Contents

Breakthrough, Vol.17, No.3, February 2015

The 102nd Indian Science Congress — Flights of Fancy

The 102nd Indian Science Congress was held at the University of Mumbai premises from 3rd to 7th January, 2015. It was heartening to see that an impressive number of distinguished scientists including Nobel Laureates from across the world participated in the Congress and discussed on various topics of scientific and social importance such as Biodiversity Conservation, Clean Energy, Space Technology, Nanoscience, Nutrition and Health, etc.

At the same time, we noted with deep concern the proceedings of the Symposium on 'Ancient Sciences through Sanskrit' organised on Sunday, 4 January. The papers presented in the symposium included 'Ancient Indian Aviation Technology', 'Neuro Science of Yoga: Understanding the Process' etc. The way the session was conducted contradicted the established practices in scientific conferences in several ways.

- One of the speakers Captain Bodas claimed that "ancient Indian aeroplanes travelled from one country to another, from one continent to another, and from one planet to another" and that "in those days, aeroplanes could move left, right, as well as backwards, unlike modern planes which only fly forward." He did not bother to cite any archaeological or other evidence to support the claim. He only referred to the texts of Shri Bramhamuni Parivrajaka and Shri G R Josyer. It is worth recalling that these texts were scientifically scrutinized in 1974 by a team of scientists from Indian Institute of Science, Bangalore, led by renowned aerospace scientist Prof. H. S. Mukunda[1] who concluded that (a) the planes were at best poor concoctions, (b) the geometries were unimaginably horrendous from the point of view of flying; and (c) the principles of propulsion make them resist rather than assist flying.
- Some of the other preposterous claims made by the speakers during the session are as follows:

  "Findings of ancient Indian sciences have been taken by Germans by exploring Sanskrit literature who used them to master us but now, we should master them by learning more about ancient sciences."

  "To understand Einstein, one needs to read Vedas"
- None of the speakers of this session were scientists of any repute, and scientists who are known to have worked extensively on ancient Indian science were not among the speakers.
- Most shockingly, the chairperson did not allow questions to be asked. Questioning is the very essence of scientific thinking but was not allowed in this science congress!

[1] A critical study of the work "Vymanika Shastra" by H.S. Mukunda, S.M. Deshpande, H.R. Nagendra, A. Prabhu, and S.P. Govindaraju, Scientific Opinion, 1974

Indians can justifiably be proud of our varied and colourful cultural history spread over more than two millennia. Our contributions to philosophy, art, music, literature, astronomy, mathematics, and medicine are recognized the world over. The richness of our culture is the direct outcome of the openness with which our ancestors welcomed and assimilated the essence of other cultures. The result is a wonderful collage that we have come to recognise as our cultural legacy.

In fact, past Presidents of Indian Science Congresses in their addresses — like Acharya Prafulla Chandra Ray's talk on 'Dawn of Science in Modern India', 1920, Sir Ram Nath Chopra's talk on 'Rationalisation of Medicine in India', 1948, and Prof. P. Parija's talk on 'Impact of Society on Science', 1960 — dealt with science in India in an objective and educative manner while giving due recognition to the achievements in science in ancient India. We are deeply astonished and outraged that such a hallowed assembly of scientists has been misused to make false and chauvinistic claims about ancient India, tarnishing the genuine contributions of the great science personalities of yore.

Scientific enterprise is a quest to understand and explain natural phenomena based on theories that are supported by observations and experimental evidence. It is a dynamic process that involves constant advancement. The theory of relativity, quantum mechanics and molecular biology evolved in this process. No great scientific or technological accomplishment, whether it is aeronautics, plastic surgery, in vitro fertilisation or stem cell therapy, can be made without a substantial theoretical edifice. The glorious advancements in the field of aviation or neurosciences or biological sciences are all built on the edifice of modern science. Hence, to claim that such innovations already existed in ancient India is not only false, unhistorical and against the ethics of science but also dangerous as it can inflame fanatical passions. As Darwin said, false facts are more dangerous than false views.

In this context, we note with deep appreciation that Dr. Ram Prasad Gandhiraman, scientist with NASA's Ames Research Centre, USA, tried to mobilize scientific opinion against this session of the Indian Science Congress, and for the session to be canceled. But the effort went unheeded, and the session was organized in spite of the public opinion against it.

After the Indian Science Congress was over, our organization initiated an online petition protesting against this attempt to undermine the scientific process, to allow the platform of the Indian Science Congress to be misused for propagating unscientific views. The petition received overwhelming support of the scientific community, and within two weeks more than 1200 signatures were recorded. The petition was submitted to Prof. S. B. Nimse, General President of the 102nd Indian Science Congress, and a copy was forwarded to the Minister of Science & Technology, Government of India on 29th January 2015. We hope that this demonstration of protest by the scientific community will persuade the organizers of the Indian Science Congress and other scientific conferences, seminars and symposia to follow the scientific process strictly in every session.

Opinion of eminent scientists

Prof. S. Mahadevan

India's Rich Cultural Legacy — Myths Versus Reality

All Indians can justifiably be proud of our varied and colourful history dating back several millennia. Our contributions to

Prof. P. M. Bhargava, Prof. V. Rao, and Prof. V. Ramakrishna addressing the Press Conference at Hyderabad condemning the presentation of unscientific papers at the Indian Science Congress.

philosophy, religion, art, music, literature, mathematics, and medicine are renowned the world over. The richness of our culture is the direct outcome of the openness with which our ancestors welcomed and assimilated the essence of other religions and cultural traditions. The net result is a wonderful collage that we have come to value as our cultural legacy.

In spite of being the custodians of such a rich legacy, it is very disheartening to see that certain individuals and organisations are trying to redefine/rewrite our cultural history, often in the name of misplaced nationalism. This is all the more dangerous when it involves democratically elected governments. There is a deliberate effort from these quarters to distort and reinterpret our epics and mythologies to make false claims about our scientific and technological superiority, undermining our genuine contributions in these areas.

The scientific enterprise is a quest to understand and explain natural phenomena based on theories that are supported by observations and experimental evidence. It is a dynamic process that involves constant up-gradation. Older theories are abandoned in the light of new observations and experimental evidence. The theory of relativity, quantum mechanics and molecular biology were born essentially to refine what was known and expanded the boundaries of our knowledge in new directions. No great scientific or technological discovery, whether it is in aeronautics, automobile design, in vitro fertilisation or stem cell therapy, can be made in a vacuum. There is a substantial theoretical edifice behind all these discoveries. Mythologies on the other hand are products of rich imagination and should be enjoyed for what they are. Any attempt to reinterpret them or to make claims that they represent a record of our past technological superiority based on tenuous arguments is unacceptable and counterproductive. No cause is served by such actions other than undermining the credibility of our genuine contributions of the past. It does not advance our science in any way. It only legitimises and strengthens pseudo science such as astrology.

Everyone has a right to believe in any idea at a personal level however absurd it may be. But when personal beliefs and prejudices encroach into public responsibilities such as designing text books or planning curricula, there is a serious issue. Such tasks should be strictly left to professional educators and intellectuals. Political organisations have no say in the matter. It is the responsibility of the government of the day to protect its citizens' rights to quality education free of pseudo science and superstition. Any government that fails to do this is in violation of its constitutional responsibility. As citizens, we should be aware of our rights and join hands to demand it from governments that fail to deliver.

Professor Mahadevan is with the Molecular Reproduction, Development and Genetics Lab, Indian Institute of Science, Bangalore. He is a former Editor of the science magazine *Resonance*.

Professor Pushpa M. Bhargava

The happenings at the Indian Science Congress are a farce. The scientists who attended it are to be blamed for this more than anybody. Any science paper has to be backed by evidence and fanciful, unverified aspects cannot be part of a scientific paper. To unduly glorify India's past in the field of science is not proper. The Prime Minister started it all by saying ancient India possessed all the latest cosmetic surgery wherewithal, which is not correct.

The government is trying to use the modern technology but is spreading all kinds of unscientific ideas which clearly show its inconsistency. Though there are unknown phenomena still which is not unravelled by science yet science accepts without any shame or guilt the same and does not claim it knows everything. But verified truths like $2 \times 2 = 4$ are incontestable. But godmen and pseudo-sadhus claim that they know everything in this universe which is against the tenets of science. Such tendencies must be effectively countered by educating the people and spreading the correct truths.

Professor Bhargava was the founder Director of the Centre for Cell and Molecular Biology (CCMB), Hyderabad.

Prof. Visweshwara Rao

It is unfortunate that outsiders, particularly politicians were attending the Science Congress. The mix of politics and science is very dangerous. No scientist there has protested the unscientific papers presented in the Congress. This incident cannot be seen in isolation. Almost every day some minister or some religious head is issuing statements which are fraught with dangerous consequences. They are even urging the women belonging to Hindu religion to beget more children which is highly disgusting and unacceptable. Whoever attempts to fanaticise the people in this country cannot succeed as it was proved in the past. People of the country are far more rational than the government thinks.

Professor Rao is former Dean, Osmania Arts College, Hederabad.

Sri. Vakulabharanam Ramakrishna

Earlier, the rulers brought astrology to be included in the university syllabus, but due to the spirited resistance of the people they had to withdraw it. Every religion is part of study of history, and every historian studies the religion but religious study is an altogether different matter which the rulers are attempting to impose. We are not opposing any religion, we are only opposing superstitions.

Professor Ramakrishna is a retired Professor of the University of Hyderabad.

Prof. Jayant V. Narlikar

When, fifteen years ago, the UGC introduced astrology as a science course I did not see many scientists take a public stand. In many cases I found myself 'protesting in wilderness'. It is one thing to be a drawing room critic and another to take a public stand. My stand on the issue is clearly spelt out in my Penguin book *The Scientific Edge* and it is no different from the petition. My views can be quoted freely.

Professor Narlikar is a famous cosmologist and astrophysicist, and former Director of the Inter-University Centre on Astronomy and Astrophysics, Pune.

Text of the Online Petition: Stop the attempts to dilute the integrity of scientific process in science meets

We convey to you our deep concern with the proceedings of the session on 'Ancient Sciences through Sanskrit' at the Indian Science Congress held from 3rd to 7th of January at Mumbai. In this session a talk titled 'Ancient Indian aviation technology' by Captain Bodas and Ameya Jadhav claimed the existence of aircraft in India 6000–7000 years ago, which "travelled from one country to another, from one continent to another, and from one planet to another" and that "in those days, aeroplanes could move left, right, as well as backwards, unlike modern planes which only fly forward." The speaker did not bother to cite any archaeological evidence and just referred to the texts of Shri Bramhamuni Parivrajaka and Shri G. R. Josyer which have already been debunked in a study conducted in 1974 by a team of scientists from the Indian Institute of Science led by Prof. H. S. Mukunda.

Another talk in that symposium dealt with the "fusion of science and spirituality due to inter-penetration law". Yet another talk claimed that "to understand Einstein, one needs to read Vedas"—a claim without any reference to which part of which Veda throws any light on relativity and how it was historically possible to conceive the theory of relativity before the advent of Newton's laws of mechanics and Maxwell's laws of electromagnetism.

We are deeply astonished and shocked that such a hallowed assembly of scientists has been misused to make false and chauvinistic claims about ancient India. Such attempts only serve to make Indian science a butt of ridicule, and undermine the true contributions of ancient India in science. We also note with dismay that none of the speakers of this symposium were scientists of any repute, and scientists and scholars who are known to have worked extensively on ancient Indian science were not among the speakers.

It is the established practice that in any reputed science conference, the papers are first reviewed by experts before being accepted for presentation at a conference. We are not sure whether this process was followed for all the presentations. We are not against talks on debatable topics in a science conference, but it is the responsibility of the organizers of the conference to ensure that the method of science is followed in making a claim, and to ensure that sufficient time is available for discussion and questions from the floor of the house. However, In the Indian Science Congress–2015, this accepted scientific procedure was not honoured, and attendees who wanted to put questions to the speakers were not allowed to do so.

We are deeply concerned about the renewed attempts to mix science with mysticism and history with mythology, and the attempts to propagate unscientific superstitious beliefs in the name of science. We urge the scientific community to be vigilant about these attempts, to protect the integrity of the scientific process, and not to let scientific institutions, conferences, symposiums and meetings to be used to propagate pseudo-science.

We are strongly in favour of a true appraisal of the achievements of ancient India in different branches of science and technology and bring them to the notice of the world. Commendable efforts have already been made by serious historians of science which have brought out many of the great achievements in ancient and medieval India. Such efforts need to continue rather than making false claims which belittle our rich heritage in the eyes of the world. □

A Brief History of Science Part 8: The Development of Science in Ancient India

Soumitro Banerjee*

IN THIS INSTALMENT of the essay I shall deal with the development of science that happened in ancient India. At the present time it has become all the more necessary for the people to understand the rich heritage of science in ancient India, because some unauthenticated claims are being made from different quarters that are undermining the actual contributions of ancient India in science and technology.

The term "ancient" is somewhat vague, as it can mean any time in the past. So, to make our discussion more concrete, we shall divide the time-span into three parts: (a) the period of the Indus Valley civilization, (b) the Vedic age, and (c) the post-Vedic period.

The Indus Valley Civilization

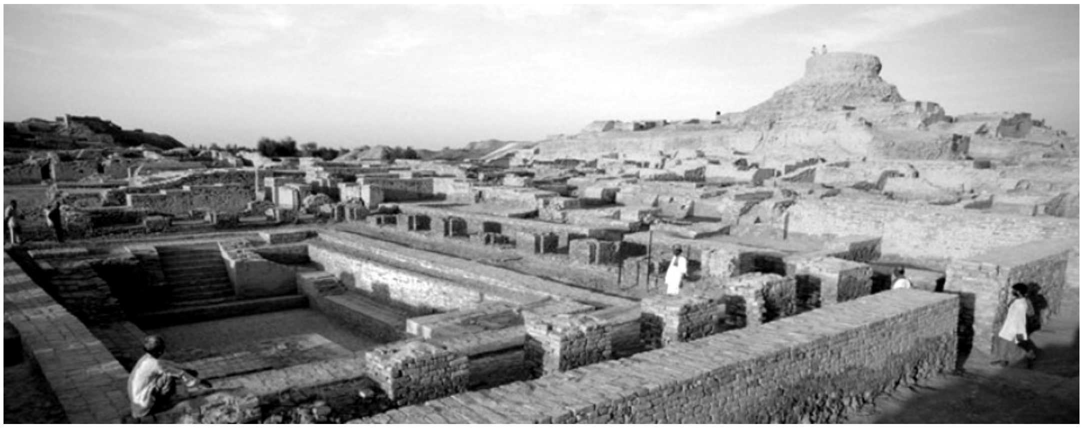
The ancient civilization discovered through excavations in Harappa, Mahenjo-Daro, Dholavira, Lothal, and about a hundred other sites in Western India and Pakistan was, in the opinion of many experts, the most advanced civilization of the Bronze Age. Radiocarbon dating has revealed that this civilization, also known as the Indus Valley civilization, existed over a period from about 3500 BC to about 1800 BC, out of which the period from 2800 BC to 2500 BC was the time of maximum development.

Archaeologists were particularly surprised to see the planned layout of these ancient cities. Large and small roads (9 feet to 34 feet wide), brick houses built over square and rectangular plots of land, large granaries, public baths, arrangements of lighting the streets — all these indicate that civil engineering, town planning, and architecture were quite advanced in this civilization. There are many remarkable items of civil engineering, such as, drainage systems for water (open and closed), irrigation systems, river dams, water storage tanks carved out of rock, moats, homes with private bathrooms and drainage, multiple-storied buildings with stairs, and even a dockyard.

Such architecture requires knowledge of geometry, especially the construction of squares, rectangles, and rectangular parallelepiped. The Indus Valley people designed a ruler (Mahenjodaro ruler) that was divided into ten equal parts. All bricks had the ratio 1:2:4, regardless of their size and location. The seals also show intricate geometric patterns. It was an agriculture-based society. But the artefact discovered in these sites indicate significant advancement in textiles, pottery, and metallurgy (copper and brass) also.

Archaeological evidence indicates that by about 1700 BC, the Harappan civilization was on the verge of decline. The causes of

*Dr. Banerjee is a Professor at the Indian Institute of Science Education & Research, and General Secretary of *Breakthrough Science Society* .



Picture of the Mohenjo-Daro ruins, with the great public bath in the foreground.

its decline are not certain. Climatic changes and long spells of draught (or flooding) may have led to the decline in agriculture. The increase in population and the decrease in agricultural output may have created economic problems leading to a gradual decay of culture. The physical existence of the civilization possibly ended when the inhabitants were forced to abandone the cities to move to other areas with better prospects of livelihood. Such decline and extinction of a culture are not uncommon in ancient civilizations; Inca and Maya civilizations of South America offer similar examples.

The Vedic Age

Some tribes speaking Proto-Indo-Iranian languages migrated from Asia Minor into West Asia and Europe from around 2500 BC and a few influxes occurred into North-Western India sometime between 1800 BC and 1500 BC. These were horse-riding pastoral migratory tribes whose livelihood came mainly from animal husbandry. They did not create urban civilizations like Harappa and Mahenjo-Daro (cities grew in Aryan-speaking land only after 600 BC); they did not have a written script; they were also significantly backward in terms of science and technology in comparison to the people in the Indus valley civilization. But they fought and won against the non-Aryans, settled in the Indian subcontinent, and slowly gave birth to a very rich culture that was to have tremendous impact on the history of the subcontinent.

The thousand year span from the migration of the Aryan-speaking people till the onset of the Buddhist era (approximately from 1500 BC to 500 BC) is called the Vedic age. The Vedas are the highest cultural creations of that period. Even though rituals, worship, chants and hymns constitute a lion's share of the Vedas, these are also our prime sources for an objective assessment of the actual progress of science in that period.

From these works we see that the late Vedic people wrote numbers in a system that had 9 basic number-symbols. Zero had not been discovered and the place-value system has not been invented at that time. So they needed new symbols for 10, 20, 30, $\cdots$ 100, 1000, etc. There were also names for higher powers of 10. Historians are surprised by the fact that they could conceive large numbers in spite of the handicap of not being able to write such numbers. In the *Taittiriya Samhita* and *Shulvasutra* we see mention of arithmetic progression and geometric progression. They could add, subtract, multiply and divide simple fractions. We also see attempts to find the square root of 2 and 3 in terms of continued fractions.

The *Shulvasutras* are a collection of texts written between 800 BC and 200 BC, so these could be said to belong to the late vedic and early Buddhist periods. The oldest sutra attributed to Baudhayana is thought to be composed between 800-600 B.C. These are basically the laws of measurement with the aid of a rope (shulvasutra literally means "rules of the cord"), much of it meant for erecting sacrificial altars. In these texts, we find clear instructions of how to locate the East-West line at any place, how to construct a square, how to obtain the perpendicular bisector of a given line, etc. They had to solve some problems of geometry to tackle the construction of raised platform or *vedi* used in *yagnas*. For example, they had to construct platforms of circular, square, and rectangular shapes, of the same area. The *Sulvasutras* gave methods of geometric area-preserving transformations from one geometric shape to another, such as from a square to a circle and vice versa, from a square to an isosceles triangle, to a rhombus etc.

There is also indication that the theorem known by the name of Pythagoras was known to the writers of the *Shulvasutras*. Baudhayana gave the following general statement of the Pythagorus theorem: diagonal of a square produces double the area, and for a rectangle the squares produced by the length and breadth of the rectangle together equal the area produced by the diagonal. He also gave a set of numbers like (3, 4, 5), (5, 12, 13), (8, 15, 17), (7, 24, 25), and (12, 35, 37) which form "Pythagorian triads" — triplets of integers that follow the rule $x^2 + y^2 = z^2$. But no proof was given. It is now believed that people in many parts of the world, including India, Egypt, and Greece, knew about this result and made use of it in constructions of various sorts. Pythagoras in 6th century BC presented a rigorous mathematical statement and proof, which we find in Euclid's writings. Baudhayana also described a method for approximate calculation of the square root of 2:

$$\sqrt{2} = 1 + \frac{1}{3} + \frac{1}{3 \cdot 4} - \frac{1}{3 \cdot 4 \cdot 34} \approx 1.4142156$$

It should be noted, however, that these real developments have no link with what is taught nowadays in schools in some states in the name of "Vedic Mathematics".

In the late Vedic period agriculture was started in addition to animal husbandry, and they had to formulate a calendar in order to fix the timing of sowing, reaping, and other agricultural activities. That provided the primary motivation for studying the motion of the objects in the sky. In addition, fixing of the times of holy events like the performance of a *yagna* also induced people to look for auspicious events in the sky. The Vedic literature show that they counted months on the basis of the phases of the moon, and the year on the basis of the motion of the sun. Since a whole number of moon-months do not make a sun-year, the extra days were counted as "mal-mas", when no auspicious event could be held. The year was divided into two parts: when the sun moved towards the North (*uttarayana*), and when the sun moved towards the South (*Dakshinayana*), and they could identify the summer and winter solstices. In addition they named 27 stars along the path of the sun and the moon, and could specify the positions of the sun and the moon in the background of these stars. It is important to note that in the

Vedic period there was *no* astrology—in the sense of beliefs in the influence of planets on human lives. The word *Jyotisha* was used in the sense of astronomy.

The most remarkable developments happened in medical science. The Atharva-Veda contains many ideas about anatomy, physiology, and medicines which, though not quite correct in the light of modern science, were much advanced when compared to the knowledge of the other societies of the same period. The Ayurveda was written in the late Vedic period in continuation of this tradition. It is divided in eight chapters: medicine, surgery, treatment of eye, ear, nose, and throat diseases, treatment of psychological problems, treatment of children, poisons and their effects, chemistry and preparation of medicines, and treatment of sexual diseases. Such attempt to systematize the empirical knowledge of that period is undoubtedly remarkable.

Even though the main content of the *Rigveda* was chants and hymns in praise of the gods and asking material benefits in return, the gods of that period were actually embodiments of natural forces or deification of some Aryan leader (like *Indra*) successful in defeating the non-Aryans. That is why historians opine that the essential content of the thought process of men in *Rigvedic* times was materialistic, what anthropologists term as the "magic phase". That is why the *Rigvedic* hymns reflect a healthy curiosity about natural phenomena, which was conducive to development of scientific enquiry.

Many people carry a misconception that spiritualism is the only characteristic feature of the Vedic times. Actually many different philosophical currents were very much alive during this period. One of these philosophical currents is called *Lokayata* (sometimes also called *Charvaka*). It did not believe in the existence of *atma* or soul, refused to accept anything on the basis of belief, and theorized that everything in the world is made of four constituents or *chaturbhuta*: earth, water, air, and fire (a fifth one, sky, was added later). It believed that when a man dies, his body returns to these four constituents, and does not go to heaven or hell. Whether the ideas like *chaturbhuta* were correct in the light of modern science is not of our concern. What really matters is the fact that it sought to explain the world through material processes and phenomena. Other philosophical lines of thought like *Nyaya-Vaiseshika* and *Samkhya* also existed. Notwithstanding the differences between these lines of thought, at the basic level they were also materialistic philosophies. Under the influence of these philosophical currents, there was a healthy curiosity about the material world, and we see steady progress in man's understanding of it.

But the later Vedas laid too much emphasis on ritualistic practices like *yagnas, homas*, chants, and on prescribing what to do and what not to do. Such an environment hampered the natural enquiring mind of men, and so the scientific enquiries subsided. When the "end" of the Vedas or *Vedanta* came, it sought to create an alienation of the individual from the material world. Seeking nirvana away from life and society became the ideal for the learned people. This created a condition detrimental to scientific enquiry, and as a result, we do not see much development of science in the late Vedic period.

Post-Vedic period

This condition began to change in the 6th century BC when a group of people, disenchanted by the suffocating intellectual atmosphere dominated by ritualistic practices, started looking for alternative philosophical ideas. Jainism and Buddhism

The method of "squaring a circle" in Boudhayana *Shulvashutra*

"If you wish to square a circle, divide its diameter into eight parts; then divide one part into twenty-nine parts and leave out twenty-eight of these; and also the sixth part (of the preceding sub-division) less the eighth part (of the last)."
According to this prescription, the side of the square will be

$$a = \frac{7d}{8} + \frac{d}{8}\left(1 - \frac{28}{29} + \left\{\frac{1}{6}\left[1 - \frac{1}{8}\right]\right\}\right) = 0.87868 \times d$$

Now we know that the area of the square is a^2 and that of the circle is $\pi r^2 = \pi d^2/4$. As per modern calculation, the value of a should be $0.8862 \times d$, and thus their prescription was reasonably good.

were born in this period. Even though we mainly hear of these two religions, historians have shown that the materialist philosophical thoughts like *Charvaka, Samkhya*, etc., that were born during the Vedic period found resurgence in this period through man's attempts to find alternate ways to interpret the world. Even Buddha did not believe in the existence of god. The presence of such rich array of philosophical currents and the clash of ideas created an intellectual atmosphere that aided scientific enquiries. That is why we see a resurgence of science starting from the 6th century BC. But this period can no longer be called the "Vedic" period.

The materialistic line of thinking was alive in India for a long time, and slowly died out after about 9th-10th century AD (we'll talk in detail about it later). And this 1600-year period from 6th century BC to about 10th century AD was the golden age of ancient Indian science. We shall discuss this era with reference to the different areas of human endeavour.

Medical Science

After *Atharvaveda* and *Ayurveda*, medical science reached an altogether different dimension since the 6th century BC in the hands of a few eminent medical practitioners like Athreya and Susruta (6th century BC), Jivaka (566-486 BC) and Charaka (time controversial). The unusual aspect of this development is the practice of surgery which was unequalled in the world before the initiation of modern methods of surgery after the European renaissance. *Susruta Samhita* mentions 121 kinds of surgical instruments, and has detailed instruction on how to run the knife and other instruments on different organs, how to sew the wound with plant-fibre after a surgical procedure, what to do in case of broken bones, etc.

The most unusual aspect of these is the procedure to rejoin severed noses and ears. In those times a common punishment was to cut off the culprit's nose and ears. After this was carried out, if the King learned that the punished person is not really the criminal, then the doctor would receive instruction to rejoin the nose and ears. The detailed account of the procedure in the writings of both Susruta and Charaka indicates that they succeeded in some cases. However, there is no description or instruction on how to place the head of an elephant on a human torso, as claimed by Prime Minister Narendra Modi.

Chemistry

Everywhere the primary motivation in the study of chemistry came from three directions. Medical practice demanded one to know the properties of different kinds of substances and mixtures that could be used for medical purposes. For that reason, wherever medical science had advanced, knowledge about the properties of the substances that have some medicinal use also advanced hand-in-hand. Second, the demands of metallurgy have induced man to experiment with different metals and their alloys in an attempt to obtain harder and non-brittle material. Third, the belief that it is possible to transform other substances into gold by chemical processes also prompted man to try out various things. In India the studies in chemistry were initiated from all these angles. Since medical science and metallurgy significantly advanced in this country, it is expected that knowledge of chemistry also must have advanced in step. That is what had actually happened.

Susruta Samhita and *Charaka Samhita* describe the properties of six metals (iron, tin, lead, copper, gold, and silver), five types of salts (depending on their source rather than their composition), and a few alkalis. They also give elaborate procedures for preparing mild and strong alkaline substances (potassium carbonate and sodium carbonate) which were used to treat wounds. Books written in the later periods also mention the use of mercury, zinc, and sulphur. A process called "killing" metals is described in some books, which is nothing but reactions that produce substances whose properties are different from those of the original metal. A detailed account of this knowledge can be found in Acharya Prafulla Chandra Ray's famous book "The History of Hindu Chemistry". Quite a few books on chemistry, like *Rasa-ratnakara, Rasa-hridaya, Rasarnava, Rasendra-churamani, Rasakalpa*, etc. were written between 11th and 14th century AD. But by then chemistry had become a part of mystic practices or *tantravidya*. That is why modern chemistry could not take birth from that.

Experiments in metallurgy have a very rich tradition in India. The extraction of metals from ores and the mixing of different metals to obtain brass and steel of the required strength demanded people to experiment with various ingredients and processes. Since all weapons are made of metals, this pursuit had patronage of the kings. That is why, even though the cultivation of knowledge subsided in India after the 10th century, the art of metallurgy could advance more or less unhindered for a long time. In many archaeological sites we see instances of specific metals prepared for specific purposes.

Out of these the famous iron pillar of Qutub Minar in Delhi demands special mention. The 24 foot tall pillar built in the 4th century AD has not rusted as yet. The preparation of the specific kind of metal and the technology of fashioning such a huge pillar are truly examples of technical excellence reached during the Gupta dynasty. But the *Hindutva* proponents go a bit far in claiming that modern science has not advanced enough to produce rust-less steel similar to that produced by the ancients. This is however not a fact. Scientists have examined the composition of that iron and have found that it has excessive quantities of phosphorous. This is not surprising, since phosphorous is naturally present in the iron ore and gets mixed with iron in the process of its extraction. Even though phosphorus prevents rusting, this phosphorus is removed by reacting with oxygen in the modern steel-making process, because phosphorus makes steel brittle. But for such a large pillar, it does not matter if the material is brittle, because the bulk holds it together. The iron for the pillar was prepared without removing the phosphorus, and that is why it does not rust. But the same material cannot be used to make swords, for which they adopted a different technique.

The technology of producing Wootz steel which was renowned for making swords with exceptional sharpness and toughness originated in India. This was exported to Europe and the Middle East where it was known as Damascus steel. Another important Indian contribution to metallurgy was in the isolation, distillation and use of zinc. There is evidence of zinc ore mining at Zawar in Rajasthan from the fifth century BC, The earliest confirmed evidence of zinc smelting by distillation is dated back to 9th century from Zawar.

Linguistics

It is known that Sanskrit was not a spoken language. It is a language created by "purifying" the spoken languages like Pali, Prakrit etc. Such purification itself is a feat in linguistics. But in the early stage, when the Vedas were initially composed, there was no standardization in its form. The feat of standardizing the language by extracting the rules of its grammar was performed by Panini (4th century BC), considered the greatest grammarian of antiquity. Because of this contribution, Sanskrit became easier to learn and post-Panini Sanskrit became the common medium of discourse and exchange among the learned section of the people of the entire subcontinent. The development of this common medium of exchange played a great role in further development of ideas in this multi-lingual region.

Another remarkable achievement of this period is to arrange the consonants in a 5×5 matrix depending on which part of the mouth is touched by the tongue and how much air is exhaled while pronouncing an alphabet. This highly scientific way of arranging the alphabets is not found in any other language in the world.

Mathematics and astronomy

In ancient India, astronomy and mathematics progressed hand in hand, as the astronomers also practised mathematics and mathematicians cultivated astronomy. That is why these two subjects, where ancient Indians had made major contribution, will have to be discussed together.

We have already discussed the advances in these two subjects during the Vedic age, which are found in texts like *Shulvasutra*, the *Brahmana* literature, and the *Vedanga Jyotisha*. In the post-Vedic period, the Jain mathematicians (between 400 BC and 200 BC) initiated the process of freeing mathematics from religious and ritualistic motivations, and made it stand on its own ground. They were particularly interested in very large numbers, and could conceive infinity. In the writings of the mathematician Pingala (3rd century BC) we see important works on number theory including what are now known as Pascal's triangle and Fibonacci numbers. Important mathematical works of this period are *Surya Prajnapti, Vaishali Ganit, Sthananga Sutra, Anoyogdwar Sutra*, and the *Satkhandagama*.

In astronomy, we do not see any major work in the late Vedic period, and the first signs of resurgence in the post-Vedic period are visible in the texts written between 100 and 500 AD, which are collectively named as *Siddhanta-Jyotisha*, and the first major advancement in mathematics, after the *Shulvasutras*, can be found in the writings of Aryabhata (end of 5th century AD).

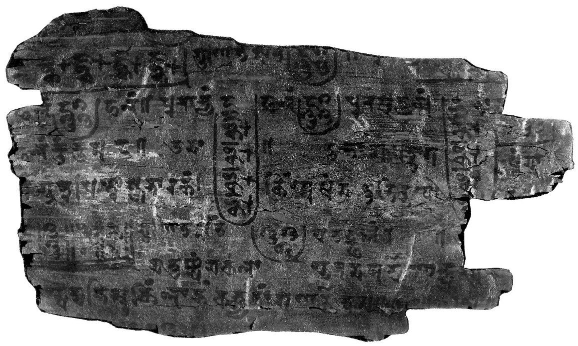
The Siddhanta Jyotisha is not one book. It is actually a common name given to a large number of books (like *Surya-siddhanta, Pitamaha-siddhanta, Vashista-siddanta*, etc.) of similar content. Out of these some books like the *Romaka-siddhanta, Poulish-siddhanta, Yavana-siddhanta* contain ideas culled from Greek and Roman astronomy of the post-Alexander period. These resulted from the opening of trade routes between India and Europe following Alexander's invasion, and the cultural exchanges resulting from that. It is in these books that astrology appears for the first time in Indian literature; so the superstition seems to have been imported from the West.

One important aspect of the *Siddhanta-Jyotisha* books is the attempt to find the periodicities of the motion of the sun, the moon, and the planets. But their way of expressing it was different. Today we know the period of revolution of the Earth around the sun is 365.24219 days (the day measured in terms of the earth's rotation around its own axis), and that of the moon around the earth is 27.3216 days. But in the time of *Siddhanta-Jyotisha* it was not known that Earth moves around the sun or that it spins around its own axis. People saw the sun going around the earth, but they noticed that it does not return to exactly the same position at sunrise every day. After every 365 days it comes to more or less the same position, and according to that the year was counted. But they had noticed that the position after 365 days was also not exactly the same. By noticing the shift after every year, they calculated the period after which it would return to exactly the same position. This "periodicity" of the sun's motion was called a *Mahayuga*. According to many *Siddhanta-Jyotisha* books, a *Mahayuga* contains 4,320,000 years. If one calculates the period of revolution of the earth around the sun from this figure, the length of the year becomes 365.258 days, which is very close to the modern estimate. Similarly they had calculated the periods of the moon and the planets — the period within which the object revolves a whole number of times. These come to be very large numbers, and historians were surprised to see the mention of such large numbers in astronomical literature of that time. Actually, before the invention of the place-value system of writing numbers, there was no way of expressing the periodicity of these bodies other than in whole numbers. That is why this ingenuous way was adopted.

Since Indian kingdoms of that time had trade relations with the kingdoms in Greece, Rome, and Arabia, there was exchange of knowledge between the scholars of these regions. Through these exchanges the knowledge created in India percolated to Greece, Rome, and Persia, and ideas from knowledge-centres like Baghdad, Athens and Alexandria reached India and became integrated into its body of knowledge. We know that the Greek philosopher Eratosthenes of Alexandria (276-194 BC) measured the diameter of the Earth by observing the shadows of vertical sticks in two different places. We see the mention of exactly the same method in *Siddhanta-Jyotisha*. The motions of the planets as seen from the Earth are not uniform. Sometimes they are fast, sometimes slow, and sometimes they even move in the reverse direction. To explain such peculiar motion, the Greek astronomer Ptolemy (90-168 AD) had proposed that these do not move around the Earth in circles, rather there are circles over circles — called epicycles (see the 2nd instalment on this essay). In Aryabhata we see a similar explanation of planetary motion, based on two epicycles.

It is however remarkable that Aryabhata was the first to talk about the spin of the Earth about its own axis. This means he was the first to guess that the sun is not really moving around the Earth; rather we see it moving because the Earth itself is spinning about its own axis. But this idea was not accepted by other eminent scholars like Brahmagupta and Varahamihira, who criticised Aryabhata for infusing fanciful

The Bakhshali manuscript



The Bakhshali Manuscript is a mathematical text written on birch bark which was found near the village of Bakhshali in Pakistan in 1881. Only about 70 pages have survived, and are now kept in the University of Oxford.

The manuscript is written in an earlier form of *Sarada* script which was mainly in use from the 8th to the 12th century AD. It is a handbook of rules and illustrative examples together with their solutions. It is devoted mainly to arithmetic and algebra, with just a few problems on geometry and mensuration.

ideas into astronomy. Even though Aryabhata talked about the diurnal motion of the Earth, he did not reach the same conclusion as Copernicus, as he described planetary motion in the same way as Ptolemy. He, however, gave the correct scientific explanation for the solar and lunar eclipses.

In his book *Aryabhatiya* written in 499 AD, we see many contributions in mathematics, including square root and cube roots of numbers, arithmetic progression, solution of simultaneous equations, etc. We also see treatments of infinite series including formulae like

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

After Aryabhata, the cultivation of astronomy and mathematics gained momentum, and continued unhindered for many centuries. In this period it was enriched in different directions by eminent scholars like Varahamihira (6th century), Brahmagupta (7th century), Mahavira (9th century), Munjal (9th century), Sripati (10th century), Sridhara (11th century) and Bhaskara (12th century). But before going into this glorious phase of Indian science, we have to understand the greatest contribution of India in the world of knowledge — the discovery of zero and the invention of the place-value system of writing numbers.

Writing of numbers requires a basis. In different parts of the world, different bases were used to write numbers. The Babylonians used base 60, the Mayans used base 20. In India, Arabia, and in many other parts of the world, the number system had base 10 since antiquity. This means that there were 10 number-symbols (1 to 10) to write numbers up to 19 (19 = 10+9). Another symbol representing 20 would be required for writing numbers from 20 to 29, and then it would require another symbol, so on and so forth. Thus, such a number system would require a large number of symbols to write big numbers. This was the problem with the Brahmi and Kharosthi numbers found in stone tablets of Ashoka's time. The same was the problem of the Roman number system. If you try to write a number like 3905 in Roman script, you would realize the difficulty.

But today we write arbitrarily big numbers with ease, with only 10 number symbols. This has been possible due to two major discoveries that happened in India. The first was the realization that the absence of something, or zero, is also a number. The second was the invention of the place value system. In the modern decimal system of writing numbers when we write 3905, we actually construct it as

$$3 \times 10^3 + 9 \times 10^2 + 0 \times 10^1 + 5 \times 10^0$$

Here a digit assumes a "value", a power of 10, depending on the position where the digit is written. This system of writing numbers was developed in India. The literature of that time shows that this way of writing numbers was started sometime between the 1st and 3rd centuries AD. Zero may have been discovered a century or two before that, because the place value system is not possible without the use of zero. We see the use of the place value system in Aryabhata and the later mathematicians like Brahmagupta and Varahamihira. Their writings were translated into Arabic, through which the Arabs came to know of this system. The Arab world was very fast in adopting it. Through them, it reached Europe. That is why the English numerals are still called the "Arabic" numbers, even though the system was invented in India.

With the introduction of a new number system, society faced a new problem. None of the old methods of adding, subtracting, multiplying and dividing numbers would be applicable to the new number system. So one had to freshly develop the methods of arithmetic suitable for this new number system. At that time many techniques were invented, some of which have come to be adopted universally — the ones that students learn in school today.

In mathematics another area in which India made big contribution is algebra. The contribution of the ancient Greeks in mathematics is restricted to geometry. They could not advance much in arithmetic and algebra because they could not invent zero and the place value system. In contrast, the Indian mathematicians did not have this handicap, and so could progress significantly in these directions. The unknown quantity (x in modern algebra) used to be written in Devnagri script using the alphabet "ya", or if two unknown quantities were involved, using the first letters of Sanskrit words for different colours. They used to write equations using these notations, and proceeded to solve many of these equations. Much of the Indian contribution to algebra concerns linear and quadratic equations. Brahmagupta (628 A.D.) gave the first explicit solution of the quadratic equations. Later it was systematized by Sridhar Acharya in the eleventh century.

Another important contribution was in the field of indeterminate equations. When an equation has two unknowns, it is not possible to obtain the values of the unknown quantities. But Brahmagupta, Sripati and Bhaskara showed that in particular situations, such as when the quantities to be found are whole numbers, it is possible to find solutions. Brahmagupta gave a general solution to the linear Diophantine equation $ax + by = c$, where a, b, and c are integers. The solution of second order indeterminate equations of the form

$$x^2 - Ny^2 = 1$$

(called Pell's equation) using whole numbers is considered one of the greatest contributions in number theory. Bhaskara developed an algorithm called *Chakravala* for solving indeterminate equations like the Pell's equation in a systematic way.

However, the Indian contribution in geometry is meagre, mostly confined to mensuration. We see rules of finding the areas of rectangles and triangles in the writings of Aryabhata and Brahmagupta. Brahmagupta also gave a formula for the area

The spread of the Indian numeral system

It is worth quoting from a speech delivered by the Nobel Prize winning Pakistani physicist Dr. Abdus Salam [5]:

"Almost 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 Hindu scholars. From this conference, the first international conference in an Arab country, dates the systematic renaissance of science associated with Islam. 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 realized 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 Hindu astronomer, Kankah, on Hindu numerals, then unknown to anyone outside India."

of a cyclic quadrilateral (whose diagonals are perpendicular to each other). Even though the value of π is stated as $\sqrt{10}$ in some *Siddhanta Jyotisha* manuscripts, people like Aryabhata succeeded in obtaining it in much greater accuracy (3.1416).

In trigonometry also we see significant advancement. Aryabhata introduced a number of trigonometric functions. Varahamihira gave a table of the sines and cosines (he called jya and kojya) in his book *Panchasiddahntika*. From his writings we see that many trigonometric relations taught at school today were known in his time. Bhaskara obtained the sines and cosines of even smaller angles, for example he gives $\sin 1^\circ = 10/573$, $\cos 1^\circ = 6565/6569$. Note, however, that the Greek astronomer Hipparchus (2nd century BC) was the first to prepare a sine table and to use it for astronomical calculations.

Bhaskara's astronomical work of the 12th century covers topics such as latitudes and longitudes of planets, lunar and solar eclipses, the moon's crescent, conjunction of the planets with each other, conjunction of the planets with fixed stars, etc.

The Kerala school of mathematics and astronomy (14th to 16th century) made significant advances in astronomy and especially mathematics, including fields such as trigonometry and analysis. They made important contributions to the field of infinite series and provided the first example of power series. Rudiments of calculus are also present in their works, but they did not formulate a systematic theory of differentiation and integration.

The centres of learning

In the Vedic age the way of imparting education was personal. A learned person or sage would teach a handful students in his own home. The students lived for a few years with the teacher, gave service in the teacher's home and field, looked after the cattle, and in return got an education. But in the Buddhist period, the Stupas and Mutts started emerging as centres of learning, where a large number of monks and bhikkhus lived together and exchanged knowledge.

This model slowly caught on, and a number of specialized centres of learning emerged where a large number of teachers and students lived in a compound, and the teachers could teach a larger number of students. The oldest of these is situated in Takshashila, the capital of Gandhara (present Kandahar province in East Afghanistan) which started developing from a time slightly before Buddha, but reached glory during the Buddhist period. Later, in the 5th century AD, another centre of learning was established in Nalanda with the patronage of the Magadh kings. Even though these two were the most famous, many more relatively smaller centres of learning have been found, like Pushpagiri in Odisha, Odantapuri and Vikramshila in Bihar, Jagaddal in Bengal, Balavi in Gujarat, etc. Some of these were so famous that students came from far-away places like China.

In these centres of learning, education was imparted in an organized manner somewhat like the Buddhist monasteries. However, the form and content of education were personal in nature. The residential facilities and class-rooms in these centres of learning enabled a teacher to teach 20-30 students at a time depending on one's ability and fame, and facilitated exchange of ideas among many scholars. These centres of learning were undoubtedly great initiatives in ancient India that helped knowledge to be consolidated and expanded.

The decline of science in India

In spite of such a rich tradition in the cultivation of science and technology, after the 9th-10th century it subsided, and then was completely extinguished. Bhaskara can be said to be the last spark of light before it became dark. After him for more than 800 years, there was practically no contribution to science coming from India.

What was the reason behind the decline and fall of Indian science? The famous 19th century chemist Acharya Prafulla Chandra Ray investigated this issue in his book "The History of Hindu Chemistry". According to him, three factors were responsible for this decline in the cultivation of science.

The first was the introduction of the caste system in a rigid form. According to him, the interaction and exchange of ideas between the doers and the thinkers is an essential precondition of the cultivation of science, and casteism blocked this process. "The arts being thus relegated to the low castes and the professions made hereditary, a certain degree of fineness, delicacy and deftness in manipulation was no doubt secured, but this was done at a terrible cost. The intellectual portion of the community being thus withdrawn from active participation in the arts, the how and why of phenomena—the coordination of cause and effect—were lost sight of—the spirit of enquiry gradually died out among a nation naturally prone to speculation and metaphysical subtleties and India for once bade adieu to experimental and inductive sciences. Her soil was rendered mortally unfit for the birth of a Boyle, a DesCartes or a Newton and her very name was all but expunged from the map of the scientific world."

The second reason was the introduction of the "shastras" or moral code books that specified what can and cannot be done. "The drift of Manu and of the later *Puranas* is in the direction of glorifying the priestly class, which set up most arrogant and outrageous pretensions. According to Susruta, the dissection of dead bodies is a sine qua non to the student of surgery and his high authority lays particular stress on knowledge gained from experiment and observation. But *Manu* would have none of it. The very touch of a corpse, according to *Manu*, is enough to bring contamination to the sacred person of a Brahmin. Thus we find that shortly after the time of *Vagbhata*, the handling of a lancet was discouraged and Anatomy and Surgery fell into disuse and became to all intents and purposes lost sciences to the Hindus."

The third reason was the influence of the Vedanta philosophy, which taught people to see the material world as maya or illusion, on the learned section of the people. "The *Vadanta* philosophy, as modified and expanded by Samkara, which teaches the unreality of the material world, is also to a large extent responsible for bringing the study of physical science into disrepute. Samkara is unsparing in his strictures on Kanada and his system. One or two extracts from Samkara's commentary on the *Vedanta Sutras*, will make the point clear." Thus, according to Acharya P. C. Ray, a scientist's queries are directed at the material world, its processes, phenomena and events. If one sees the material world as *maya* or illusion, one cannot do any science. The spread and intellectual dominance of the Vedanta philosophy as propagated by its powerful exponent Samkara (8th century AD), was responsible for the elimination of the materialistic philosophies like *Lokayata*, and for the death of science in India.

The unscientific claims

In recent times various claims are being made—mainly by the Hindutva protagonists—by mixing science with mysticism, and history with mythology, in order to create an imaginary picture of India's past glory based on religious chauvinism. It is not possible to go into an in-depth analysis of such claims in this article. But I shall briefly deal with some of them, to enable the reader judge for themselves the veracity of the claims.

Claim 1: Indus Valley civilization was a part of the Vedic era

On this issue, we need to understand why, soon after the discovery of the Harappan sites, historians and archaeologists had come to the conclusion that this was a pre-Vedic civilization. They had found four important clues.

1. The Harappan people knew how to make bricks, but the Vedic people did not. Not a single brick has been found in the one thousand year span of the Vedic age. After the Indus Valley civilization, the first brick-built building was found in the Buddhist period, during the reign of the Maurya dynasty.

2. The horse is the main animal in the Vedic literature. But no horse bone has been found in any of the Indus Valley cities. The main animal depicted in the Indus Valley art, sculpture and seals, is the bull. Not a single picture of a horse has been found. This implies that this animal—the horse—was not known to the Harappan people, but was very common in the Vedic age.

3. The Harappan people had a written language, though scientists have not succeeded in deciphering the script because it has no resemblance with any of the modern languages. In contrast, the Vedic people did not have a written language in the early part of the Vedic age. That is why the *Rigveda* was communicated through *sruti* (to listen) and *smriti* (to memorize), and was written up much later.

4. No description of the Harappan cities are found anywhere in the literature of the Vedic age. There are no references to structures built on platforms, or the grid pattern of streets and the careful construction of drainage systems, to granaries, warehouses and areas of intensive craft production, to seals and their function, etc. "If the two societies were identical" writes the eminent Historian Romila Thapar, "the two systems would at least have to be similar."

There have been attempts by the Hindutva protagonists to contradict these pointers. In the year 2000 a book titled "The Deciphered Indus Script" was published by N. S. Rajaram and N. Jha which claimed that the scripts are actually worship of river Saraswati, in Sanskrit. They also claimed to have found the image of a horse in a Harappan seal. The claims were soon debunked by archaeologists who showed that the translation was a complete piece of imagination. There are linguistic rules that have to be observed in any decipherment, which make it necessary for a claim to stand the test of linguistic analyses. No such scientific process was followed in the claim of Rajaram and Jha. Moreover, the broken seal was photographed by shining light from one side so that the shadow looks like the image of a horse. For details see the article by the Harvard Indologist Michael Witzel and historian Steve Farmer in Frontline (September 30, 2000).

Claim 2: Vedic Aryans were original residents of India

Today Hindutva theorists are claiming that the Aryans did not come from outside the land. Some of them change the antiquity of the Vedic culture — some say it is 10000 years old, some say 50000 years. That is why it is necessary to understand on what basis the scientists have come to the conclusion about the antiquity of the Vedic age.

1. The first evidence is linguistic: It has been found that the languages spoken in Europe and in India have a common root. These languages are classified under a group, called the Indo-European family of languages. That is why it is believed that this language group has radiated along with human migrations, starting from a common birthplace. Linguistic evidence suggests that the Indo-Aryans split off from the Indo-Iranians around 1800-1500 BC.
2. The second evidence is zoological: The horse is the prime animal in all Vedic literature, but this animal is not native to the Indian subcontinent. There is no wild horse in any of the Indian forests. Wild horses are found in Asia Minor. Signs of the existence of horses in large numbers are found in India only after a certain time. That is why scientists have come to the conclusion that the horse-riding Aryans entered India around that time.

Nowadays there are attempts to disprove this theory by showing that there were horse fossils in Harappan sites, but the claims have not gone beyond newspaper articles as professional archaeologists did not find scientific merit in such claims. There are also attempts to show that the genetic make-up of Indians has not changed in millennia; hence the Aryan migration did not happen. This is sheer nonsense as many invading populations like Kushans, Huns, Mongols, Pathans, Portuguese, and English have settled in India and their genes have become integral part of the Indian gene pool. But the most important point is that, out of the various classifications on the basis of physical characteristics, "Aryan" was never identified as a "race". The idea of an "Aryan race" was originated by the German fascists, which has been debunked long since. Scientifically it is a language group, and those who spoke that group of languages are called Aryans.

Claim 3: Vedic Mathematics

Nowadays we see attempts to introduce certain calculation techniques into school curriculum in the name of "Vedic Mathematics". It should be clear from the above discussion that the discovery of zero happened much after the Vedic age, in the

Buddhist period. The techniques in these Vedic Mathematics books include the use of modern decimal number system, and hence these cannot be Vedic in origin. The proponents are basically counting on the fact that he average Indian considers anything written in Sanskrit as “vedic”.

The way Latin was the common language of academic discourse all over Europe before the advent of modern languages like English, German, etc., in a similar way Sanskrit was the common link language of the educated people of India from antiquity all the way up to the medieval period. That is why, anything written in Sanskrit is not “Vedic”.

But the most worrisome aspect of these “Vedic Mathematics” books is that most of their content is not obtained from ancient literature at all and are creations of people in the modern times, written in Sanskrit. Sometimes text written in modern times are inserted into ancient literature (Prof. Narlikar calls these as *prakshipta* or inserted [5]), and then the whole *shloka* is cited as pointer to certain calculation technique invented by the vedic people. Sometimes the text in the *shlokas* are just cryptic phrases from which any meaning can be extracted. The techniques given in the Vedic mathematics books are at best some shortcuts for number crunching that do not help the young minds to grasp the beauty of mathematical logic at all.

Conclusion

Thus we see that there was significant cultivation of science in India in the ancient time, but a lion’s share of it was done in the period from 6th century BC to about 10th century AD. The contribution of India to the world of knowledge in this period is truly something to be proud of. But this period is not the Vedic period, and the impact of the Lokayata and Buddhist philosophies was principally responsible for the development of science in this period. We also have to keep in mind that the glorious tradition of cultivation of science was halted and finally terminated in India, due to the imposition of a rigid caste system, and due to the *sastras* that dictate what to do and what not to do, and due to the revival of the *Vedanta* philosophy.

The preposterous claims about the science in ancient India — like the claims of aircraft that flew from one planet to another, of surgery to place an elephant’s head on a human body, of in-vitro fertilization for giving birth to Karna — will only make Indian science a laughing stock before the rest of the world, and will undermine the actual contributions of India to the world of knowledge. Any right-minded person should defend the actual history and be proud of it, and should debunk the ludicrous claims. □

References:

1. A People’s History of India 3: The VedicAge — Irfan Habib and Vijay Kumar Thakur, Tulika books, 2003.
2. Science in History — J D Bernal, MIT Press 1971
3. History of Hindu Chemistry — Acharya P.C. Ray, Indian Chemical Society, 1956; and Cosmo Publications, 2010. Note that the chapter on decline and fall of Indian science was edited out in the later versions of the book.
4. Vigyaner Itihas (Bengali) — Samarendra Nath Sen, Shaibya Publishers, 1955
5. The Scientific Edge — Jayant Narlikar, Penguin Books, 2003

Getting on Top of Cancer

Uma Ramachandran *

NOBODY EXPECTS to get cancer, but when it does strike, one's world is stirred violently. Even if the cancer has been detected early and one has the financial means to see it through, one is invariably not prepared for the huge emotional drain it leaves you and your family in.

Cancer is one of the most dreaded diseases, often called the 'killer disease.' It is not like any other disease which can be cured or kept under control by simple medication. Lots of hype is floated around this disease. Hence it is an uphill task to create some basic awareness regarding this disease. For example, when we see a signboard near a Cancer Institute in one of our Metropolis which assures the public that 'Cancer is not contagious!', we realize how uphill the task is, in face of the widespread misconception about the disease. There is also several misleading information on the internet. It carries many unauthenticated advertisements for this fruit or that 'herbal preparation', which claim to be superior to chemotherapy or to be given as adjuvant.

What is cancer? It is unlike any other disease in that it undergoes unregulated cell division in any organ of our body, creating a lump or tumor (not in the blood, however) and also has the potential if not treated, to travel to other vital organs like liver, lung, bones etc. and colonize them. Cancer is not a modern day disease as many think. It has been reported as early as 2625 BC in Egyptian papyrus. If it has not been more documented, it is because it is thought to be a 'disease of old age' and in the olden days, people did not live long enough for tumors to appear and if did, they died soon after. The first treatment was described in 400 BC by a Greek historian on a Persian queen called Atossa who had her breast excised due to the appearance of tumor. We do not know if the tumor reoccurred, how or when she died. However, the procedure proved to be a temporary success and she lived long enough to goad her husband, the King, to invade Greece, the country which is west of Persia.

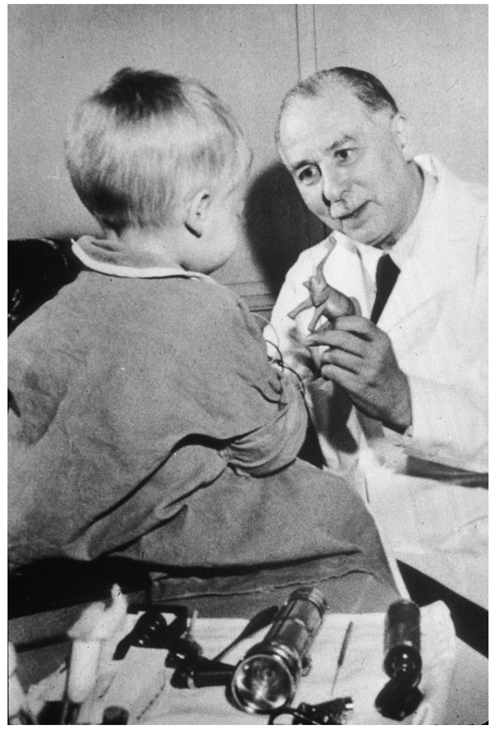
For long, the nature of cancer biology eluded the scientists. There have been persistent and heroic attempts, especially in the last century, to understand and stem this disease. Initially, it was attacked rather radically by doctors through surgery, if it appeared as localized tumors. Halstead led the way with his 'radical mastectomy.' From 1891-1907 there was brazenly held belief by surgeons that aggressive operations on cancer tumors - 'the more radical the better'- would cure cancer and stop it from recurring at that place.

By 1886, after Röntgen had discovered X-rays, it was noticed that it could selectively kill rapidly dividing cells. At last there was another weapon with which to fight cancer! Soon after, by 1902, with Curies' discovery of radium, which emitted radiation, surgeons could beam thousand fold more powerful burst of energy on tumors. How-

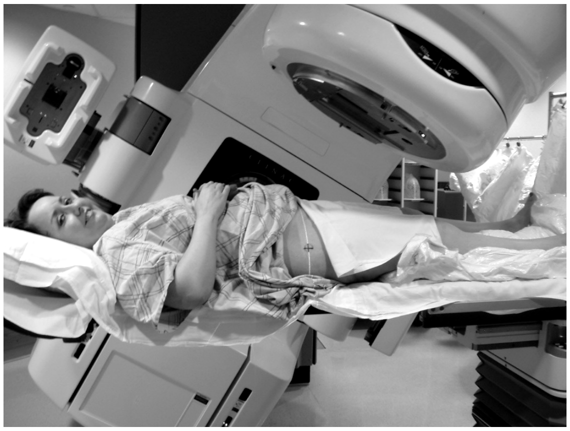
*Dr. Uma Ramachandran is a retired Professor from National Institute of Pharmaceutical Education and Research, Mohali. She has wide experience in Pharma industries too.

ever, the euphoria over radium therapy had to be toned down as it was learnt that it was a 'double-edged sword': too much exposure caused cancer! In fact, Madame Curie, who worked with radium ore for years, died of leukemia in 1934. The battle on cancer was moving very slowly. The Fortune magazine published an article in 1937, entitled, 'Panoramic survey of cancer medicine,' which was far from comforting. The fact was that no new principle of treatment, whether for cure or prevention was introduced for a very long time. Of course, the method of treatment became more efficient and humane; crude surgery without anesthesia or asepsis had been replaced by modern painless surgery. But the fact remained that cancer 'cure' still had only two principles — the removal of the diseased tissue or its destruction using radiation. A need was felt for a more discriminating therapy and a systemic therapy which was not just localized. Paul Ehrlich, a scientist associated with dye industry, had some luck in finding chemicals which worked as anti-microbial and succeeded in containing a few diseases like syphilis. He tried to find an anti-cancer drug from his vast arsenal of chemicals consisting of amides, anilines, sulfa derivatives, arsenic, bromides etc. None worked.

Dr. Farber, a pathologist working in Boston's Children Hospital, turned to cancer research in 1947. He targeted leukemia (which causes uncontrolled multiplication of blood cells in bone marrow), that could be easily monitored and littered in the laboratory. It was known then that folic acid accelerated growth of blood cells which proved a great boon in the treatment of patients with anemia. Would an anti-folate decelerate the growth of blood cells? Farber injected his leukemia patients with Aminopterin, an anti-folate and lo and behold, there was remission in many of the patients! This marked the early successful chemotherapy. This was followed by various other chemicals which were shown to be cytotoxic which randomly killed all actively dividing cells including the normal cells. Chemotherapy was often given as a mix of two or more drugs as a 'cocktail.' Around this time, a substantial Government funding was set aside by President Nixon, due to huge public pressure, for setting up and running a National Institute of Cancer. These funds were used in conducting many clinical trials. Unfortunately, it was a time when not much was known about cancer biology and hence cancer chemotherapy was more consumed by a fiery obsession to obliterate cancer cells by a logic that every poison might be 'a drug in disguise!' Often, the patients were taken to the brink of endurance just to gain a few



Dr. Sydney Farber — Father of modern chemotherapy.



Modern-day radiation therapy.

months of remission.

By the end of the twentieth century, scientists were able to prove that cancer is caused by the mutations (alterations) in a set of genes which we all carry, called the oncogenes. Scientists were able to link gene mutations in cancer cells to the complex and multifaceted abnormal behavior of these cells. The first discovered set of oncogene and anti-oncogene (tumor suppressor gene), ras and Rb retinoblastoma respectively, were cloned and were shown to produce cancer in healthy laboratory animals. This was a transformative moment in cancer genetics. In the decade between 1983-1993, a horde of other oncogenes and anti-oncogenes were swiftly identified in human cancers: myc, neu, fas, ret, akt (oncogenes) and p53, VHL, APC (anti-oncogene). All mutations are not lethal. There are many passive mutations which a person may accumulate over the years — disease of old age — due to accidents in the copying of the DNA during cell replication. Others are 'driver' mutations which play a crucial role in the biology of cancer cells. For example, during a screening of a woman with breast cancer, 127 mutations were found of which only about ten directly contributing to the actual growth and survival of the tumor. Though each cancer has its own uniqueness, all cancers carry with them one or the other form of gene mutation which activates proto-oncogenes and/or inactivates tumor suppression genes due to which we see unregulated cell division.

With this understanding, the stage was set for vast drug hunting efforts. Until the 1980s, no drug had reversed oncogene activation, or a tumor suppressor's inactivation. Even tamoxifen, the most specific cancer targeted drug discovered to date, works by attacking the dependence of certain breast cancer cells on estrogen and not by directly inactivating an oncogene or an oncogene pathways. Some well known examples of oncogene targeted drugs are Herceptin and Gleevac. Since the discovery of Gleevac, twenty-four drugs have been listed by NCI as cancer targeted therapies. These drugs have been shown to be effective against breast, lung, colon and prostate cancers, sarcomas, lymphomas and leukemias. Dozens more are under development.

Answers to the question, 'what causes mutations?' is not simple. While some of the mutations are passed on through heredity (<20%), many occur during one's lifetime due to environmental pollution, and lifestyle choices including food habit. Identifying what triggers these mutations is a daunting task. In a few cases there has been progress. For example, smoking was identified as a risk factor for lung cancer; and estrogen and progesterone as given in long term HRT (hormone replacement therapy) were identified as potential risk factor for breast cancer by conducting large scale human studies. However, identifying many other carcinogens are based on experimental animal studies. Indiscriminate overuse of pesticides is also partially responsible for many incidents of cancer; hence the clamor for organically grown food products. Un-

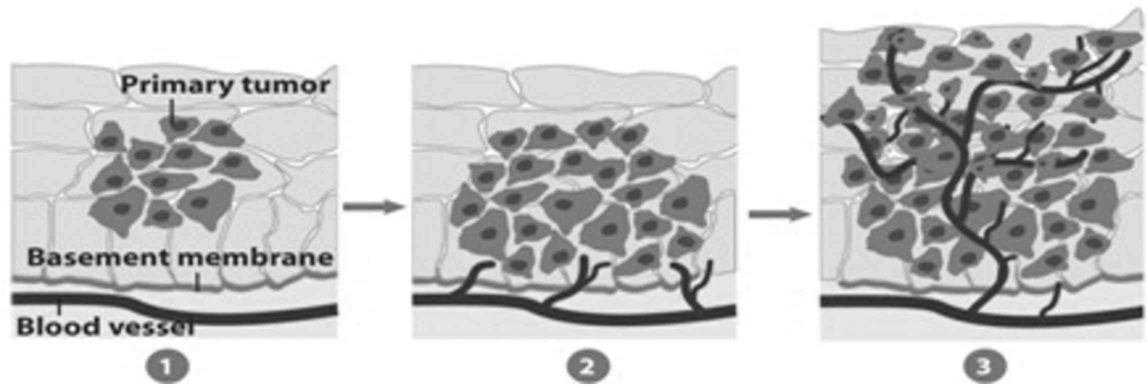


Figure 1: Stages of tumor growth leading to angiogenesis.

derstanding of the link between nutrition and risk of a particular cancer is still at its infancy. However, it is quite certain that low fiber, red meat diet increases risk of colorectal cancer and generally, obesity is linked with breast cancer.

Many a times, small tumors formed in our body can be 'benign'. They turn malignant only when it gets a supply of blood vessels which provides nutrition and also a means of migration to other tissues (metastasis). The phenomenon (as shown in Fig.1) is called angiogenesis. Cancer can be effectively fought by 'balancing ' angiogenesis. There are lots of food which can slow down angiogenesis, like red grapes which have a compound called resveratrol, tomatoes which have lycopenes and many other fruits and vegetables rich in antioxidants. Extracts from various natural products or other synthetic ones can be easily tested in the laboratory to see if they can prevent angiogenesis. There are also angiogenesis inhibitor drugs like Avastin.

A section of doctors believe that by stating that cancer is a disease of the gene is being a 'reductionist.' It is whole lot more; a complex biological system gone awry. We must not just concentrate our funds only on understanding cancer but also on how best to control it. More money is being spent on treating than on early identifying methods which can make it clear what we are up against. An early detection by profiling the chromosomes in a person's spit is one good development. A more inter-disciplinary approach including the enabling technologies like computer modeling, protein analysis etc. must be put into use to diagnose and treat the whole body.

Cancer has now become one of the top causes for death in India. There is an urgent need for public awareness programmes which highlight the fact that with so many advances in medicine, cancer is curable if detected early. Also cancer can be prevented by being aware of the risk factors and by leading a healthy lifestyle. □

Phlogiston, Oxygen, and Birth of Modern Chemistry

K. Sampath *

THE WORD "chemistry" may have originated from Egyptian or Greek words meaning earth. It is the science concerned with the composition, structure, behavior, and properties of elements and compounds, as well as changes they undergo. All substances we see around us are made up of elements and compounds, and all changes are either physical (phase transformations) or chemical (reactions) or a combination of the two. In common parlance, "chemistry" also means affinity, as between two individuals.

A theory matures gradually, as the result of experimental observations. Care has to be taken in the interpretation of experimental results. Time must be ripe for the acceptance of a scientific discovery, else it may be put in abeyance or is forgotten. One theory may block the acceptance of another and ad hoc assumptions may be used to rescue a theory, which otherwise is under dispute. Some of these issues will emerge as the development of modern chemistry is discussed in the present article.

Some of the names which will be discussed are well known to us, while some others may not be famous. They are: Aristotle, Roger and Francis Bacon, Boerhaave, Macquer, de Morveau, G. E. Stahl, Henry Cavendish, Hooke, Cannizzaro, James Watt, J. J. Becher, Joseph Black, J. Ellicott, Joseph Friend, Joseph Priestley, Lavoisier, Samuel Williams, Pott, Robert Boyle, Stephen Hales, Carl Scheele, Van Helmont, Volta, Berzelius, and Clausius. We have deliberately kept out of discussion all developments post 1900.

The action of acids, dissolution or combination of substances and distilleries were familiar in the world since ancient times. The technology of smelting and refining of metals, production of glass-ware and pottery, development of natural colouring materials and dyes for artists and medicinal substances had all been achieved by 17th century. Chemical technology was ahead of modern chemistry in this regard.

Until late in the 18th century, chemistry was associated with the practice and teaching of medicine, besides alchemy. Alchemists and artisans during ancient times up to middle ages made a lot of progress in standardization of some reactions, metal extractions, designing of some alloys and crude compounds having desirable properties. But there was no unified theory that could explain the entire gamut of possibilities. One could not predict beforehand what would happen if A and B were mixed together under condition C. The development of chemical technology itself was thus insufficient to provide the basis for the establishment of modern chemistry.

Alchemists produced and collected vast amount of data. But there was a need for a proper intellectual frame work (paradigm) in place to explain the observed data and

*Dr. Sampath is a retired scientist of the DRDO. Email: skasturi41@gmail.com

suggest further inquiry. All the data could not be resolved or understood in simpler terms. Since ancient times, philosophers attempted to enumerate building blocks of nature. From Thales to Aristotle, four elements were identified as the primary constituents of matter: fire, air, water and earth. Ancient Indians and Greeks also brought in ether. These might have originated from the sea, earth, wind and sky around us. But these were insufficient in explaining simple experience. According to Van Helmont 'everything in the world could not be resolved into water'. Even fire was considered as hidden in many substances, which gets released in the form of flame during combustion.

Francis Bacon and seventeenth century scientists suggested that heat might be a form of motion in microscopic particles of matter. Artisans and metallurgists made advancement in their field and had accumulated vast knowledge on complicated chemical interactions, and they were aware of conditions for such chemical reactions but not the reasons. Theoretical knowledge was missing, that resulted in failure of understanding the constituents of air and water.

To achieve this understanding of air and water, idea of existence of gases and process of combustion and calcinations was necessary. Study of important phenomena such as combustion, calcinations and respiration were in progress. Also, considerable amount of study on air was done. These two branches had obvious relations with one another. The formation of hypotheses depended on instruments to collect gases, knowledge of distinguishing between gases, crucial role of weighing of gases and further realization of the experimental outcome.

Three categories of substances were known at that period of time namely: some metals, oxides (calx), a few combustible substances like charcoal, sulphur and phosphorus.

Except for gold and a few other noble metals, it is their oxides and not the metals themselves which occur freely in nature. Metals could be obtained by heating certain materials (metallic oxides) with charcoal. Metals, at first sight, look similar, as they have similar superficial properties. Other solids were called "earths" (which we call oxides nowadays). At high temperatures, a metal was found to turn back to "earth", but could be regained on heating the "earth" with charcoal. A pure "earth" of this sort was named as calx. The process of forming the "earth" by heating a metal was called "calcination".

These facts, inherited from the middle ages and before, were fitted together by the introduction of a common principle called phlogiston by J. J. Becher (1635-1682). When phlogiston was added to a calx, the latter turned into metal, which could be regained by removing the phlogiston from the calx. Phlogiston was in a way a metalizing principle. Since metals were so alike, "something" was obviously the same in all cases. It was natural to think that there must be some common principle involved in the process of making various metals from their calxes and vice versa. "We shall call this common principle as 'phlogiston' " said Becher and his pupil Stahl.

What was phlogiston itself? Nobody could see it. Charcoal was a phlogiston-rich material and on heating with a metallic calx gave up its phlogiston to the calx, making a metal. On burning charcoal, the phlogiston either appeared as fire or combined with the air. Sulphur was found free in nature; it burned when heated and yielded sulfuric acid. Clearly, sulphur was only sulfuric acid highly phologisticated. Burning set the phlogiston free and yielded acid.

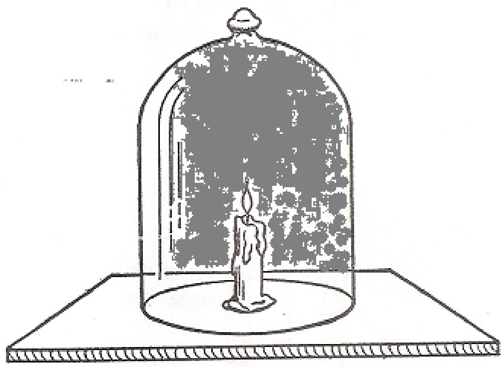


Figure 1: The experiment by Samuel Williams to demonstrate the existence of phlogiston.

The process said above is explained diagrammatically:
Calx + phlogiston (from charcoal) → metal
Metal heated in air → Calx + phlogiston to air
Charcoal burned → phlogiston (to air) accompanied by fire
Phologisticated vitriolic acid → phlogiston (to air) + vitriolic acid (sulfuric acid).

Phlogisticated vitriolic acid is known as sulphus to us. The concept of phlogiston brought all those philosophers each standing on with their separate theories, into one intellectual frame. The theory was almost accepted at the time of the American Revolution and was the basis of the chemistry then taught to college students as part of their instruction in natural philosophy.

The diagram in Fig.1 illustrates the way in which Samuel Williams taught the phlogiston theory in the class during 1780-88. When a bell jar is placed over a lighted candle, the candle will soon go out. According to phlogiston theory, the air has been saturated with phlogiston and hence can hold no more. *This line of reasoning apparently supported the phlogiston theory.*

When a bell jar is placed over a lighted candle, the candle will soon go out; according to modern theory the oxygen in the jar has been used up. *This line of reasoning supports the oxygen theory.* From these, one can see that pure reasoning alone may lead to either conclusion. One should never depend on a single experimental result alone.

One and half century before Lavoisier, a Frenchman Jean Rey studied the calcinations of tin and showed that the calx weighed more than the tin from which it was formed. Jean Rey said, "This increase in weight comes from the air, which in the vessel has been rendered denser, heavier, and in some measure adhesive ··· which air mixes with the calx ··· and becomes attached to its most minute particles ···." Boyle also confirmed the increase in weight of metals in 1673, but did not support Rey's hypothesis.

Boyle put forward the alternative hypothesis that fire, the Aristotelian principle, had passed through the walls of the glass used and combined with the metal, thereby giving it weight. According to Boyle something was *added* to the metal in calcinations, namely fire, while in phlogiston theory something viz. phlogiston was *removed*.

Increase in weight was the hitch in the formation of Phlogiston theory. To justify the theory (for the increase in weight) many explanations were suggested. The German chemist Pott opined that departure of phlogiston increased the density. J. Ellicott thought that presence of phlogiston weakened the repulsion between the particles and ether resulting in diminution of mutual gravitation. The French chemist Macquer suggested that phlogiston was the pure component of light and heat.

Therefore, if one analyzes in the light of the prevailing theory alone, wrong conclusions are often obtained. A faulty reasoning (relying on Aristotelian principle) led philosophers like Boyle to wrong conclusions. Boyle focussed on the heat and flame while Jean Rey thought about the role of air.

Jean Rey's idea had been lost for 150 years but facts of calcination remained. The fact that a calx weighed more than the metal was known throughout the 18th century, but this was not recognized as being fatal to phlogiston theory. A theory is never discarded merely because of a few facts with which it cannot be reconciled. It is either modified or replaced by a better one, never abandoned with nothing left to take its place.

The reason for increase in weight on calcination had been accommodated by the modification of theory as shown below.

Metal heated in air $\rightarrow$ pure earth + phlogiston to the air

Pure earth + water from air $\rightarrow$ calx.

In other words, absorption of water by the pure earth corresponded to gain in weight. The sum of the weights of the substances entering into chemical reaction is equal to the weights of the products – the principle of balancing weights. As soon as balance was introduced into chemistry, the phlogiston theory was discarded.

In 1660 Boyle showed that air was necessary for fire. John Mayow and Robert Hooke explained burning and respiration of animals in terms of air being deprived of its elastic force. Stephen Hales spoke the same language fifty years later. They had demonstrated that air in which the material had been burnt or animals had respired would no longer sustain fire or life. They also showed that there was an actual diminution of the volume of the air in such cases. In spite of all these facts the chemists of 18th century talked in terms of phlogiston. Within a limit it was a fruitful concept. It appears that sometimes scientific discovery may be sidelined or disregarded.

The chemists of 18th century could recognize and manipulate metals and calxes, inflammable substance like phosphorus, sulfur and charcoal as being solids. Even some liquids like sulphuric (vitriolic) acid and mercury were known individually.

But it was difficult to distinguish different gases as they all look alike, except few which are coloured. Only physical verifications could be done and no chemical test of gases was known at that time. Thus nitrogen could not be distinguished from carbon dioxide, or hydrogen from carbon monoxide. Gases are compressible and are subject to thermal expansion almost equally. It was not possible to measure densities of solids or liquids accurately, let alone of gases. From Boyle to Priestley, the experimenters were largely in the same predicament. They spoke of different "airs" or fumes" but hardly knew whether differences were real or due to the presence of some impurity. For example, Joseph Black and Henry Cavendish both produced carbon dioxide, but they thought it was tainted air.

History of gases covers a hundred years from Boyle to Priestley. Priestley carried out extensive experiments with "airs" and improved techniques of handling these airs and simplified experimental procedures. Before Priestley's work, only three "different airs" were known. Subsequently he had discovered eleven more including oxygen.

However, chemical properties of each gas are unique and the preparation of each gas is also different. Understanding these differences finally led to a solution of the above problem.

Joseph Priestley improved the apparatus to collect gases. In 1774, he isolated oxygen but thought it to be "phologisticated nitrous air" (now nitrous oxide). In March 1775, after further tests he realised that it was more effective than ordinary air and named it as "dephlogisticated air." Swedish chemist Scheele had already recognised the existence of two separate gases in the air

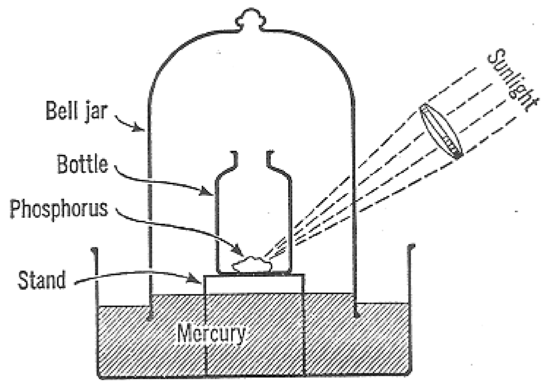


Figure 2: Lavoisier's experiment on the increase in weight of phosphorus on calcinations. A weighed piece of phosphorus is placed in bottle and the bottle is covered with a bell jar. The mercury seals off the air within the bell jar from the rest of the atmosphere. When the phosphorus is ignited by the sun light focused through a burning glass, a white calx is formed within the bottle and mercury level rises in the bell jar. The bottle containing the calx is removed and weighed. Calx is thus found to weigh more than the phosphorus.

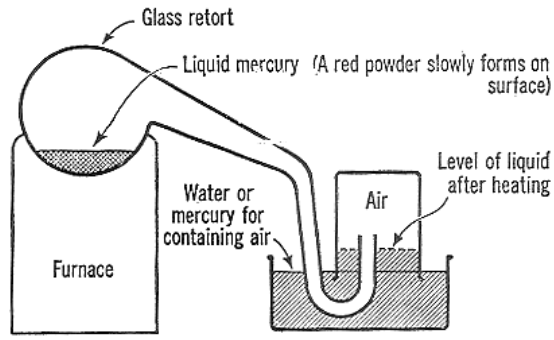


Figure 3: Diagram of Lavoisier's apparatus to show that mercury heated in air absorbs oxygen.

but published this finding later.

It was known that action of acids on metals produces hydrogen. It is natural to think that metals were compounds that released its hydrogen. Many acids were known but their components were not known. An utter chaotic atmosphere prevailed as for as the fundamentals of chemistry were concerned.

At this juncture Lavoisier appeared in the scene. He surveyed all available study of gases by his contemporaries and priors. He grasped the ideas of his predecessors which were scattered around, and performed experiments to understand them properly. He made a complete study of the air that is released from substances and also that combines with them.

Lavoisier started experimenting with the burning of phosphorus and sulfur. In 1772, in a famous note he wrote as follows: "About eight days ago I discovered that the sulfur in burning, far from losing weight, on the contrary gains it; $\cdots$ it is the same with phosphorus; this increase of weight arises from a prodigious quantity of the air that is fixed during the combustion and combines with the vapours. This discovery, which I have established by experiments that I regard as decisive, has led me to think that what is observed in the combustion of sulfur and phosphorus may well take place in the case of all substances that gain weight by combustion and calcination; and I am persuaded that the increase in weight of metallic calces is due to the same cause." Lavoisier outlined the new chemistry — a new concept, from experimental observations.

First Lavoisier mistook the gas (carbon dioxide — the "fixed air" of those days) which evolved in the reduction of calx with charcoal, for the gas (oxygen) absorbed in calcination. Priestley's discovery of oxygen and Lavoisier's repetition of some of Priestley's experiments with this new gas led to the development. At the outset, Lavoisier recognized that something was absorbed from the air during calcination.

No doubt there were experimental difficulties, faced by all scientists of those days, which conditioned the evolution of new concepts. To determine whether air is absorbed or not during calcination of a metal is not easy. The process takes a long time, high temperature is needed and both increase in weight and the amount of oxygen absorbed may be small. But with phosphorus and sulphur, the experiment was relatively easy to perform. Further the effect observed is larger for these two.

In terms of modern chemistry, sulfur and phosphorus have low atomic weighs (32 and 31) vis-a-vis oxygen (16). During burning, 2 atoms of phosphorus combine with 5 of oxygen (P_2O_5), 1 atom of sulfur with 3 of oxygen (SO_2). The atomic weight of metal is high, the number of atoms of oxygen combining with them fewer.

62 weights of phosphorus yields $(31 \times 2) + 80(5 \times 16) = 142$ parts of product (P_2O_5). The increase is $> 50\%$ For tin, the change is $118 + (2 \times 16) = 150$, the product being SnO_2. The increase is 25%.

The corresponding differences would be reflected in the volume of oxygen absorbed. Secondly, calcination of tin was a long process at high temperature in a furnace. Thus no entirely satisfactory way of measuring the volume of air absorbed was at hand in 1770.

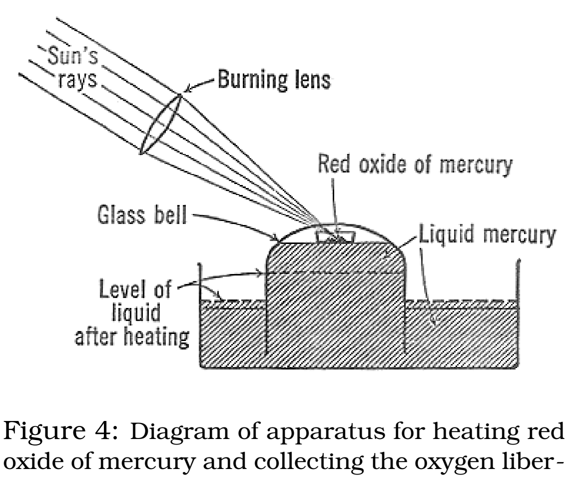


Figure 4: Diagram of apparatus for heating red oxide of mercury and collecting the oxygen liberated.

Important advances in science can be based on quantitative measurement only if the measured quantity is large as compared with possible systematic and accidental errors.

Everyone knew that calx weighed more than the metal from which it was formed and phlogiston theory could not accommodate this fact. People attempted reconciling this fact with phlogiston theory, which to many was an admirable one. A short-lived attempt involved assigning a negative weight to phlogiston. Before the 19th century, heat was considered a material substance, caloric. The entire subjects of thermodynamics and atomic and molecular theory of matter lay far in distant horizon.

Let us review the steps involved in the development of Lavoisier's new idea:

1. Something was getting absorbed from the atmosphere in calcination of metals and in combustion. What is the nature of this unknown substance?

2. The use of calx (mercury oxide) might provide the means for finding this unknown substance. There was only one metal known in Lavoisier's time which, when calcined in air, yielded a product that at a still higher temperature reverted to the metal. This was mercury, the only liquid metal.

3. Preparation of oxygen from mercury oxide and the failure to recognize clearly that it was not just purified air.

4. Priestley's publication that the gas from the mercury oxide was not common air but something new, eminently respirable air which causes candles to burn more brightly.

5. The composition of water was established by the experiments of Cavendish.

6. Lavoisier's quick recognition that combustion and calcination involve the absorption of a constituent of the atmosphere, the new gas oxygen.

Priestley was partly responsible for Lavoisier's perception that the road to success lay in the study of mercury oxide. The gas evolved from heating mercury oxide causes a candle to burn even more brightly than in ordinary air. Priestly thought it was nitrous gas (N_2O). Lavoisier himself prepared a gas by heating red oxide of mercury. He examined the gas and showed that it was not carbon dioxide but oxygen.

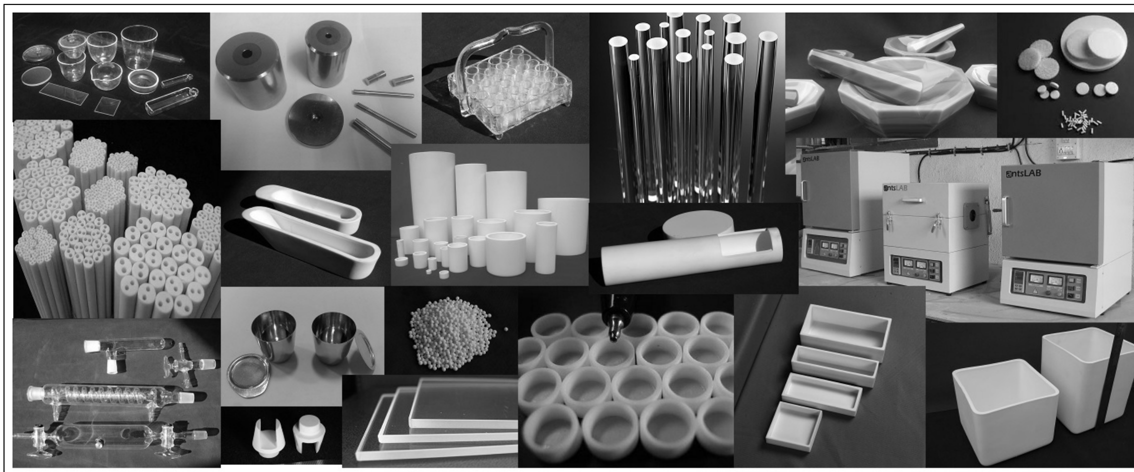
In 1776 Volta was firing gases with electric spark and the information came to Priestley. Priestley exploded hydrogen and oxygen with an electric spark and found the production of dew inside the glass vessel — which was nothing but water. Cavendish also confirmed the production of dew and showed that it was pure water.

With the discovery of the composition of water the chemical revolution was complete. Lavoisier worked with another Frenchman de Morveau and revised chemical nomenclature — a new language of chemistry, which is still the basis of the language used today. □

References

1. J.B. Conant, Science and common sense, Yale University Press, 1952.

2. Herbert Butterfield, The Origin of Modern Science 1300 - 1800, The Fee Press, 1965.



Probiotics — The Bugs Beneficial to Human Health

S. Padmavathy and N.K. Asha Devi *

Introduction

One of the secrets to optimal health is cultivating a great relationship with bacteria. While many people will be reaching for their favorite antibacterial soap with the belief that bacteria are only likely to cause diseases. The fact is on the contrary. Without certain species of bacteria, we literally cannot live. Moreover, our digestive tract is home to a thriving population of life — promoting gut bacteria that reside within us from the moment of birth. These microflora are so critical to our survival, that without their presence, every aspect of our health would suffer.

Our digestive tract, all 30 feet of it, is one of the most complex and immensely important organs of the body. The healthy functioning of our digestive system is profoundly dependent on the one hundred trillion micro-organisms that dwell there, outnumbering the ten trillion cells that make up our body by ten to one! While it is commonly believed that intestinal functions are related only to the absorption and assimilation of food, a healthy digestive tract is intimately connected to our overall well-being. Medical science has only recently discovered that it plays a fundamental role in our immunity, emotional health and, even, hormonal balance.

*The authors are with the Department of Zoology & Microbiology, Thiagarajar College, Madurai – 625 009, Tamil Nadu, India. Email: padma.phd2009@gmail.com

Why Do We Need Bacteria?

There is a false perception that all bacteria are harmful. There are more bacterial cells in the body than human ones. In order to have a healthy functioning digestive tract we must have a healthy and robust gut flora population. More than 99 percent of microbes living in our intestinal tract are a very diverse group of bacteria, numbering between 500 to 1,000 different species collectively; they add about three pounds to our weight. The rest are yeast or parasites. To keep things in order, a healthy gut population needs to be composed of about 85 percent beneficial micro-flora.

The vast majority of our gut bacteria reside in our small and large intestines. The bacterial population of the large intestine, which is more hospitable to microbes, outnumbers that of the small intestines by about 100,000 to 1. We might liken our gut flora to a large, thriving and diverse community of microbe species, living harmoniously in their particular neighborhood. Each colony contributes their unique functions to the benefit of the whole.

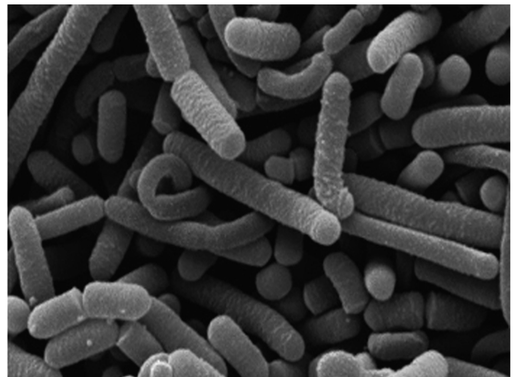
Microbes are a natural part of the human nutrition system. Our micro-flora are little factories that convert plant and animal products into usable nutrition. Humans require many nutrients that can only be manufactured by these industrious microorganisms. For instance, trillions of cells of bacteria manufacture the vital nutrients like B vitamins (thiamine, riboflavin, niacin, biotin, pantothenic acid, pyridoxone, cobalamine), folic acid, and vitamin K. Friendly bacteria are also hard at work allowing for the efficient absorption of essential minerals including calcium, copper, iron and magnesium.

Significance of Beneficial Microbes

Friendly microbes help to prevent diseases in several ways. They deprive invaders of nutrients and secrete acids that friendly microbes can tolerate. They also reinforce the mucosal barrier of the intestines, which block dangerous pathogens, toxins and allergens. Some bacteria stimulate the immune system by increasing T-cell counts, while others produce natural antibiotic and antifungal substances.

Beneficial bacteria play another major role: they are responsible for insuring a strong immune system. An impressive 70 percent of our immune cells line the intestinal wall. Probiotics are the beneficial bacteria that compete with harmful ones. However, this equilibrium between beneficial and harmful is a delicate balance. Many of our habits are wreaking havoc on our friendly bacteria. Junk food diet, pharmaceutical drugs such as antibiotics, steroids, birth control pills, environmental chemicals, and psychological or mental stress all impact our gut flora. Specific beneficial strains can be killed or crowded out, allowing their neighborhoods to be overtaken by harmful bacteria or yeast, such as *Candida albicans*.

It is now coming to light that the trillions of probiotics, which populate our inner ecology, are our best friends — providing beneficial, nutritional and therapeutic functions necessary for overall human health and vitality.



Lactobacillus acidophilus

What are Probiotics?

The term *probiotic* was derived from the Greek meaning "for life" and was first introduced by Ferdinant virgin in 1954 [1]. WHO (World Health Organization) defined probiotics as "live microorganisms when administered in adequate amount confer health benefits on the host. It is a live microbial food ingredient that is beneficial to health."

Probiotics are live microorganisms, native of human gut, which can colonize in the alimentary tract and can produce beneficial effects for the host. Nowadays probiotics are emerging as alternatives for antibiotics in the treatment of many gastrointestinal diseases as these probiotics are devoid of side effects. They offer an alternative and additional therapy for the usual intestinal problems such as diarrhoea, irritable bowel syndrome etc. and act as nutritional support. Acting through different mechanisms, probiotics help to restore the normal flora in the gut, resulting in beneficial effects for the host, including amelioration or prevention of a specific disease rate.

Sources of Probiotics

Probiotics can be incorporated into various kinds of foods (especially dairy products – milk, curd, yoghurt, and cheese). The ability of probiotics to withstand the normal acidic conditions of gastric juices and the bactericidal activity of the bile salts, as well as the production of lactic acid that inhibits the growth of other microorganisms, allow them to be established in the intestinal tract. Probiotic containing products are available for human nutrition, aquaculture and as animal supplements [2].

Fermented dairy products have been repeatedly shown to enhance tolerance to lactose compared with unfermented products or lactose alone [3]. In humans, Bifidobacterium sp. alone or with other bacteria, when introduced in food products, have been able to decrease colonic inflammation [4], to prevent colonization by opportunistic pathogenic ones in antibiotic treated radiotherapy patients [5] and prevent antibiotic associated diarrhoea [6].

In recent decades, the development and consumption of functional probiotic foods has been increasing alongside awareness of their beneficial effects in promoting gut health as well as in disease prevention and therapy, and this has raised interest in health-promoting foods [7].

Probiotics containing foods for Human Health

Scientists have argued that patients should consume probiotics as part of their daily diet [8]. They point out that the modern diet is designed to inhibit beneficial organisms. Increased exposure to anti-microbials and preservatives through our food depletes the commensal flora, resulting in impaired or suboptimal immunity that reduces the ability to fight infection. The recognition of the important role that certain bacteria (lactobacilli, bifidobacteria, and others) play in health has resulted in a global interest probiotic foods. A healthy amount of these good bacteria in the gastrointestinal tract can help to maintain a balanced digestive system, which enables the body to break down food more efficiently and get as much nutrients as possible from this food.

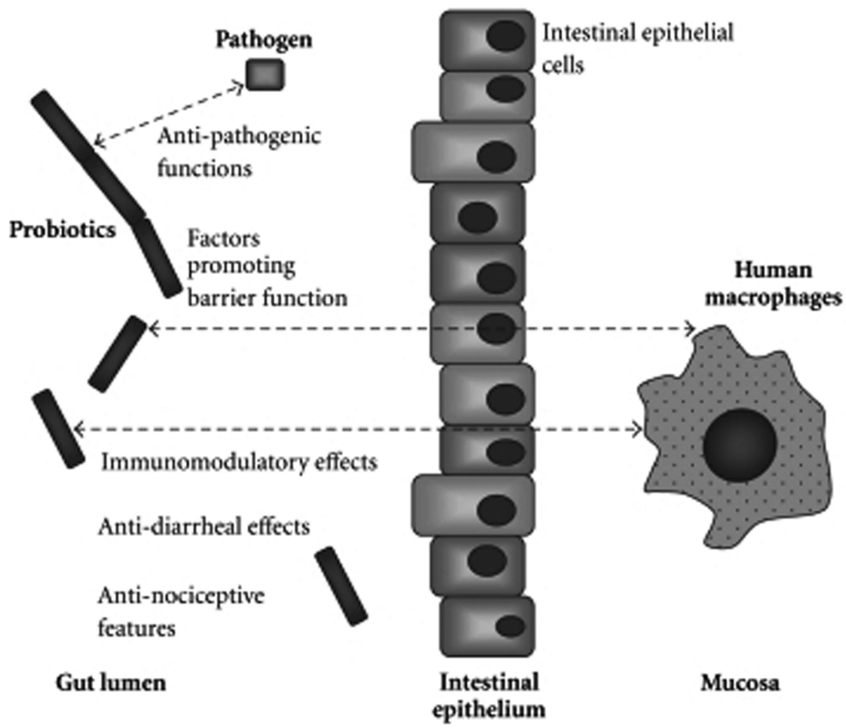
The health benefits of probiotics for digestive health have long been known. But in recent times the emphasis has been towards the positive benefits of probiotics for women's health. Several studies conducted in various research laboratories round the world have shown that the existence of probiotic bacteria can do so much for women's health, both in terms of preventive as well as therapeutic purposes.

Some of the health benefits of probiotics to women are:

- Well-balanced urogenital flora
- Less painful menstrual cycle
- Lower susceptibility to urinary tract infections
- Prevention of many serious health conditions.

Probiotics can help one to avoid health problems such as chronic fatigue syndrome, fibromyalgia, and many ailments stemming from a poor immune system. But the question that is being posed by many health experts today is whether taking probiotic supplements is enough to make a substantial difference. One of the issues that has been raised is the high probability of the good bacteria dying before reaching the intestine. They may either be digested completely by the pepsin in the stomach or they simply may not have enough food to live on as they make their way into the digestive tract. In any case, if the good bacteria die out, they will obviously be useless.

One solution to this is to take a good prebiotic supplement that will provide sustenance for these good bacteria and will keep them working in your favor. You can maximize the benefits by taking a supplement



The mechanism of probiotics. Courtesy: Britton and Versolavich (2008), Journal of Probiotics and Gastrointestinal Infections.

that can provide you the benefits of both probiotics and prebiotics in a single capsule, like those that are made from kiwi, for instance. Kiwi is one of the best natural sources of phenolic compounds, soluble fibers and digestive enzymes, which are all essential for the maintenance of a healthy and balanced digestive system. These same components are also crucial to the prevention of UTI (urinary tract infection) and vaginal infections, as well as many other health problems common among women. In other words, a good kiwi-based supplement is indeed a preferable alternative to regular probiotics for women.

The actual mechanisms of action of probiotics in the vagina have not been proven and are probably multifactorial. The production of lactic acid, bacteriocins, and hydrogen peroxide seems to be important. Another factor may be the production of biosurfactants and collagen-binding proteins that inhibit pathogen adhesion and to some extent can displace pathogens. A third factor may be the production of molecules that take part in cell-to-cell signalling. Clearly, more research is needed.

Overall benefits of probiotics:

- Probiotics boost immune response by inhibiting growth of pathogenic organisms
- Probiotics detoxify the intestinal tract by protecting intestinal mucosa levels
- Probiotics develop a barrier to food-borne allergies
- Probiotics neutralize antibiotic-resistant strains of bacteria

- Probiotics reduce the risk of inflammatory bowel disease (IBS) and diverticulosis
- Probiotics balance and regulate the immune system
- Probiotics help to reduce estrogen dominance
- Probiotics synthesize needed vitamins for healing
- Probiotics prevent diarrhoea by improving digestion of proteins and fats
- Probiotics restore vaginal health
- Probiotics reduce the risk of osteoporosis
- Probiotics support balanced mental and emotional health

Conclusion

The beneficial bacteria in the gut, intestine, and other parts of the human body maintain a delicate micro-ecosystem that is crucial for our well-being. We need to be aware of the problems that can result from the disruption of this micro-ecosystem due to various factors including unhealthy food habits and intake of antibiotic drugs. Probiotic bacteria may add a low-cost low-risk layer of protection from infection and disease. Probiotics have been advocated for the prevention and treatment of a wide range of diseases, and there is strong evidence for their efficacy in some clinical scenarios.

The future success of the science of probiotics depends on extensive cooperation between food technologists, medical and nutrition scientists, and an understanding of current and future food and health needs from consumer information experts. Probiotics present a great opportunity for improving the health of the citizens by creating new food and medicinal products through multidisciplinary teamwork. With further research, this medical therapy may prove to be one of our most effective tools against new and emerging pathogens that continue to defy modern medicine in the 21st century.

References

1. Thangam, M., Girish Kumar, C.P. and Anitha Devi, C.P. (2005). Bacteria for Breakfast: Probiotics for Good health. Adv. Biotech., pp. 15–20.
2. Gaur, Y., Narayan, K., Chauhan, S. and Ali, A. (2004). Bacteriocinogeny: concept, nomenclature, prevalence and application. Ind. J. Microbiol., 44 (1): 1–30.
3. Shah, N. (1993). Effectiveness of dairy products in alleviation of lactose intolerance. Food. Australia., 45: 268–271.
4. De Simone, C., Ciardi, A. and Grassi, A. (1992). Effect of Bifidobacterium bifidum and Lactobacillus acidophilus on gut mucosa and peripheral blood B lymphocytes. Immunopharmacol. Immunotoxicol., 14: 331–340.
5. Korschunov, V.M., Smeyanov, V.V., Efimov, B.A., Tarabroma, N.P., Ivanov, A.A. and Baranov, A.E. (1996). Therapeutic use of an antibiotic-resistant Bifidobacterium preparation in men exposed to high-dose gamma irradiation. J. Med. Microbiol., 44: 70–74.
6. Colombel, J.F., Cortot, A., Neut, C. and Romond, C. (1987). Yoghurt with Bifidobacterium longum reduces erythromycin-induced GI effects. Lancet., 2: 43.
7. Salminen, S., Ouwehand, A.C., Benno, Y. and Lee, Y.K. (1999). Probiotics: how should they be defined? Trends Food. Sci. Technol., 10: 107–110.
8. Bengmark, S. (2002). Gut microbial ecology in critical illness: is there a role for prebiotics, probiotics, and synbiotics? Curr Opin Crit Care., 8:145–151.

Organizational news

Hudhud Cyclone Relief Work

A very severe cyclonic storm Hudhud hit Vishakapatnam in Andhra Pradesh on 12th October 2014. The peak wind speeds reached 180 km/h. Hudhud caused extensive damage to the city of Visakhapatnam and the neighbouring districts of Vizianagaram and Srikakulam of Andhra Pradesh. The cyclone wrecked homes, uprooted trees and power lines, blocked roads and caused extensive damage of crops. Lakhs of people had to take shelter in relief camps.

The State Chapter of Breakthrough Science Society collected cyclone relief fund from teachers, students and general public. In a public programme on November 17, note books, exam pads, pens, pencils and other education kits were distributed to students affected by the cyclone. Shri S. Govindarajulu, Advisor, BSS State chapter spoke on this occasion and explained about cyclone and its impact. Others present were Mr. R. Gangadhar, Convenor, BSS, Mr. L. Neelakanta and Mr. Sai Venkatesh. Mr Gangadhar also spoke about the aims and objectives of BSS.

Seminar on Superstitious practices and Black Magic in Ernakulam, Kerala

Breakthrough Science Society in association with Democratic Lawyers Forum organised a seminar on the topic “Should Superstitious practices and Black Magic be legally proscribed?” at the Bar Council hall, High Court of Kerala on Dec 11, 2014.

Speakers of the seminar in Ernakulum, Kerala

Justice Dama Seshadri Naidu in his inaugural address stressed the need for conducting activities to promote scientific approach among the people in addition to the legal measures. Speaking on the occasion, Justice Sukumaran said that even while our Constitution stipulates that we should follow scientific approach, many people occupying important positions in the society including constitutional positions are forgetting this fact. Dr. Babu Joseph, former Vice Chancellor, Cochin University said that astrology is not something that originated in India and it is also not a science; and it is not necessary to hang on to it in the name of patriotism.

Advocate B K Rajagopal, Prof Susan John, Shri G S Padmakumar, Shri Francis Kalathungal and several others participated in the deliberations. The seminar was organised as a part of the nationwide campaign against superstitious practices and black magic.

A poster campaign was conducted

throughout the state to enact the bill to ban black magic and propagation of superstitions.

Other programmes

Kerala

Ernakulam: Talk on 2014 Physics Nobel prize winning discovery Blue LED by Dr. Louis Godfrey, Ex. PVC, CUSAT Kochi, on Nov.8, 2014.

Kottayam: Talk on 2014 Physics Nobel prize winning discovery Blue LED by Dr. Rajagopal, HoD, Dept. of Physics, CMS College Kottayam on Nov.8, 2014.
Talk on Offshore Oil Exploration by Sanath Nair, Radio Officer, Offshore oil rigs (Marine) on Dec 13.
Class on science and society, organised by Madam Curie Science Club, Vadakara, Kottayam, on Dec 21
Sky Watch programme at Bharananganam, Kottayam, on Dec 27

Pathanamthitta: One day workshop for science activists on Dec. 20, 2014.

Thiruvananthapuram: Seminars on 'Evolutions in Nanotechnology -V Challenges Ahead' on 17th January 2015, and on Crystallography on 20 December 2014, at the Kerala State Science and Technology Museum, Thiruvananthapuram.

Karnataka

Bangalore distroct: Rajajinagar People's Science Fest, Two days Science Fest at local level, Bangalore, December 20 2014

Tumukur distroct: Science Day, Science Model Demonstration, Chart Exhibition and Movie show at Ankasandra Village, Tumukur District, December 1 2014

Davanagere district: Vigyana Habba, Science Fest at N.M.K High School, Davanagere District, January 10 2015

Chitradurga district: Movie Show, 'Marie Curie' show at Govt. Junior College Hosadurga, Chitradurga District, November 14. Miracle Busting, 'Micracle Busting' show at Govt. High School, Madhure, Hosadurga Taluk, Chitradurga District, December 27.

Andhra Pradesh

A science convention was organised in Kurnool, Andhra Pradesh state on 'Ancient Indian Science — A critical study' on 22 January at Brindavan Institute of Technology and Science. Mr. G. Satish Kumar, Convenor, BSS Karnataka State Chapter, and Mr. R. Gangadhar, Convenor, AP&TS State Chapter attended as main speakers. 300 students participated. A committee also was formed with Mr. V. Viswanath Reddy as convenor and Mr. P. Venkateswarlu as co-convenor.

West Bengal

An arsenic detection camp was organized on 25th December at Duttapukur, North 24 Parganas district. 75 water samples from local area were tested. The camp was conducted by: Dr. Tapan Shi, Abhisek Sahu, Apurba Bera, Sujay Pramanik and Asish Samanta.

Anti-superstition shows, discussions on various superstitions, and sky-watching programmes were organized by most science clubs associated with *Breakthrough Science Society* . At present most science clubs are engaged in signature collection demanding enactment of an anti-superstition bill.