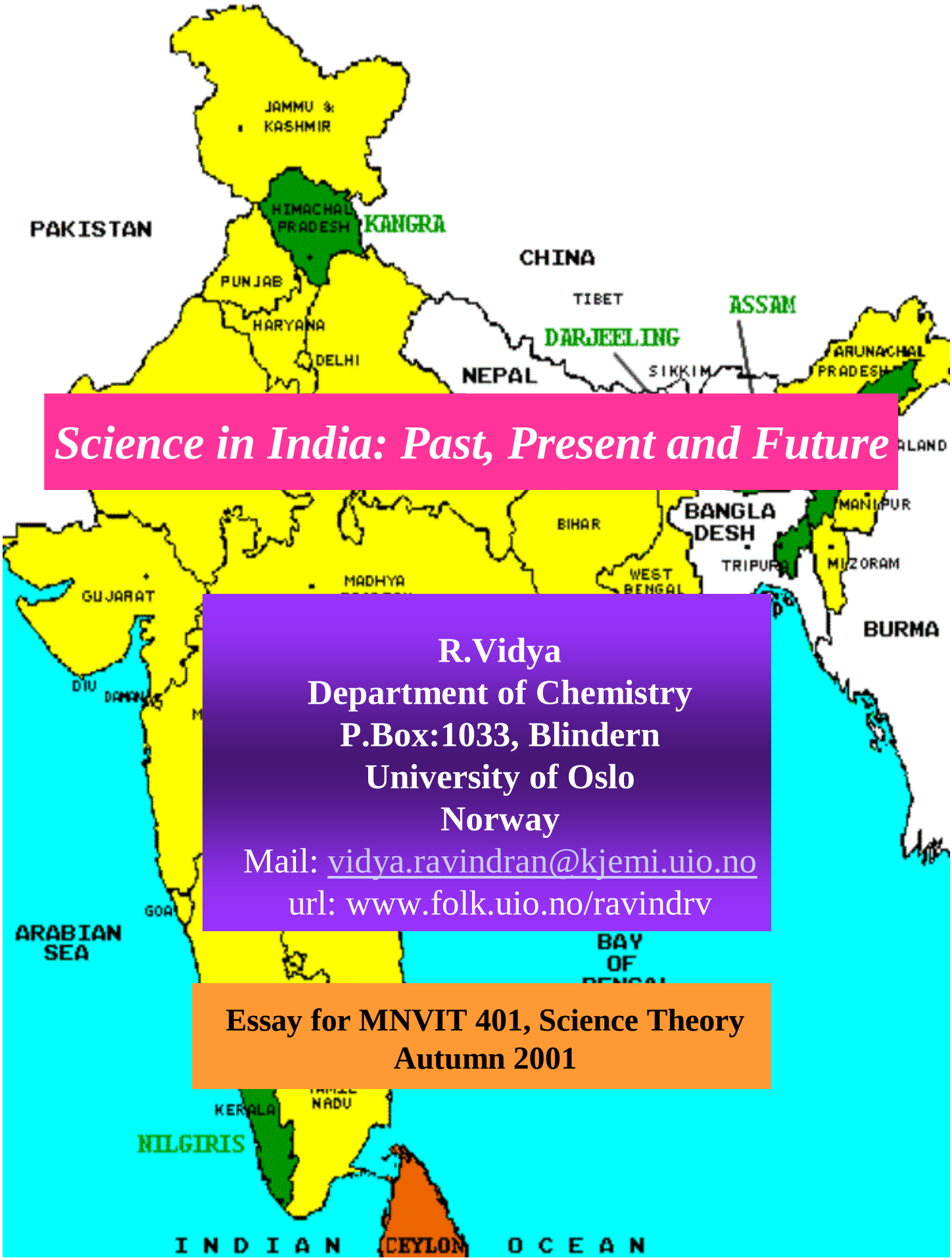

Science in India: Past, Present and Future

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If we were to look over the whole world to find out the country most richly endowed with all the wealth, power and beauty that nature can bestow - in some parts a very paradise on earth - I should point to INDIA.

-Max Müller, Orientalist,
in his lecture delivered at University of Cambridge, England, 1882.

Abstract

In this essay I try to analyze the status of science in India in the past, present and future. As the history of Indian civilization starts more than 5000 years ago, it is an insurmountable task to list the development of Indian science in a chronological order. Therefore, I discuss the salient scientific achievements in various times and its implications on the society and vice versa. In spite of having developed fore-front research in Mathematics, Astronomy, Chemistry, Medicine etc., even before 2000B.C, Indian Science has undergone a dull-phase in the past 1000 years. The possible reasons for this recession such as political, cultural and religious impacts are outlined. Though India was lagging behind many of the industrialized nations in the 1950s, it emerged a power to reckon with in the late 20th century. The influence of science on the status of life and people's view of the scientists is also analyzed. Finally I would like to list some of the challenges faced by the Indian science in the future.

INTRODUCTION

Science as a method of acquiring knowledge, its systemization, interpretation and drawing conclusions helps man to widen the horizons of understanding. This knowledge helps him to develop his social, economic and cultural life. Every civilization that has developed economically and socially has attributed its success to Science and technology. India is proud to have one of the oldest civilizations in the world, with one sixth of world population and one third of scientific and technological manpower. In spite of being culturally and socially- rich, India is not very "rich" in the true sense of the word. For economy to progress, and life-style to improve, scientific development in India is imminent. So to shape the future with scientific ideas, clear understanding of the present is essential. Behind the present lay the long and tangled past out of which the present has grown. Tracing back the chain of scientific achievements in the past would give hints

for futuristic developments. I was just wondering how much past should I have to look back, for ancient India's scientific achievements date back from time immemorial. In this essay I have attempted to sketch the scientific developments in India in various points of time.

Indian pre-history began with the vast Harappan or the Greater Indus Valley civilization which represented a cultural continuum extending from $\sim$ 7000 to 1400 B.C. The excavations done at Harappa and Mohenja-daro (now in Pakistan), in 1930's by John Marshall of England, put the age of India's oldest civilization as more than 3000 B.C. It is interesting to note that at this dawn of India's history, she does not appear as a puling infant, but already grown up in many ways. She is not oblivious of life's ways but has made considerable technical progress in the arts and amenities of life. The Indus valley people not only created things of beauty but also the utilitarian and more typical emblems of modern civilizations. The high point of this civilization was the mature urban Harappan phase ($\sim$ 2500-2000 B.C) characterized by well-planned cities, extensive external trade, manufacture of artistic seals, development of Harappan script.[1, 2] etc.,

Later came the *Vedic* period. There is reportedly clear evidence of the positions of some stars at the time of the earliest *Vedas* which, calculating for the precession of the equinoxes, dates as early as 8,000 B.C.[3] The period of Indus valley civilizations is a matter of controversy and whether *Vedic* period precedes or follows it adds new dimension to the issue. Therefore I am not going to dwell on the period of the two cultures, instead [2] is referred to know more about *Vedic* and *puranic* science. The cultural, religious, social, literary, and political life of the people of *Vedic* period is well documented in four *Vedas* which are *Rg*, *Yajur*, *Sama* and *Atharvana*. The *rishis* or saints have tried to answer many of the mysteries of the world through their intuition and experience. *Rg* veda is the oldest book whose main contents are composed in 4500 B.C. The oldest Greek classics Iliad and Odyssey of Homer were written about four to five hundred years later.[4] *Rg* veda was a compilation of 1028 hymns composed by a large number of authors over many generations.

India's whole culture had been fashioned by geography. Lofty mountains in the north and the oceans on the other three sides made India into nature's protectorate. At the same time north-western mountain passes permitted inflow of people and ideas. It has maintained an unbroken cultural tradition and reinforces it by periodic intellectual inputs from other cultural areas. The unique combination of antiquity, continuity and unselfconscious interaction with the outside world was/is India's hallmark.

India could not have continued a cultured existence for thousands of years, if she has not possessed something very vital, enduring and something that was worthwhile. The search for the sources of India's strength and for her deteriotion is long and intricate. She fell behind in the march of technique, and Europe which had been backward in many matters took the lead in technical progress. Behind the technical progress was the spirit of science and a bubbling life. New techniques gave military strength to the countries of Europe and it was easy for them to spread out and dominate the East. Why this should have happened so is more difficult to unravel, for India was not lacking in mental alertness and technical skill in earlier times.

In order to elucidate ancient India's supremacy in Science, I give some of the samples in the following.

FIELDS OF EXCELLENCE IN ANCIENT INDIA

Mathematics:

One of the most-developed fields of science in ancient India was Mathematics. It is said that the number system which we call *Arabic* has originally been developed in India and introduced in the Persian Gulf by Arab travelers. The important number *zero* is also first introduced by ancient Indian mathematicians.The earliest undoubted occurrence of *zero* appeared in India in a manuscript of AD 876.[4] The most prominent and famous mathematicians were Aryabhatta (AD 476), Bhaskara-I (AD600) Sridharacharya (AD 990), Sripathi (AD 1039-56), Bhaskara -II (AD 1150)., Varahimira, Brahmagupta and many others. Sripathi wrote a treatise on mathematics (*Ganitatika*) wherein he dealt with permutations, combinations, proportions, notional places etc., Bhaskara-II has written two books on astronomy (*Siddhantha Sironmani and Goladhaya*) and one in Mathematics (*Lilavathi*). In the former books he explains the revolution of planets and in later, the theory of numbers and differential and integral calculus. Bhaskara-II describes the properties of *zero* in his commentary on Aryabhatta's work. The common feature of the ancient Indian scientists is that they were astronomers-astrologers and mathematicians.

Astronomy:

The whole history of astronomy has been the result of interplay of two factors, utilitarian and cultural. Whenever cultural areas felt self-assured, they advanced astronomy. Having secured their place on earth, these cultures sought to be the ones to unravel the mysteries of the heavens. Therefore there is no wonder that the ancient Indians excelled in Astronomy. *Siddhantas* (meaning 'Proven in the end') were the names given to the astronomical works. Aryabhatta was the earliest of the astronomers, who wrote *Aryabhatiya*. A notable feature of Aryabhatta's work was his reference to the Earth's spin about its own axis. Earth rotated by one minute of arc in 4 seconds of time. He also pointed out that for an eclipse to occur, the moon should be at one of its nodes, ie., at one of two points where the lunar orbit intercepts the ecliptic. Later, Bhaskara-I and Bhaskara-II and scores of other astronomers emerged. The *Surya Siddhantha*, a textbook on astronomy of ancient India -last compiled in 1000 BC computed the earth's diameter to be 7,840 miles and the distance between earth and moon as 253,000 miles. These compare to modern measurements respectively as 7,927.7 miles and 252,710 miles.[5] In Indian scriptures such as the ancient *Srimad Bhagavatam*, estimated the age of earth as 4,320 million years. Argon-dating undertaken some decades ago put the age of the earth at 5,000 million years.[5] It is important to note that, throughout the *Siddhantic* period instruments and observations played second fiddle to computations.[6] The modern astronomy was developed in India by French Jesuits rather than British colonizers.

Medicine:

The two major systems of medicine prevalent in ancient India before the advent of Unani were *Ayurveda and Siddha*. The *Atharvana Veda* which is the last of the four *Vedas*, contains mainly details about *Ayurveda*. While *Ayurveda* was popular in northern India, *Siddha* took its place in Southern India. The *Ayurveda* texts list about 700 plants, 1900 formulations , animal products from 165 species and a large number of mineral preparations. Using *Ayurvedic* concepts, the ancient phycisians were able to perform even

plastic surgery. The first detailed description of surgical replacement of nose is found in (*Sushrutha Samhitha*, medicinal treatise written by Sushrutha. The two early methods practiced in India namely the cheek-flap method and median forehead flap method are still used by modern surgeons. Tools for performing surgeries, various types of bandages and ointments were used as were basic procedures for ensuring cleanliness and limiting contamination. The *Siddhar's* knowledge of Iatro-chemistry, minerals, metals and plants was stupendous. This was successfully used by them from time immemorial. Processes like calcination of mercury minerals, and metals and the preparation of a super salt known as *muppa*- animated mercury pills with high potency possessing marvelous properties of transmuting metals and capable of rejuvenating the entire human system bear ample testimony to the unparalleled knowledge of the *Siddhar's*.[7]. Besides the treatment by medicine, there exist a lot of *Siddha* works in Tamil on *Kaya kalpa* (alchemy). It has to be mentioned that India is a vast country with many different cultures and many different languages. *Tamil* is one such language which is said to be formulated even before Sanskrit (about 3000 BC). The grammar book of *Tamil* is *Tholkappiam* which has been universally accepted as the oldest grammatical book in the world. One of the literary master-piece *Thirukkural* is the second-most translated book in many languages, after the Holy Bible. In *Tamil* we can find many literary works with scientific insights. However for the sake of brevity, I am not able to eloborate on it further.

Chemistry:

Coloured and wheel-made pottery were found at Harappa. During Harappan period, copper, lead, silver, gold and alloys like bronze and electrum (having 20% gold and 80% silver) had been known. But iron was not known in that period. They were quite good in metallurgy that they knew the know-how of hardening of copper, metal-forging techniques like field working, annealing, running-on, revetting etc., The literary landmark of post-vedic, Buddhist period (500 BC to AD 500), *Kautilya Arthasastra* (written by Kautilya, the prime Minister of the Maurya emperor ChandraGupta) defines the duties of a mining inspector, that he must know the different types of copper ores, the ways to distinguish them, location of the ores etc., Similarly he assigns the duties of gold and salt inspector also. These facts obviously show that the ancient people were well-versed in metal-working, iron and steel making, glass, pottery, jewellery-making, dyeing of clothes and tanning of leather etc.,

Progress in medicine also led to developments in chemistry and chemical technologies. The manufacture of alkaline substances, medicinal powders, ointments and liquids was systematized, as were chemical processes relating to the manufacture of glass. Advances in food processing took place as did the manufacture of personal hygiene products and beauty aids such as shampoos, deodorizers, perfumes and cosmetics.

Physics:

Though the physical world seen by different schools of thought are different there was a commonality - in recognizing both the heterogeneity of natural phenomena and the search for basic elements in the foundation of nature and the laws which explain natural phenomena. In order to explain the heterogeneity of nature, five element theory *Panchapootha* was developed. According to this theory, nature consists of Solid, Water, Gas, Radiance (or fire) and Space. The concept of space - *Akasa* is considered as eternal as well as non-eternal. It was developed to provide a positive frame of reference for material

objects. It is quite similar to the Western thought of all-pervading ether medium. Even the concept of the atom - the smallest, indivisible particle, has a clear forerunner in the Sanskrit *anu*, or tiniest possible particle.[5] *Brihath Sathaka* operates with the divisions of the time of the day into 60 *kalas* of 24 minutes each. The smallest unit of time (3 x 10^{-8}second) is surprisingly close to the life-spans of certain mesons and hyperons.[8] In the 14th century *Rigveda of the Sun*, the speed of light has been calculated as 300,000 metres a second, and the age of the universe is 8.64 billion years. Both figures are fairly equal to the modern day measurements.[9] Indian Architecture has been a thing of beauty. Owing to the varied landscape, the Architecture displays a wonderful variety.

DECLINE IN SCIENTIFIC ACTIVITY

Though ancient Indians were excelling in many fields, one senses a progressive deterioration during centuries. As Nehru puts it[10] *"The urge to life and endeavors becomes less, the creative spirit fades away and gives place to the imitative. Where triumphant and rebellious thought has tried to pierce the mysteries of nature, comes the wordy commentator with his glosses and long explanations. The urge to adventure and the overflowing life which led the distant colonization and transplantation of Indian culture fades away. And in this place comes narrow orthodoxy which even taboos the crossing of high seas. A rational spirit of enquiry so evident in earlier times which might have led to the further growth of science, is replaced by irrationalism and a blind idolatry of the past."* It is quite possible that Indians, when they traveled to other countries were aware of the development of knowledge, acknowledged its value and used it in their contributions. But when conservatism set in and foreign travel was tabooed by the Brahmans, the isolation of Indian scientists began. As a consequence of this social restriction on the intellectual climate there was stagnation of Indian science. The development/non-development in every society depends on social, political and cultural milieu. The reasons for decline in scientific activity can be explained as follows:

Political:

The wealth of India was attracting many invaders from all over the world. Frequent changes in dynasties and Kings with different approaches to knowledge prevented institutionalization. Owing to the absence of Institutionalization of education the continuity and accumulation of knowledge and expertise did not take place. Kings and nobles used science for purposes of power to control the people. The educated elite who develop abstract knowledge, use principles and the rationality for their own purposes but for the common uneducated people, they develop and propagate myths, dogmas, superstitious beliefs and the mantras to make them conform. As the society was mainly agriculture based, study of planetary movements and prediction of monsoons became imminent. This led to development in astronomy which later transformed into astrology. So, making people to abide by was made simpler for the elite.

Social:

Unlike the present society of unending development with unending demand on natural resources, ancient society was almost stable. Though kings might come and go with various religious and other beliefs, the basic fabric of the society remained the same; it was based on agriculture and industry dependent on the use of renewable resources

remained largely unaffected. According to Al Pacey " The kind of technology which any society develops must depend on its utility to mobilize labor for relevant skills, and to encourage innovation." Owing to the fact that, India largely remained an agricultural society, no new challenges arose to create new knowledge to help solve problems. As the proverb goes **Necessity is the mother of invention**, there was no need for innovations, and so no great technological break through happened. It is said that the harsh winters in Europe with very short days have led to the invention of electric bulbs, heaters and other amenities of life. But the mild climate in India made life more comfortable than in Europe which is one of the reasons for absence of technological advancement. Moreover the population had a limited growth owing to large child mortality, mortality due to epidemics and incessant wars. Therefore there was abundance of natural resources but only limited demand on them. During 10th to 18th century India was using natural renewable resources with the exception of armament industry. These resources were used to meet human needs and sustain a social system. During the *vedic* period the scientific knowledge was diffuse and people in lower strata of life as vegetable-vendors were well-versed in Indian mathematics.[11] However the later practice of *casteism* became the most important reason for lack of scientific development and diffusion of knowledge. The practitioners and custodians of science were the Brahmans. They represented the educated elite and they dominated socially. Varahamira remarked, "What then we are to say of Brahmans, if he combines with his purity the height of Science". Scientific activity and knowledge remained a preserve of the elite while arts and crafts remained with the less privileged groups. As a result, the problems generated by technology were not attempted by scientists. The widening of scientific knowledge and creation of theoretical understanding of the problems were hampered by the social practice of casteism. The education in general and science in particular were the preserves of the higher-caste people and lower-caste were not given any taste of education. This greatly affected the scientific progress.

Religious Impact:

Some may think that Indian culture represent essentially the principle of life negation and not of life affirmation. Both principles are present in all religions and cultures but in varying degrees. But Indian culture never emphasized the negation of life. However the concept of *austerity* was preached by the prevalent religious systems such as Hinduism, Buddhism, Jainism and Islam. These religions preached a code of conduct for the use of materials and introduced the concept of limiting one's needs and practicing austerity as a virtue. Though kings and nobles led a luxurious and lavish life, the vast masses were imbued with a philosophy of austerity. Further, in the religious systems attainment of salvation or *Moksha* was thought to be the ultimate goal and of individual pursuit. So individual skills only counted, not the technology.

LACK OF TECHNOLOGICAL DEVELOPMENT

The capacity to intervene with nature is based on the technological capacity humans are able to generate. This capacity also generated dreams to go beyond nature, to soar higher and to leave a remarkable mark behind. The development/ non-development of technology needs to be examined in the context of natural environment and the way

humans shape the conditions of their existence. The process of diffusion of scientific knowledge is different from the process of diffusion of technology. The former is either through oral discourse of through the written text, which may lead to different interpretations by different proponents. In the case of technology it is through demonstration. Major innovations in technology can only take place when the technical knowledge is well developed in a theoretical framework and is applied to improve or change the technology. It is detrimental to both society and science when the available scientific knowledge is divorced from technology or when no interaction is between scientists and technologists or artisans and craftsmen. This is what happened in medieval India due to social and religious environment prevalent in that period. The basic feature of technological developments in India is based on trial and error and improvement of practices. This is due to the lack of theoretical development owing to the separation of scientists and scholars from artists and craftsmen. This was also due to the absence of institutionalization of empirical experiences into a research system for the development of technology. The input of scientific knowledge to technical process and application of scientific method for technology are essential for the development of technology and in turn, the society itself. On the other hand, during the same period Europe and later Japan had very good interaction between scientists and craftsmen.

Another interesting and intriguing phenomenon is the lack of large-scale machinery in the medieval India. Irfan Habib quotes Babur about the abundance of skilled laborers, *A good thing in Hindustan is that it had unnumbered and endless workers of every kind.*[12] Though many of the Islamic, West and even Asian country like China were mechanically minded, in India, there was little use of machines. Pacey[13] says *no report of machines with gears, pulleys or cranks before 1200 in India.* In India the organic view of nature was more prevalent. The natural forces were thought of God's will or interplay between different Gods. In this scenario, machines could not fit into as a form of nature.

There was diffusion of knowledge and technology to some extent, that every household were able to meet their needs like making clothes and its dyeing, preparing food preserves, making cosmetics, medicines and dietary supplements etc., However, these cannot be called as new technologies as they were inherited from ancestors, and every civilization has its own way of meeting such needs.

During AD 1000-1800, India was lacking a methodology for developing innovations and new technologies and hence it was not able to develop the methodology of invention. However, Europe was able to develop this by linking scientific knowledge with technologies and creating the necessary institutions to promote this process. This made India to be dependent which was fully exploited by colonial powers.[11] When people like Savai Jai Singh tried to unify the base of Science, incorporating new knowledge that was being produced in Europe then came the colonization. The colonizer reinforced the conservative ethics and religious grouping of the people. It imposed a new scientific system in a new language, completely marginalizing and delinking the earlier knowledge system with the new. The educational system introduced by Lord Macaulay had nationally-repressive system for Indians as a class of clerks, made many to look into Indian history and science through the western prism.

DIFFERENCE BETWEEN TRADITIONAL INDIAN SCIENCE AND MODERN SCIENCE

There is a need to understand and respect the distinction and uniqueness of each scientific system. There is a room for a dialogue between various systems and a need to avoid crude and quick equations or the judgment of one system by another. Various civilizations have evolved sciences, technologies and knowledge systems having their own individual characteristics and bearing the stamp of the world view and values of the society which gave rise to them. An open minded study of traditional systems of knowledge is likely to provide us with a valuable starting point in a quest for a holistic approach not only to Science but also in various other areas of human endeavor.

The essence of modern laboratory method is to isolate any problem from its environment in order to minimize the *controllable* parameters. In contrast, the traditional approach attempts to solve problems by taking them in their entirety with all their interlinkages and their complexity. The traditional Indian sciences seem to adopt the holistic method of looking at the world in its integrity. According to Charaka, science is dependent upon **Yukthi** - a quality of the intellect that enables it to perceive phenomena brought into existence by a multiplicity of causes. A feature of many traditional scientific systems that often puzzles anyone trained in modern science is the apparent constancy of theories. It appears that in key areas nothing has changed for centuries or millennia. It is sometimes said that theories have been fossilized because no growth took place after some "dark ages". It has often escaped the observer that there may be a different approach to a scientific endeavor or a different way of organizing science which may lead to a certain "constancy" of the fundamental theories. The efficacy of Indian systems of medicine captured the interests of elite and modern medical scientific world. Upon the introduction of *Unani* and *Allopathy*, the respect given to the traditional medical systems declined. Many of the invaluable medicinal scripts written in palm leaves and bark of the birch tree were destroyed owing to the ignorance of traditional knowledge system. Even in my family, one of my grandfathers who has been well-versed in *Siddha* medicine used palm leaf scripts. But they were buried with him thought to be not useful any longer. The question of whether *Ayurveda* is scientific is raised by many in India. However, prominent physicians now show that *Ayurveda* is indeed a scientific knowledge system based on Methodological, Epistemological and Sociological criteria.[14]

INDIAN SCIENCE AT PRESENT

In the nineteenth century there was widespread use of science by the British to further their commercial and political interests. Indians came into contact with modern science, when they were assigned the peripheral role of providing cheap labour. Once introduced to modern science, Indians finally strove to become full-fledged members of the international republic of science in their own right. During 1950s in the advanced countries "Big Science" activities, which grew from the industrial and technological base established by the World War II, took great leaps forward. The peoples of India and other less developed countries, on the other hand were involved during 1950s with restructuring their societies after 200 years of colonial rule. And as India had not been involved in wartime

science, it had no infrastructure to build science and technology systems. As a result, India fell behind in the race for big science.

The first Prime Minister of Independent India, Jawaharlal Nehru had a vision of science as an integral tool in the task of development. His views had two merits, the first was having a humane and peaceful world-view as its fundamental premise, and the second its strong link to secular and rational thought. He had the viewpoint that the investment in advanced science and technology was an investment for the future, an attempt to keep up with the knowledge explosion of the twentieth century, even as the basic tasks of development were attended to. The Council of Scientific and Industrial Research (CSIR) was established in 1942, and today it is networking 39 laboratories and more than 100 universities and field centres. The Council's research programmes are directed towards the effective utilization of the country's natural resources and development of new processes and products for economic progress.

The nation-wide Science and Technology (S & T) infrastructure has grown from Rs.10 million at the time of independence (in the year 1947) to Rs.30 billion, slightly more than 1% of GNP. Now India has the third largest number of scientists and technologists in the world. There has been a significant growth in India's capability and accomplishments in several high technology areas such as nuclear, space, S&T, electronics and defence research and development. The Government is committed to make S&T an integral part of the socio-economic development of the country.

Among the developing fields, Atomic Energy is leading. India's power requirement will be provided by eight nuclear power reactors with a total of 1400 MW generation capacity. The scientists and the Government now try to obtain 20,000 MW of electricity in 2020 from atomic energy alone. As the power is essential for industry and in turn, for economy to flourish a time-bound, result-oriented approach is followed.

After independence from the British, self-reliance in food production was the major achievement. Most of the countries in the world think that India is a poor country, unable to feed its people. But it has to be noted that for the past five years the food grains such as rice, wheat and other pulses are produced in surplus amount. This was made possible by the supreme research done in the field of agriculture. The project was titled '**Green Revolution**' in the 1970's and led by an efficient scientist Dr.M.S. Swaminathan. Bio-scientists and different government agencies are successful in producing high-yielding, disease-resistant hybrid crops. This was the main reason for the success of Green Revolution. Along with the Green Revolution, the **White Revolution** (for diary products) was initiated. Now scientists are trying to attain the achievement made by Green Revolution in White Revolution too.

The Indian space programme has made significant strides towards establishing operational systems for national development. The Indian Space Research Organization (ISRO), under the Department of Space is responsible for research, development and operationlisation of space systems in the areas of satellite communications, remote sensing for resource survey and management, environmental monitoring, meteorological services etc., India is the only developing country to develop its own remote sensing satellite. ISRO reached its landmark, by launching the first Geo-Stationary Launch Vehicle (**GSLV**) in July,2001. Even though Indian space research is inflicted by fund reductions and economic sanctions by the developed countries, it continues to make strides. As the Polar

Satellite Launch Vehicle (**PSLV**) and GSLV soar high in the blue-sky, so do the self-confidence of the people and the pride of the Indian scientists. The development made by India in defence research is remarkable. India is able to produce indegeniosly many of the state-of-the art missiles and other armory. In the field of telecommunication and Information Technology India made amazing progress. From only 6 Radio stations and only one TV transmitter in 1947, to more than 200 radio stations and more than 1000 TV transmitters now, is a remarkable progress indeed. With the help of satellites almost all Indian villages are inter connected with telephones, radios and television networks.

A multi-pronged approach has been evolved for result-oriented research and development with special emphasis on micro-electronics, telematics, high performance computing and software development. Though Bio-technology and Oceanography are not well-developed earlier, they are now paid due attention with the establishment of separate government organizations for these during 1980's.

There is some criticism in the scientific community that the Government over-spends for defence research. According to the R & D budget, of the year 1988-89, Defence research bagged about 27% of total money allocated for research. while agriculture and alternate energy which are the higher priorities for common man only received 9 and 17% respectively. The political and geographical factors that make government to spend more for defence research is in some way justified because the national security should be preserved at any cost.

Though the wisdom of the government and scientists involved in the testing of atom bomb in 1997 was questioned and is a matter of controversy (which will not be elaborated here) it has to be emphasized that the Indian science and technology has an upbeat attitude that economic sanctions could be weathered without much damage. The private sector, which have contributed almost nothing to S&T research in India and preferred foreign collaborations, now expressed their full support for indigenous development of technologies. This is the blessing in disguise for research and development for India. This has been emphasized by the fact that the technological milestones such as Light Combat Aircraft (**LCA**) and GSLV were delayed by the economic sanctions but were never stopped.

India is excelling in medicinal research also. Many of the diseases like polio, tuberculosis, small pox etc., are completely eradicated. Owing to the low-cost and higher efficiency of the surgeons and physicians, many people in countries like Unite Kingdom and Germany now like to go to India to get medical treatment. However, it has to be acknowledged that it is an uphill task to provide the health-care to all people in India. India being a democratic and secular country can not impose strict population control measures as some communist countries do. But there is some good news too, that some of the developed-states in India show stabilization and even declining of population growth.

INDIAN SCIENCE IN THE FUTURE

The most serious challenge facing India's S&T establishments is that of human resources. Several committees have advised the government even 20 years ago that, the capacity of generating and sustaining technological growth had to be strengthened considerably. Because, the number of people available for such enterprises is very small

in relation to the country's high rate of population growth and corresponding social needs.[15] The quality of new entrants will obviously determine the quality of the organization in the future. More and more talented youngsters opt for software industry, and less people wish to take up higher education in sciences. Hence the research institutions face major crunch of qualified personnel.

There are voices of concern saying that Indian science today heavily skewed toward nuclear, military and space research. In spite of having third largest stock of scientific and technological personnel in the world, India's S&T had little effect on the daily life of Indians. One of the major difficulties facing is the starvation of research funds for universities and institutions of higher learning. The result is that the quality of higher education is also affected. India spends around 1% of its annual GNP for R&D. Though it is not adequate for a country that plans to develop as a knowledge society and achieve high rates of growth based on scientific and technological achievements. However, it does indicate a sizable commitment to S&T. It has to be acknowledged that even in developed nations there is growing concern that funding allocated for R&D is not sufficient.

The Green revolution ensured that scientific innovation spread directly from lab to land. As the traditional ownership of farming assets are with the farmers themselves, it was easier for them to accept and employ technological innovation. In contrast, due to some policies of the government, it was far easier for industrialists to purchase technology from overseas than to develop their own. Therefore the culture of interaction between the industry and the research institutions as prevalent in developed countries is almost totally absent in India. However, the pharmaceutical and drug industry are now developing their own R&D facilities. Like in US, the mission based approach has led to many success in the sectors like space and atomic energy. The same method has to be adopted for industrial research in order to promote it further.

According to Jacob Bronowski[16] "the activity of science is directed to seek the truth and it is judged by the criterion of being true to facts. We can practice science only if we value the truth". It is important to have the critical and rational spirit in society for science to flourish. It bears emphasis that science and scientists fulfill their social responsibility[17] in assisting in the task of expanding the realm of operation of free and critical enquiry in society.

Article 51-A(h) of the Indian Constitution states that *"it shall be the duty of every citizen of India...to develop the scientific temper, humanism and the spirit of inquiry and reform"*.[18] However, the main challenge facing the scientific community is to make the people have a scientific temper while they enjoy the fruits of science. There is wide spread obscruantism and absence of radical thinking even among the educated lot. Therefore it is the duty of every scientist to propagate a scientific temper, and to popularize science.

It is important to get out of traditional ways of thinking and living. Even though they were good in the past, have less significance today. There is no visible limit to the advance of science, if it is given the chance to advance. The applications of science are inevitable and unavoidable for all countries and peoples today. But something more that mere application is necessary. It is the scientific approach, the adventurous yet critical temper of science, the search for truth and new knowledge, the refusal to accept anything without testing, the capacity to change previous conclusions in the face of new evidence, the reliance on observed fact and not on pre-conceived theory, the hard discipline of the

mind- all this is necessary not merely the application of science but for life itself and the solution of its many problems.

Science has dominated the Western world and everyone pays tribute to it. India has a greater distance to travel and yet there may be fewer major obstacles on the way, for the essential basis of Indian thought fits in with the scientific temper and approach. It is based on a fearless search for truth, on the solidarity of man, on the free and cooperative development of the individual and the species, ever to greater freedom and higher stages of human growth.

I hope that the Present Prime Minister Mr. Vajpayee's slogan **"Victory to the soldier, Victory to the farmer and Victory to Science (Jai Jawan, Jai Kisan and Jai Vigyan")** will lead India to development in all spheres of life.

CONCLUSION

For science and technology to attain its peak in a society, favorable political, cultural, social and religious scenario are essential. India remains a interesting case-study for this concept. When men were free to think and work they were able to excel in many exciting frontiers of science. But when the social and political milieu of scientist and thinkers deteriote so do the science. This is the main reason why there was not much scientific breakthroughs in the last 1000 years. After India became free from the clutches of foreign rulers, the sociological clutches are also released slowly. So India is making strides to become self-reliant in every field of science. However major revamps are needed to make scientific development as a vector of social development.

Before concluding I would like to quote Jawaharlal Nehru, the first Prime Minister of Independent India- **"We are citizens of no mean country and we are proud of the land of our birth, of our people, our culture and tradition. That pride should not be for a romantized past to which we want to cling. We have a long way to go and we must hurry, for the time at our disposal is limited and the pace of the world grows ever swifter"**.

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