates and most original of all the physicians and one of the most prolific as an author."

Muhammad ibn Musa al-Khwarizmi

Muhammad ibn Musa al-Khwarizmi (c.780-c.850) was a mathematician, astronomer and geographer. He has also been mentioned in Latin literature as Algoritmi or Algaurizin. He was bron in a Persian family, probably in Chorasmia. It has been argued by D. M. Dunlop that Muḥammad ibn Mūsā al-Khwārizmī was in fact the same person as Muhammad ibn Shakir, the eldest of the three Banu Musa.

Latin translation of his work on Indian numerals, On the Calculation with Numerals (written about 825), introduced the decimal positional number system to the western world. He presented the first systematic solution of linear and quadratic equations in Arabic in his treatise, Compendious Book on Calculation by Completion and balancing. He is regarded as inventor of algebra. It was his systematic approach to solving linear and quadratic equations that led to algebra. The word 'algebra' is derived from 'al-jabr', one of the two operations he used to solve quadratic equation.

He revised Ptolemy's Geography. He also wrote on mechanical devices like astrolabe and sundial. The words 'algorism' and 'algorithm' stem from the Latin version of his name Algoritmi. He took part in a project to determine the circumference of the Earth and and in making a world map for al-Mamun, the caliph. Al-Khwarizmi's Zij al-Sindhind was the first of many Arabic Zijes based on the Indian astronomical medthds called the sindhind. It consisted of about 37 chapters on calendrical and astronomical calculations and 116 tables with calendrical, astronomical and astrological data. It has also contains a table of sine values.

Modern MEA Scientists

Ahmed Hassan Zewail

Ahmed Hassan Zewail (born February 26, 1946) is an Egyptian scientist, known as the "father of femtochemistry", he won the 1999 Nobel Prize in Chemistry for his work on femtochemistry and became the first Egyptian scientist to win a Nobel Prize in a scientific field. He is the Linus Pauling Chair Professor Chemistry, Professor of Physics and the director of the Physical Biology Centre for the Ultrafast Science and Technology (UST) at the California Institute of Technology.

Zewail's key work has been as a pioneer of femtochemistry—i.e. the study of chemical reactions across femtoseconds. Using a rapid ultrafast laser technique (consisting of ultrashort laser flashes), the technique allows the description of reactions on very short time scales - short enough to analyse transition states in selected chemical reactions.

His work started with the question, how fast did the energy within an isolated large molecule like naphthalene redistribute among all the atomic motions? They had to build an apparatus with a vacuum chamber for molecules coming out of the source as a collimated beam at supersonic speed. The challenge was to build an ultrafast laser to be used with the molecular beam. The beam and the picosecond laser system were interfaced. The goal of the project began as wanting to directly measure the rate of vibrational-energy redistribution for an isolated molecule using the picosecond laser.

They wanted to see the process from birth to death of a molecule. In this experiment the isolated anthracene molecule was unexpected and contrary to popular wisdom. During redistribution the population was oscillating coherently back and forth. There was no decay, but there was rebirth and all molecules moved coherently in a phase. In a large molecule, each vibrational motion is like a pendulum, but there are many motions because a molecules has many atoms. If the motions were not coherent, the observation would have been much different.

The results of this experiment revealed the significance of coherence and its existence in complex molecular systems. The finding of coherence were significant because it showed that through the expected chaotic motions in molecules, ordered motion can be found, despite the presence of a "heat sink", which can destroy coherence and drain energy. Coherence in molecules had not been observed before not because of a lack of coherence, but because of a lack of proper probes. In the anthracene experiments, time and energy resolutions were introduced and correlated.

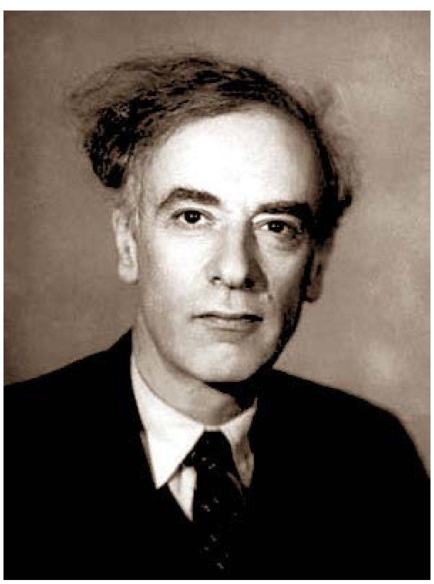
Though Zewail continued studies on vibrational-energy redistributions, he started new studies on shorter time resolutions for molecules showing different chemical processes and rotational motions.

Dr. Hulusi Behçet

Dr. Hulusi Behçet (1889-1948) is a famous Turkish dermatologist. He was born in Istanbul on February 20, 1889. His father was Ahmet Behçet and his mother Ayqse Behçet was also Ahmet's cousin. After the Turkish Republic was established and the "Family Name Law" was accepted, his father Ahmet Behçet, who was among the friends of Mustafa Kemal Atatürk, the founder of Turkish Republic, received private permission to use his father's name Behçet.Dr. Hulusi Behçet pursued his education at Gülhane Military Medical Academy. After he had become a medical doctor, he specialized in dermatology and venereal disease at Gülhane Military Medical Academy and he completed his specialization in 1914. His first observations on Behçet's Disease started with a patient he met between 1924-1925. Dr. Behçet followed the symptoms of three patients whom he had had for years, then he decided that they were the symptoms of a new disease (1936). He published these cases in the Archives of Dermatology and Veneral Disease.

He died from a sudden heart attack on March 8, 1948. Today, this disease is universally called Behçet's Disease in medical literature.

Lev Davidovich Landau



Lev Davidovich Landau (January 22, 1908 – April 1, 1968) was a prominent Soviet physicist, from Baku, Azerbaijan, who made fundamental contributions to many areas of theoretical physics. His accomplishments include the independent co-discovery of the density matrix method in quantum mechanics (alongside John von Neumann), the quantum mechanical theory of diamagnetism, the theory of superfluidity, the theory of second-order phase transitions, the Ginzburg–Landau theory of superconductivity, the theory of Fermi liquid, the explanation of Landau damping in plasma physics, the Landau pole in quantum electrodynamics, the two-component theory of neutrinos, and Landau's equations for S matrix singularities. He received the 1962 Nobel Prize in Physics for his development of a mathematical theory of superfluidity that accounts for the properties of liquid helium II at a temperature below 2.17 K (−270.98 °C).

Modern Arab S&T Centres

CSEM UAE Innovation Center

It is s joint venture between CSEM of Switzerland (www.csem.ch), and the government of the Emirate of Ras Al Khaimah. CSEM or Swiss Center for Electronics and Microtechnology is a Swiss Research and Development company with expertise in Micro Nano Technologies, Microelectronics, Systems Engineering und Communication Technologies. CSEM founds an innovation center in the United Arab Emirates. Neuchâtel, March 15, 2005 – CSEM and the government of the emirate of Ras Al Khaimah (RAK) signed an agreement for the establishment of an innovation center in the United Arab Emirates (UAE). The aim of this new center is to promote innovation and the incubation of new technologies. The center is being set up as the culmination of close collaboration between CSEM and the government of Ras Al Khaimah (RAK). This ambitious strategic partnership is intended to enhance the UAE's presence in the field of high technology, allow local and regional businesses access to innovation and strengthen the links between universities and industry in the Middle East. In keeping with its mission, CSEM will develop high technology in this part of the world, actively supporting innovative projects from initial concept to commercialization. Particular emphasis will be paid to key areas for the region, such as water purification, desalination, and applications in the solar energy and petrochemical industries.

International centre for Biosaline Agriculture, UAE (ICBA)

The International Center for Biosaline Agriculture (ICBA) is a not-for-profit, international center of excellence for research and development in marginal environments. ICBA was established in 1999 through the visionary leadership of the Islamic Development Bank , the Organization of Petroleum Exporting Countries (OPEC) Fund, the Arab Fund for Economic and Social Development and the Government of United Arab Emirates. The host country, through the Ministry of Water and Environment and the Environment Agency – Abu Dhabi extended the agreement with IDB in 2010 and increased their financial support to the Center. The Center originally focused on the problems of salinity and using saline water for irrigated agriculture. Over the last 13 years, ICBA has evolved into a world-class modern research facility with a team of international scientists conducting applied research to improve the well-being of poor farmers in marginal environments. In 2013, the Center developed a new strategic direction addressing the closely linked challenges of income, water, nutrition, and food security. The new Strategy takes innovation as a core principle and identifies five innovations that form the core research agenda:

- Assessment of natural resources; climate change adaptation; crop productivity and diversification; aquaculture and bioenergy, and policy analysis.
- ICBA is working on a number of technology developments including the use of conventional and non-conventional water (such as saline, treated wastewater,
- Industrial water and seawater); water and land management technologies; remote sensing and modeling for climate change adaptation.

Vision:

- To be the global Center of Excellence for innovative agriculture in saline and marginal environments
- Mission:
- To work in partnership to deliver agricultural and water scarcity solutions in marginal environments

King Abdullah University of Science and Technology (KAUST), Saudi Arabia

KAUST was founded in 2009 and focuses exclusively on graduate education and research, using English as the official language of instruction. It offers programs in Biological and Environmental Sciences and Engineering; Computer, Electrical, and Mathematical Sciences and Engineering; and Physical Sciences and Engineering. It was recently announced that KAUST has one of the fastest growing research and citation records in the world right now. KAUST officially opened on 23 September 2009, in Thuwal, Saudi Arabia. King Abdullah Bin Abdulaziz Al Saud invited more than 3,000 distinguished Saudi and international guests, including heads of state and Nobel laureates, to join him for the KAUST inauguration ceremony on Saudi National Day. KAUST's core campus, located on the Red Sea at Thuwal, is sited on more than 36 square kilometres (14 sq mi), encompassing a marine sanctuary and research facility. KAUST was Saudi Arabia's first LEED certified project and is the world's largest LEED Platinum campus. Designed by international architecture firm HOK, it was also chosen by the American Institute of Architects (AIA) Committee on the Environment (COTE) as one of the 2010 Top Ten Green Projects.

Laboratories:

- Research institutions in the Kingdom and the region will link to the university's supercomputer and other laboratory facilities through the 10 gigabits per second (Gbps) Saudi Arabian Advanced Research and Education Network (SAREN).
- Supercomputer: Shaheen—the Arabian word for peregrine falcon—is the fastest supercomputer in the Middle East and one of the most powerful in the world. Developed by IBM, it is capable of 222 teraflops, or 222 trillion floating point operations per second.
- Visualization: CORNEA is a fully immersive, six-sided virtual reality facility that gives students and researchers the ability to turn data into 3D structures that they can interact with and examine. It was built in partnership with the University of California, San Diego.
- Nanofabrication, Imaging, and Characterization: A clean-room environment equipped with tools to support research in advanced materials, biotechnology, electronics and photonics, and MEMS/NEMS. The Imaging and Characterization Labs include a suite of 10 nuclear magnetic resonance (NMR) spectrometers and facilities for scanning, transmission, confocal, and Raman Spectroscopy, magnetic and thermal measurements, allowing scientists to examine nanostructure devices and surfaces down to the level of individual atoms.
- Coastal and Marine Resources: Located next to the Red Sea, the Coastal and Marine Resources Lab facilitates marine research. The facility
- Builds and deploys oceanographic instrumentation and provides operational services to support research vessels for marine exploration, diving, and sampling. Indoor and outdoor seawater facilities allow researchers to culture marine organisms.

- Analytical Core: These labs focus on spectroscopy, chromatography and mass spectrometry, trace metals analysis, wet chemistry, and surface analysis.
- Biosciences and Bioengineering: These facilities include genomic and proteomic labs essential to the study of cellular molecules for DNA sequencing and genetic analysis, as well as the investigation of cellular processes. The genomics facility is equipped with robots and laboratory automation.

Masdar Institute of Science and Technology

Masdar Institute of Science and Technology is an independent, research-driven graduate-level university focused on advanced energy and sustainable technologies.

The main aim of establishing the IEEE GRSS chapter is to foster remote sensing research in the UAE, said Dr. Prashanth Marpu, Chair, UAE Chapter of the IEEE GRSS. Masdar Institute has established itself as a leading organization in this region in the field of remote sensing. It has a strong group of professors who are actively involved in remote sensing research. We are proud to take a leadership role in this initiative. The IEEE GRSS chapter will help in bringing together the remote sensing researchers and professionals in the UAE. Faculty members that are part of the Institute's Earth-Observation and Hydro-Climatology Lab (EOHCL) have spearheaded key remote sensing research projects. . The EOHCL faculty are also presently involved in a joint four-year pilot study with the US National Aeronautics and Space Administration (NASA) to understand how the level of soil moisture affects dust emission in desert and dry environments. It had been selected by NASA in 2011 to be one of seven global pre-launch test sites for a new earth observation Soil Moisture Active Passive (SMAP) satellite, which was launched by NASA in January 2015. Masdar Institute is actively engaged in many more remote sensing research and development projects. The faculty team is working on a diverse range of research projects with special focus on desert and arid climate such as urban heat island studies, studying coral reefs in the Gulf, modelling solar irradiance in the UAE, and studying river drainage networks in the Eastern region of the UAE; monitoring oil spills, algal blooms, solar resources, and dust storms; national-level water budget; land-atmosphere interactions; modelling of hydro-meteorological variables; and understanding the impacts of climate change in arid regions. The EOHCL continues to play a critical role in driving these projects and bringing sustainable benefits, regionally and globally. The Masdar Institute of Science and Technology (Masdar Institute) was established by the government of Abu Dhabi as a not-for-profit private graduate university to develop indigenous R&D capacity in Abu Dhabi addressing issues of importance to the region. In collaboration with the Massachusetts Institute of Technology (MIT), Masdar Institute has developed an academic and research platform that articulates its mission and vision according to critical energy and sustainability challenges. An important characteristic of Masdar Institute is its focus on complex real-world problems that require a multidisciplinary approach for the development of solutions from an integrated technology, systems and policy perspective. This multi-interdisciplinary and integrated approach is supported by the structure of its academic programs and by the emphasis placed on engaging external partners from industry, government, and other academic institutions in collaborative activities. Serving as a key pillar of innovation and human capital, Masdar Institute remains fundamental to Masdar's core objectives of developing Abu Dhabi's knowledge economy and finding solutions to humanity's toughest challenges such as climate change.

Masdar Institute integrates theory and practice to incubate a culture of innovation and entrepreneurship, working to develop the critical thinkers and leaders of tomorrow. With its world-class faculty and top-tier students, the Institute is committed to finding solutions to the challenges of clean energy and climate change through education and research.

Research Centers:

- TwinLab 3 Dimensional StackedChips Research Center
- Sustainable Bio-energy Research Center (SBRC)
- Smart Grid and Smart Building Center of Excellence
- Renewable Energy Resource Mapping and Assessment Center

Qatar Biomedical Research Institute

Qatar Biomedical Research Institute (QBRI) was established to tackle diseases prevalent in Qatar and the Middle East, with a focus on developing translational biomedical research and biotechnology.

Research:

Qatar National Vision 2030 is the objective of an entire nation, one that is dedicated to ensuring its transition from a carbon-based economy to one built upon knowledge and innovation.

Yet what is seldom focused upon in Qatar's future vision is the most important factor behind ensuring innovation, intellectual property (IP). Aims for for building the infrastructure and the capacity to identify and protect new inventions arising from supported research within QF and to help transform these innovations through commercialization for the benefit of Qatar, the region, and the global community.

Qatar Environment and Energy Research Institute

Qatar Environment and Energy Research Institute (QEERI), a principal constituent of Qatar Foundation Research and Development (QF R&D), conducts research to support Qatar's energy independence, water sustainability, and food self-sufficiency goals. The institute will play a pivotal role at the conference by bringing together global leaders to discuss and debate issues in these critical areas, and by sharing its own innovations in energy and water security.

World-renowned experts will come together at the conference under the theme of 'Qatar's Cross-cutting Research Grand Challenges' to debate issues and combine efforts in order to forge ahead and address the challenges outlined in the Qatar National Research Strategy.

Other QF R&D constituents such as Qatar Biomedical Research Institute (QBRI) and Qatar Computing Research Institute (QCRI) will also be looking at ways to address some of these challenges.

The Qatar Foundation Annual Research Conference, which takes place at the Qatar National Convention Centre, between 24-25 November, allow national stakeholders from universities and local organizations, as well as international partners, to network, familiarize themselves with Qatar's latest research initiatives and facilitate knowledge transfer.

Qatar Computing Research institute

The Qatar Computing Research Institute (QCRI) in Doha, Qatar, is a nonprofit multidisciplinary computing research institute founded by the Qatar Foundation (QF) for Education, Science and Community Development in 2010. It is primarily funded by the Qatar Foundation, a private, non-profit organization that is supporting Qatar on its journey from carbon economy to knowledge economy by unlocking human potential for the benefit of not only Qatar, but the world.

QF carries out its mission through three strategic pillars: education, science and research, and community development. QCRI is one of three national research institutes under Qatar Foundation and specializes in applied computing research. Its research falls into two main categories: core computing and multidisciplinary computing. Within core computing, QCRI specializes in internet computing (with an emphasis on cloud computing and social networking), data analytics, and advanced computer hardware design. Within multidisciplinary computing, QCRI is focused on Arabic language technologies, high performance computing, and bioinformatics.

The QCRI focus is narrow by design. The goal for the institute is to gain recognition by focusing on a small number of areas. For example, the institute sees an opportunity to become a leader in Arabic language technologies, including Arabic-specific natural language processing, machine translation, and optical character recognition. QCRI has offices in Tornado Tower in the West Bay in Doha. QCRI has a staff of 90+ employees. Its strategic plan is to have 300 full-time scientists and staff within five years.

The stakeholders include Qatari industry, Qatar's government, and Qatari society. Specifically, QCRI's customers include the petroleum industry, the telecommunications industry, the healthcare industry, and the media industry. The petroleum industry needs advanced computer modeling to assist in the extraction and movement of petroleum products. The telecommunications and datacenter industries need the most advanced research in computing networks, broadband, and other forms of advanced computing infrastructure. The healthcare industry needs efficient and secure management of electronic patient records, clinical information systems, and data interoperability protocols for the exchange and sharing of data. The media industry needs solutions for the cataloging and retrieval of vast amounts of content generated through audio and video, and it needs Arabic language technology solutions to digitize and publish the vast Arabic language corpora. QCRI also works closely with both the basic research institutes in Qatar, including the Education City Universities on their most promising basic research findings. It also will work closely with QSTP to identify the most viable commercial applications of QCRI's research.

Research Agenda

QCRI is currently addressing several grand challenges in Arabic language technologies:

•The Arabic Language Technology Ecosystem Grand Challenge: Have an Arabic Language Technology research community in the

Arab world of 100 specialized researchers, research engineers, and developers. (5 years)

•The Arabic Machine Translation Grand Challenge: Realize Machine Translation for translating text or speech for 20 languages to and from Arabic. (5 years)

•The Arabic Intelligent Support System Grand Challenge: Provide seamless enablement of multimodal Arabic content access and processing in 25% of newly authored software that handle Arabic in the Middle East. (5 years)

•The Arabic Automated Language Tutor Grand Challenge: Assist in Arabic language learning for 1 million students via interactive Arabic language tutor that teaches literacy, phonics, and grammar. (5 years)

•The Seamless Arabic Dialogue System Grand Challenge: Transform 50% of automated commercial customer facing in Qatar to switch to Interactive Voice Response (IVR) systems. (5 years)

Robotics

Introduction to Robotics

In today's world robots are all around us, they come in a variety of different shapes and sizes, designed to do an extraordinary range of tasks. Typically when we think of robots we picture these big humanoid robots from sci-fi films like "Transformers" or the big robotic arms seen manufacturing cars on automated assembly lines.

What is a robot? A robot is "intelligent", a man made device that can move by itself, whose motion can be modelled, planned, sensed and controlled and whose motion and behavior can be influenced by programming. A robot is a general purpose, programmable manipulator. In practice it is usually an electro-mechanical system which by its movements and appearance conveys that it has intent of its own. Today, commercial and industrial robots are in widespread use, performing jobs more cheaply or with greater accuracy and reliability than humans. They are also employed for jobs that are too dirty, dangerous or boring to be suitable for humans. Robots are widely used in manufacturing, assembly and packing, earth and space exploration, surgery, weaponry, laboratory research and mass production of consumer and industrial goods. As robotic technology develops and becomes cheaper domestic robots for cleaning or mowing the lawn are available, along with robotic toys for children of all ages. When we talk about robots, what we are really talking about is machines that will do what human beings would normally be expected to do. These machines mimic the operation of the human being or at least certain parts of it. Most shop floor robots are the emulation of one arm of a human.

- Their motors are the muscles
- The general purpose computer the human brain
- Robotic vision, the eye

We combine these various elements in different ways to create the robot that we require. The most common robot used in industry today is the robot arm. These arms are used to weld, package, paint, position and assemble a host of products that we use daily. Basically a robot arm is a series of linkages that are connected in such a way that a servo motor can be used to control each joint. The controlling computer, the brain of the robot, is programmed to control the various motors on the robot in a way that allows it to perform specific tasks. The robot arm can be designed in a number of different ways, the size and shape of this arm is critical to the robotic architecture of the robot. The arm is the part of the robot that positions the final grabber arm or spray head to do their pre-programmed business. If the design of the arm is too large or small this positioning may not be possible. Many arms resemble the human arm, containing shoulders, elbows wrists and hands. The design of the human arm is exceptional and allows for precise and complicated movement.

As a rule you need one motor for each degree of freedom that you want to achieve.

A **degree of freedom** is typically one joint movement.

So a simple robot with 3 degrees of freedom can move three ways: up and down, left and right, forward and back. This simple pan and tilt robot has 2 degrees of freedom, powered by two servo motors. It can rotate left to right and lift up and down.

Many robots today can be designed to move with 7 degrees of freedom.

Degrees of Freedom

First Degree: Shoulder Pitch

Point your entire arm straight out in front of you. Move your shoulder up and down. The up and down movement of the shoulder is called the shoulder pitch.

Second Degree: Arm Yaw

Point your entire arm straight out in front of you. Move your entire arm from side to side. This side to side movement is called the arm yaw.

Third Degree: Shoulder roll

Point your entire arm straight out in front of you. Now, roll your entire arm from the shoulder, as if you were screwing in a light bulb. This rotating movement is called a shoulder roll.

Fourth Degree: Elbow Pitch

Point your entire arm straight out in front of you. Hold your arm still, then bend only your elbow. Your elbow can move up and down. This up and down movement of the shoulder is called the elbow pitch.

Fifth Degree: Wrist Pitch

Point your entire arm straight out in front of you. Without moving your shoulder or elbow, flex your wrist up and down. This up and down movement of the wrist is called the wrist pitch.

Sixth Degree: Wrist Yaw

Point your entire arm straight out in front of you. Without moving your shoulder or elbow, flex your wrist from side to side. The side to side movement is called the wrist yaw.

Seventh Degree: Wrist Roll

Point your entire arm straight out in front of you. Without moving your shoulder or elbow, rotate your wrist, as if you were turning a doorknob. The rotation of the wrist is called the wrist roll.

Robotic joints

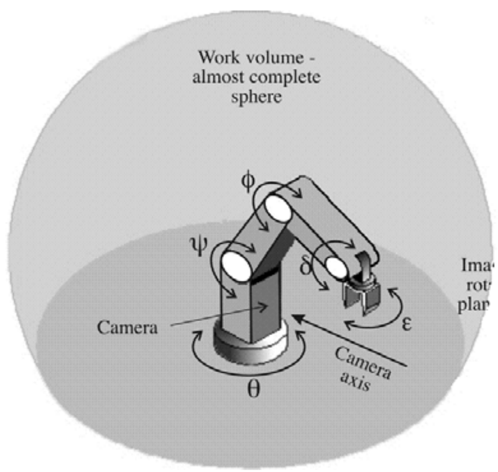
It is obvious that in order to achieve different degrees of freedom, different robotic joints are needed. Unlike human joints where we saw 3 degrees of freedom in the shoulder, the joints in a robot are normally restricted to 1 degree of freedom, to simplify the mechanics and control of the manipulator. There are two types of joints commonly found in robots: rotary joints and prismatic joints.

Rotary joints are mostly used as a waist joint. Many times these joints are the joint that pivots the entire robot. One section is fixed and the other part rotates about it. Some other uses are in case of elbow joints. In the case of the four joints they are only capable of one degree of rotation, the joint variable is the angle that the joint move to. Most rotary joints cannot rotate through 360° degrees as they are mechanically restrained by the arm construction and the servo motor.

A prismatic joint is a sliding joint. It can be used for merely a simple axial direction. These linear joints are not as common as the rotary joints but are very useful.

Work Envelope

The volume of space that a robot operates within, is called the Work Envelope The work envelope defines the space around a robot that is accessible for the end effector or gripper. As a robot moves around the limits of its reaches it traces out a specific shape. The Cylindrical robot in the last image has a visible work area of a cylinder. A Cartesian robot sweeps out a rectangular volume, a polar a partial sphere.



Classification of Robots

There are a number of factors that help decide the type of robot required for a specific task. The main factor is the type of movement needed to achieve the desired robotic motion. Some applications only require a robot to move a product along a desired axis, while other robotic arms need to manoeuvre about an object through a number of different axes at once. The arrangement of joints in different ways fulfils different coordinate systems.

Coordinate Systems/Frames

Coordinate system types determine position of a point with measurements of distance or angle or combination of them. A point in space requires three measurements in each of these coordinate types. It must be noted that the same point can be found in any system. Different coordinate systems are merely to cater for a different situation. Three major coordinate systems used in the study of robotics are:

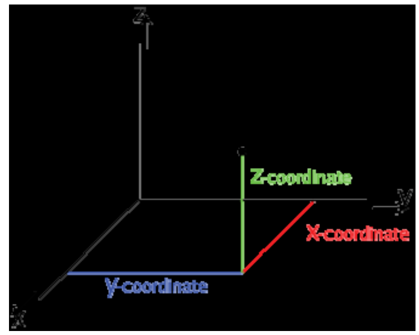
• Cartesian

• Cylindrical

• Spherical

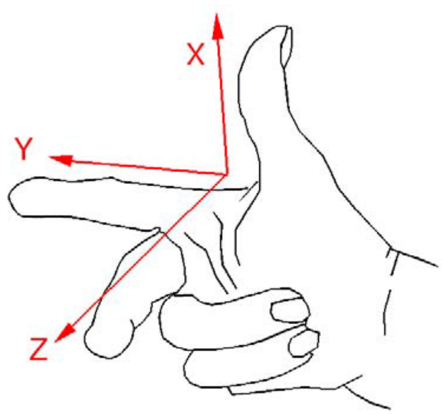
Cartesian coordinate frame

The most used and familiar coordinate system is the Cartesian coordinate system.



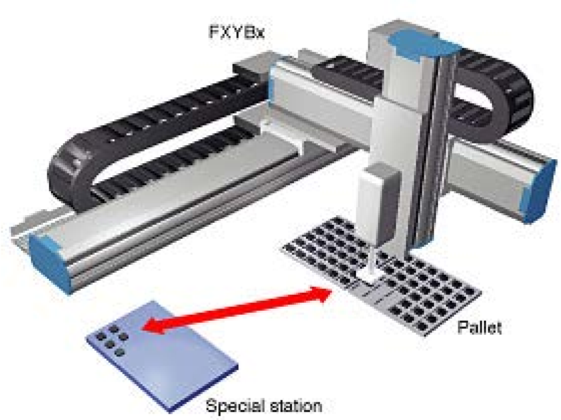
Most will be familiar with this as the X, Y; axis is at 90° to each other. A point can be located on a plane by locating the distance of a point from its origin (0, 0) along each axis. To find a point in space it is necessary to add a third axis (Z).This third axis will form a 3 dimensional grid that matches a set of coordinates to a single point in space.

The axes of machines are always defined by what is known as the right-hand rule. If we take the thumb as pointing in the direction of the positive X-Axis then the second finger is pointing towards the positive Y-Axis and the middle finger towards the positive Z-Axis. The Z axis is always in the direction of the spindle or grab arm as shown in the 'Cartesian Robot' below.

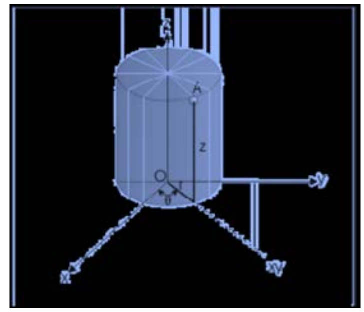


Right-hand rule

Cartesian Robots: Cartesian robots are used for pick and place work, application of sealant, assembly operations, handling machine tools and arc welding. It's a robot whose arm has three prismatic joints, whose axes are coincidental with the Cartesian coordinators. Companies need to monitor their products to ensure that they are of a high quality. Cameras mounted on the Cartesian robot above monitor the passing components for inaccuracy. Due to its construction the robot can move along with the moving conveyor and focus on a product at once.



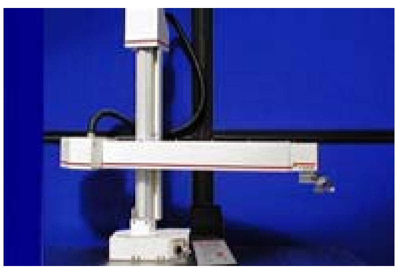
Cylindrical coordinate frame



A three dimensional point "A" in a cylindrical co-ordinate frame is considered to be located on a cylinder of a radius "R" with a height "Z". The third piece of information required to define the point comes from an angle θ on the XY plane.

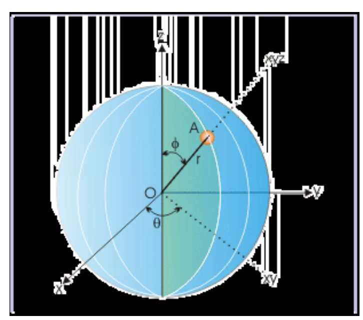
Cylindrical robots

Cylinder robots are used in assembly operations, handling of machine tools, spot welding and handling at die cast machines. They also have many uses in medical testing.



Cylindrical robot is able to rotate along its main axes forming a cylindrical shape. The medical robot is used in numerous medical applications, for DNA screening, forensic science, drug development and toxicology. These robots are suitable in medical research where hundreds of samples must be tested and the same repetitive tasks performed many times. The robot eliminates human error providing more repeatable yields and consistent results A typical example of its duties would be to pull out a drawer to access a test plates, lift out a sample plate, close the drawer and finally take the sample to another instrument to be tested.

Spherical / Polar coordinate frame



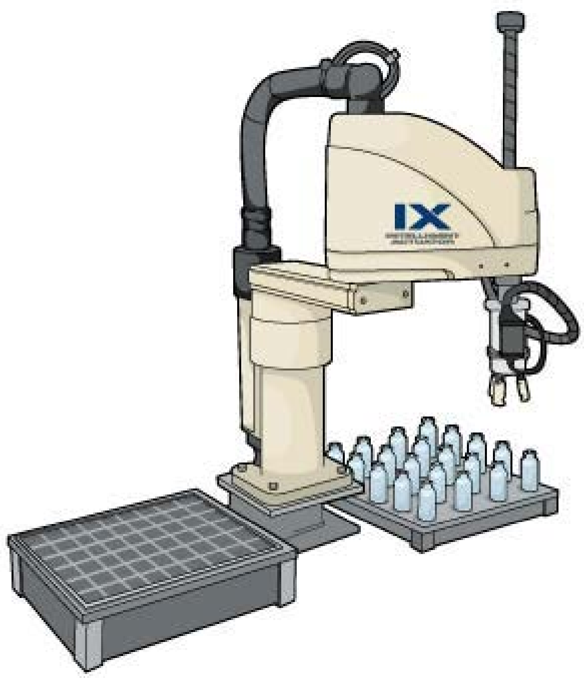
A three dimensional point A in a spherical coordinate system can be found on a sphere of radius "R". The point lies on a particular cross section of the sphere; like in the cylindrical frame the cross section makes an angle "θ" from the ZX plane. Once the plane is found the last point can be found by joining the point A to the origin, the angle (ϕ) this creates with the Z axis defines the point.

Spherical or Polar Robots

Spherical or Polar Robots combine rotational movements with single linear movements of the arm. The polar robot is sometimes referred to as the gun turret configuration. They are generally used in many welding applications mainly spot, gas and arc. Polar robots are extremely suitable for reaching into horizontal or inclined tunnels.

The main application for these types of robots is welding. They can be quite large and weigh over a 1000kg. Polar Robots are used widely in the car manufacturing industry.

The Scara Robot

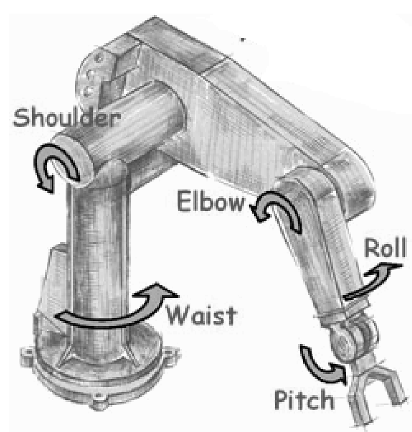


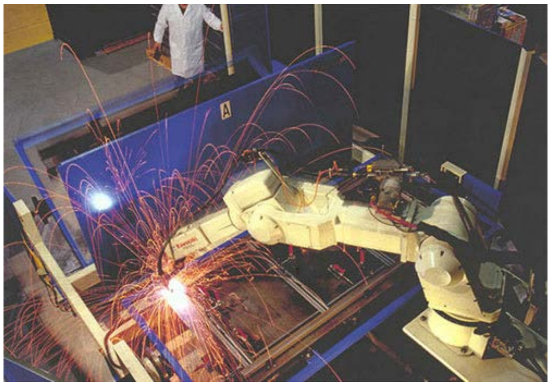
This configuration was developed to meet the needs of modern assembly work where fast movement with light payloads is required. The rapid placement of electronic components on PCB's is an obvious application. The Scara robot is a combination of two horizontal rotational axes and one linear that moves vertically.

The Scara design can quickly remove components from an assembly line and accurately stack them. The Scara robot is excellent for precision positioning and makes it very suitable for the assembly of components. The robot can pivot around to the left and change its gripping hand to a screw or drilling head. These different heads for the robot are known as end effectors.

Revolute Robot

The revolute robot or Puma as it is also known most resembles the human arm with three main rotational degrees of freedom. The manipulator rotates on the base much like the human waist. The other two rotational axes resemble the shoulder and the elbow. The additional wrist action adds two more degrees of freedom, movement up and down (pitch) and rotation (roll). A final movement is Yaw which is the movement of the wrist from side to side; this is not in the example above. This kind of robot is ideal for spray painting where it can be taught the human movements required to paint an object.





Due to their manufacture based on the human hand the Revolute robot is suitable for numerous application. These include welding, pick and place operations, component assembly and electrical soldering.

Humanoid Robot

The development of robots resembling the human body over the last number of years has been for more entertainment value than that of practicality. However this trend is changing with much research being carried out on how these robots could blend into our lives and perform human chores. The film industry has released films like ET, Transformers, AI and I robot that have all toyed with the idea of robots as humans with feelings and emotions.

ASIMO- The Honda Humanoid

Androids

An android is a robot or synthetic organism designed to look and act like a human, especially one with a body having a flesh-like resemblance. Until recently, androids have largely remained within the domain of science fiction, frequently seen in film and television. However, advancements in robot technologyhave allowed the design of functional and realistic humanoid robots

Schaft

Robotics teams from around the world competed in the DARPA Robotics Challenge Trials for 2013, as part of DARPA's project for developing robots capable of autonomously navigating disaster areas and doing useful work using tools and materials at hand. Google's Schaft humanoid robot scored 27 points and won first place as it navigated an obstacle course which was made to simulate a disaster area, while carrying out a series of tasks.

EveR

EveR is a series of female androids developed by a team of South Korean scientists from the Korea Institute of Industrial Technology in Korea University of Science and Technology. The project is headed by Baeg Moon-hong and was unveiled to the public at Kyoyuk MunHwa HoeKwan in Seoul on May 4, 2003. The EveR name is derived from the combination of the Biblical "Eve" and the r from robot.

EveR-4 also called EveR-4M, has a modular design with 64 degrees of freedom including 33 in the head (30 in the face and 3 in the neck), and 5 in the lower body (3 in the legs and 2 in an underlying wheel. It was exhibited at RoboWorld 2011 in Seoul, where experiments showed that some of its facial expressions are more recognisable than others, with correct recognition rate being highest among female participants in the 20-40 age range. The robot was exhibited again at Expo 2012 Yeosu Korea (May to August 2012). It has an artificial tongue. Unlike EveR-3, EveR-4 can be fitted with legs.

Noted Robots of 2014

QB from AnyBots

QB from AnyBots is a remotely controlled, self-balancing, virtual presence robot. It'll represent you and let you 'go' places and interact when you can't physically attend. For example, a child under medical treatment could use QB to attend classes. Or a manager could inspect a factory from a remote office.

Unbounded Robotics

UBR-1 is a working man's robot. It's designed to help with everyday tasks in factories, warehouses, supermarkets and even elder-care facilities. It's a great fetcher and placer.

Keecker

Keecker is a lifestyle robot, working in your home to provide entertainment and communications. With Keecker, you can use its built-in projector to watch a movie (or surf the web) on any nearby wall, or just immerse yourself in its music offerings. A roving projector/jukebox!

Ekso Bionics

Ekso is a bionic exoskeleton that can enable a paralyzed person to walk. Here, it's being used by Paul Thacker, an X Games record holder who was paralyzed from the chest down in an accident. With Ekso, Paul can stand and has regained the ability to walk. Bionics like these are still in their nascent stage but will continue to play a growing part in rehabilitative therapies.

Origami Robotics

Romibo is a remotely controlled, self-balancing social robot designed for learning and sharing. With mobility, speech, gesture and face-tracking, Romibo has what it takes to bring friendship and companionship year round. Besides, who wouldn't love a furry robot?

Double Robotics

Double is a remotely controlled teleconference robot. Conversations can happen anytime, anywhere, across town or across the world. Double can be your double when you can't be there in person. And it has no problem traveling from room to room or meeting to meeting.

Neato

The Neato is "the world's most evolved robot vacuum." It vacuums any floor surface and any type of dirt, mapping the best course, never repeating its steps and avoiding obstacles in its path. Power, intelligence, and even perhaps charisma, applied to cleaning your floors.

This booklet has been prepared by Igniting Minds (www.ignitingminds.org) for utilization as internal training material for participants of Shastra Pratibha Contest 2015 MEA, conducted by Science International Forum, the international arm of Vijnana Bharati, India.

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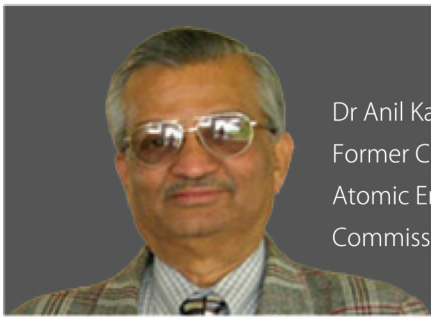

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