THE NEEDHAM QUESTION: SOME ANSWERS

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Joseph Needham spent the latter half of his long and productive life on the study and publication of Chinese science and civilisation and produced monumental monographs. His books did a great deal to explode the Eurocentric myth that Greece was the only source of all science and knowledge. Owing to his efforts Chinese contributions to the history of science are well recognised today. But he did find it a bit puzzling that despite the rich history of science in China and India, why was it that modern scientific and industrial revolution took place in Europe and not in India and China. Needham asked:

"With the appearance on the scene of intensive studies of mathematics, science, technology and medicine in the great non-European civilisations, debate is likely to sharpen, for the failure of China and India to give rise to distinctively modern science while being ahead of Europe for fourteen previous centuries is going to take some explaining".

Needham's question has intrigued many generations of scholars and philosophers. It's an important question to ponder over, not so much as to arrive at some definite answers but it gives an opportunity to all thinking Indians for introspection. We summarise below the ideas of Al-Biruni, Udgaonkar, Narsimha, Kosambi, Rahman, D.P. Chattopadhyaya, Claude Alvarez, and some other scholars. Towards the end we have discussed some of our ideas too.

Al-Biruni's Views

Al-Biruni, the scholar-traveller who visited India around AD 1000, was very critical of the Hindus on this score. Al-Biruni criticized the scientific theorems of Hindus and their mathematical and astronomical literature. Udgaonkar argues that his harsh words were possibly coloured to some extent by the arrogance of a person accompanying the conquering Mahmud.

Al-Biruni said that most of the ancient texts were composed in *Slokas,* rendering them rather unintelligible. Al-Biruni had composed a treatise showing how far the Hindus were ahead of them in science. He says, the Hindus composed their books in *Slokas* and if they wished in their astronomical books to express some numbers of the various orders, they expressed them by words. He tells us that Brahmagupta said, 'If you want to write one express it by everything which is unique as e.g. the earth, the moon; two by everything which is as e.g. black and white; three by everything which is threefold, etc.' Arabic and Urdu literature probably adopted this from India. For instance, *786* symbolically expressed *Bismillah-hir-Rahman-nir-Rahim*.

From Al-Biruni's views we also learn that India was far ahead of the west in science, maths and astronomy but due to civilisational complacency further development came to a standstill. Al-Biruni said that the Hindus were haughty, foolish, vain, stolid and self-conceited. According to their belief, there was no other country on earth but theirs, no other race of man but theirs, and no created beings besides them have any knowledge or science whatsoever that, their haughtiness

was such that, if you told them of any science or scholar in Khurasan or Persia, they would think you to be both ignoramus and a liar (Rahman 1996).

D.P. Chattopadhyaya's Views

D.P. Chattopadhyaya (DPC), a well known scholar, has a plausible explanation for the slow scientific progress in India. He thinks that the ability to swallow logical contradictions wholesale left its stamp upon the Indian national character, noticed by modern observers, as also by the Arabs and Greeks before them. The absence of logic, contempt for mundane reality, the inability to work at manual and menial tasks, emphasis on learning basic formulations by rote with the secret meaning to be expounded by a high guru and respect for tradition (no matter how silly) backed by fictitious ancient authority had a devastating effect upon Indian science. For historical descriptions of ancient Indian scenes and people, sometimes even for the identification of ruins, we have to rely upon Greek geographers, Arab merchant travellers and Chinese pilgrims. Not one Indian source exists of comparable value.

DPC explains that the *vaidika* and the *pauranika* modes of understanding and expression are highly symbolic, mystical and often rhetorical. Many writers of the Indian as well European tradition have pointed out the important distinction between the languages of mysticism, religion and poetry, on the one hand, and those of logic and science, on the other. He cautions that it would be wrong to suppose that mythical thinking has no structure in it. Without minimum structure, hidden or inarticulate in character, myths of widely different and (spatially) separated cultures would not have conveyed comparable or even strikingly similar messages/meanings.

DPC also wants us to critically assess if the *sufi* and *bhakti* spirit of resignation and reconciliation, emotion and acceptance adversely affected critical temper and scientific research in India during the second millennium. One of the reasons why science in India did not have a career comparable to that of post-Renaissance Europe is often attributed to the rise of devotionalism and mysticism as also indifference.

Rahman's Views

A pioneer in the field of history and technology in India, A. Rahman in his article, *A Perspective of Indian Science of Tenth-Eighteenth Centuries* takes a look at medieval Indian science.

Rahman says that most of the ancient texts were composed in *Slokas,* rendering them rather unintelligible. Indians probably did so to conceal knowledge from the masses and maintaining necessary control and power. Here he also brings in the caste system as being responsible for limiting knowledge to a few.

Rahman elaborates on the interaction of Arab scholars with India and says that these scholars were aware of the development of sciences in India through the work of Al-Biruni and others, particularly in mathematics, astronomy and also in medicine and had also absorbed Greek scientific tradition in terms of studying Greek texts, their translations, interpretation through commentaries and analysis of problems. In contrast to Indian writings, the characteristic features of Arab literature were:

- The use of unambiguous and refined language.
- Providing definition of terms used and giving illustrations.

- Posing of problems and providing their solutions.
- Giving examples for students or readers to solve.
- Literature displaying Aristotelian logic and rationality based on Greek philosophy.
- Literature displaying the three-fold purpose of knowledge, that is, Religious needs, agricultural requirements and meeting the everyday needs of life. In other words, Rahman says it was essentially directed towards practical needs, that is, it was utilitarian.
- Acknowledging the works of predecessors and discussing different points of view, also presenting views for or against a theory.
- Extending the base of knowledge to cover newer areas such as:
- Geography and history and writing of chronicles covering arts, crafts and various practices in different fields.
    - Geology, gemmology and development of instruments for the purpose.
    - Detailed knowledge of animals and plants.
    - Physics, specially optics, specific gravity, magnets, etc, and the concept of motion and time. Development of instruments for measuring time.
- Compilation of catalogues, Zijes, checking tables, catalogues of other astronomers. Development of instruments for the purpose.
- Translation of Sanskrit texts and familiarity with and adoption of many features from Sanskrit traditions.
- Religious considerations often coming in the way of and suppressing scientific opinion.

Referring to the interaction between Arab, Persian and Sanskrit scholars, Rahman writes that many books had been written combining these traditions, but an integrated unified tradition did not emerge to create a base for further development of science.

Rahman enumerates the following reasons for the lack of development of science in India.

- During the period India remained an agricultural society, no new challenges came up to create new knowledge to help solve new problems. The two major developments apart from the field of arts and crafts were in the area of paper technology and the development of military weaponry technology, but no theoretical development could take place.
- Scientific activity and knowledge, by and large, remained a preserve of the elite, while arts and crafts remained with the less privileged groups.
- The pluralistic tradition of Hinduism, whereby different philosophies continued to co-exist, as the faith failed to generate a unified pursuit of knowledge.
- Religious prejudices and linguistic arrogance may have also come in the way of evolution of a single tradition.
- The philosophic and theoretical framework being different, the Vedic logic on one hand and the Ptolemaic, the Euclidean and the Aristotelian logic on the other, became a major block, since both were associated with religion. The pressure of the conservatives was too much to discard the overall framework to create and develop a new integrated tradition.
- It also appears that two different processes continued to operate during the period: one towards the integration of the two traditions, and the other at keeping them apart.
- Lack of institutionalisation of education was also a handicap.

- Change of dynasties and kings with different approaches to knowledge even within a dynasty also came in the way of continuous growth of institutions and spread of knowledge within an institution.

Towards the end, Rahman wonders whether there could be a possibility of Indians developing a unified base of science, incorporating new knowledge from Europe? He says that the literature of the period and the efforts of Sawai Jai Singh indicate that development in this direction was probable. However such an eventuality was disrupted by colonisation.

Udgaonkar's Explanation

Udgaonkar has summarisd the views given by various scholars. These are listed with various other proposed socio-cultural explanations which are as follows:

Other-Worldliness of Indian Culture: It is alleged that early Indian culture was otherworldly, that it perceived the world as *Maya* or illusion, and that the conceptual world-worthlessness led to a lack of interest among Indians in any worldly pursuits. It is said that the Indians were only interested in the liberation of the soul as a goal, and not in studying the external world.

Udgaonkar points out that distortion of the word *Maya* is involved to some extent in the above argument. He quotes Vivekananda who refers to *Maya* as 'one of the pillars upon which Vedanta rests'. He, however, warns us that the word *Maya* is used incorrectly to denote 'illusion or delusion or some such thing'. Udgaonkar says that the perceived other-worldliness of Indian culture could not have been true for the majority of the population, India is also a land of Kautilya's *Arthasastra*, Vatsyayana's *Kama-Sutra* and Indian merchants have been entrepreneurial for thousand of years. Udgaonkar has also given the example of Jawaharlal Nehru who remarked, 'Probably the Semitic culture, as exemplified in many religions that emerged from it, and certainly Christianity, was far more other-worldly'. 'Indian culture taken as a whole', he further adds, 'never emphasised the negation of life, though some of its philosophies did so; it seems to have done so much less than Christianity'. Nehru points out that 'in India, we find during every period when her civilisation bloomed, an intense joy of life and nature, a pleasure in the act of living, the development of art and music, literature, song and dancing, painting and the theatre, and even a highly sophisticated inquiry into sex relation. It is inconceivable that a culture or view of life based on other-worldliness or world-worthlessness could have produced all these manifestations of vigorous and varied life. Indeed it should be obvious that any culture that was basically otherworldly could not have carried on for thousands of years. The confusion seems to have arisen from the fact that Indian thought was always laying stress on the ultimate purpose of life.'

Suppression of Scientific Spirit: Ancient Indian medicine took a momentous leap from magico-religious therapeutics to rational therapeutics some 2500 years ago. The early medical men were looking for material, natural causes for diseases. The priests considered this natural cause and effect approach to human ailments and their treatment subversive, and the Indian lawgivers were obliged to denounce it as abject heresy. This led to the downgrading of practitioners of medicines in social hierarchy.

Udgaonkar however argues that the conflict between science and counter ideology was also present in Europe in the Middle Ages. There was the inquisition, the burning at the stake of nonconformist thinkers like Giordano Bruno, the trial and humiliation of Galileo. How does one compare the conflict between science and counter ideology in India with that of Europe? Why was it that counter ideology prevails in India, whereas Europe could get over its influence. Refuting Chattopadhyaya's argument, Udgaonkar asserts that medicine did thrive in India and made advances and even spread outside India down to the 8th century. A Spanish Muslim quoted by Chattopadhyaya himself says that in 1080 AD Indian medicine was the best in the world.

Conflict between Science and Religion: It is claimed that there was no conflict between science and religion in India, unlike Europe, due to lack of hostility to science or to new ideas in philosophy and there was no persecution of atheists in India.

Udgaonkar says that this was true only for the early times when there was complete intellectual freedom, an example of openness being the *Nasadiya sukta* in the Rig Veda. Due to the canonisation of scriptures in India, there was not much scope left for research and originality in the sacred books, like *Smritis* and *Puranas,* which made it impossible for even outstanding intellectuals like Brahmagupta to counter stories like those of *Rahu, Ketu* and the eclipse. Udgaonkar enquires, "Is the view that there was no conflict between science and religion/spirituality a modern view, or does it go back to ancient times?" He quotes from Sankaracharya's commentary on the *Brhadararnyaka Upanisad*: 'Nor are the *Srutis* (the *Vedas*) supposed to have authority in matters which are contradicted by other means of knowledge, as for instance, if they said, Fire is cold and wets things'. Did scholars or people at large accept such thinking widely? During which epoch? When did the tradition of questioning, as in the *Upanisads* and *NyayaVaisesika* and other texts, lose its vigour and a static view of learning of the learned emerge?

All Knowledge is in the *Vedas*: It is not uncommon to find the claims even today that the *Vedas* are storehouses of all knowledge, spiritual and secular. Udgaonkar says that it will be useful to know how old this kind of belief is in our cultural/philosophical history? When and how did it get ascendancy? Such a belief if widely held, could lead to stagnation or even decline in science and could, therefore, be an important factor inhibiting the growth of modern science in India.

Accommodating Conflicting Opposites: Indian tendency to accommodate conflicting opposites have been mentioned as one of the causes of the declining scientific spirit. D.D. Kosambi has observed: 'the "logic" advanced by the Brahmins took good care to avoid all reality. The end result is seen in the philosophy of the great Sankara (AD 800), who threw out the proposition that "A thing is either A or non-A", and viewed the universe as divided into metaphysical categories upon several planes. The highest plane was, of course, of speculation about and unity with eternal principles. Material reality did not exist. The philosopher was thus excused if he joined the common herd on the plane of ritual observation. An oft-quoted example of this tendency of accommodating the subjective with the objective and the material with the non-material, as far as science is concerned, is that Brahmagupta wrote the popular myth about the cause of eclipses (Rahu, Ketu and all that) along with his calculation in terms of the correct astronomical explanation. Udgaonkar points out that such was the case in the West also for it is well known that Newton while working on the *Principia*, was at the same time also spending a

substantial fraction of his time on investigations in alchemy and theology. In spite of Gould's remarks that Whiston had descended through history as the worst example of religious superstition and was viewed as an impediment to science, yet Newton greatly admired the book *New Theory* by William Whiston (1696). So we cannot say that the tendency to accommodate conflicting opposites did not affect development of science in the West at all and it affected only the development of science in India.

Civilisational Complacency: Another line of reasoning puts the blame on the complacency that the Indians had developed over a period of time: they began to think that they had attained the highest knowledge that humans were capable of and progressively lost the questioning attitude and openness to knowledge from other sources.

Udgaonkar says that the complacency or intellectual lethargy that had developed continued even after the Mughals came to power. Jawaharlal Nehru refers to the curious fact that Akbar did not take any interest in building sea power, though Vasco de Gama had reached Calicut, via Cape, in 1498, and established Portuguese sea power in the Indian Ocean. What is more, this lack of interest continued even after the Portuguese started exacting toll from traders and from pilgrims going to Mecca. He, or the 'jewels' in his court, also took no interest in printing though the Jesuits presented him with a printed *Bible*. The Mughal army and the armies of other states in India depended on foreign experts for their artilleries. Why did Akbar or anyone else not send his own men abroad for training, or interest himself in the improvement of the artillery by encouraging research work? Why did they not take interest in developing Indian clocks, though imported clocks were very popular with the Mughal nobility? Udgaonkar says that the conceit of Indians was not directly responsible for lack of scientific progress but it in consequence has given rise to certain other factors, which probably let down the scientific revolution.

Social Rigidity: It is also alleged that the growing rigidity of caste system in India led to the separation of the head from the hand. Theoretical and philosophical studies were the prerogative of the Brahmins, whereas practical arts and crafts were relegated to the other lower castes. Beside this, foreign travel was also banned in the 8^{th} century, which is usually attributed to the increasing rigidity of the caste system, and the ideas of purity and impurity.

Udgaonkar points out that Indian caste system has undoubtedly inhibited mutual reinforcement of science and technology but it has been less rigid than is often thought, and social stratification elsewhere in the world was not always more dynamic and flexible. As for relations between science and religion, there indeed were clashes between rationalist and conservative views, such as between Aryabhata and Brahmagupta (6th and 7th centuries CE) but the conflict never reached the intensity of western violence in which Bruno was burnt at the stake for his irreligious beliefs. We also need to recall that the great star of scientific revolution, Isaac Newton, wrote far more words on theology than he ever did on science. Regarding the ban on foreign travels and no cross fertilisation of ideas, Udgaonkar says that banning foreign travel could not but have had a very adverse impact on the exposure to fresh ideas and new techniques, so essential for the growth of science.

Effect of Invasions: The effect of successive invasions devastated and destabilised Indian society which not only lost its prosperity but also lost centres of learning including their libraries.

Al-Biruni describes the effect of Sultan Mahmud's invasion '…Mahmud utterly ruined the prosperity of the country, and performed there wonderful exploits, by which the Hindus became atoms of dust, scattered in all direction, and like a tale of old in the mouth of people…. This is the reason why Hindu sciences have retired far away from those parts of the countries conquered by us, and have fled to places which our hand cannot yet reach …'

Udgaonkar says that the effect of centuries of unsettled conditions that prevailed before a multi-religious composite culture could emerge, needs to be analysed dispassionately without allowing either Hindu or Muslim chauvinism to distort the views.

Udgaonkar has discussed only socio-cultural parameters to Needham's question whereas there are several other aspects of Indian history of science and technology, which needed to be discussed. Roddam Narasimha has given more importance to ideological or attitudinal factors to answer the question why India failed to give rise to distinctively modern science while it had been ahead of Europe for fourteen previous centuries?

Roddam's Answer

Roddam does not seem to be convinced with the socio-cultural explanations summarised by Udgaonkar. He found that the first difficulty with the socio-cultural explanations is that they do not recognise the diversity of Indian civilisation, and in particular its philosophies. The second difficulty he has observed with the socio-cultural explanation is that they ignored the presence of strong scientific traditions in India at different periods in history. The third difficulty, which Roddam finds is that for nearly fourteen hundred years after certain fundamental developments in Greece, European science was stagnant; no great advances in terms of fundamental ideas were made in what indeed have come to be known in Europe as the Dark Ages. This was incidentally a period that was a classical age for India in spite of all the socio-cultural reasons given above.

He points out that the socio-cultural explanations may thus not be convincing but the Needham question cannot be brushed under the rug. The question should be approached from a very different perspective. Ideological or attitudinal factors which have been held responsible for India's inability to build on its early base, do not strike us as having the status of anything more than speculations or prejudices, given the importance of the question being discussed. Therefore, before asking why India and China did not give rise to modern science first, we need to ask how the European Miracle happened. Second, we have to analyse the epistemological reason why the Indian mathematical revolution did not lead to a corresponding distinctively modern scientific one.

The famous triple inventions – printing, gunpowder and magnet – changed the appearance of the whole world; the first in letters, the second in warfare, and the third in navigation. And this powerful trio came from China, as did silk and the clock escapement mechanism. Gombrich points out that there were two important omissions in the list: one was the paper on which the list was written which came from China and the other was numerals that listed them, which came from India.

The inventions that occurred in Europe in the 16^{th} century must, at least in part, have been triggered and inspired by technological flood from the east from China, through West Asia.

The second clue comes from mathematics. One of the most striking features of the scientific revolution was the mathematisation of science. Galileo used mathematics; Newton's great and epoch-making book was titled *Principia Mathemetica Philosophiae Naturalis* (The mathematical principles of natural philosophy). Where did this mathematics come from?

One can therefore argue that the long Dark Ages of Europe were broken with the help of technical and mathematical inventions imported from the east. Europe came into contact with these through the violent conflicts that took place with the Arabs during the Crusades.

Roddam has also elaborated the epistemological reason as to why the Indian mathematical revolution did not lead to a corresponding distinctively modern scientific one. The Indic approach basically was not that of model makers but of ingenious algorisers, and showed a deep and studied distrust of axioms and physical models.

Mathematical Revolution in India: Roddam points out that what Europe acquired was the algoristic or computational revolution that occurred in India. It started in 5th century CE, heralded by the great figures of Aryabhata and Brahmagupta and was perfected by the integration of zero into it. Various notations, algorithms, trigonometric sines, brief tables, etc, were discovered here. Most of the mathematical solutions discovered in India now belong to the western legacy, like second order interpolation formula which was invented a thousand years before in India and is now called the Newton-Stirling formula.

The early centuries of the second millennium witnessed an extraordinary burst of new and creative mathematics in Kerala (south India). Madhava (1340-1425 CE) discovered a series of expansions for the trigonometric functions that were equivalent to the Maclaurin series of early 18th century Europe. He also computed for *pi* the 'approximate' value of 3.1415926536, to a much greater accuracy than anything that had been achieved in any previous work. These, and other developments, unleashed a new and unprecedented computational power that would become a valuable tool in the pursuit of the exact sciences.

This algoristic mathematics, from India and the Islamic lands, combined with the classical Greek penchant for axiomatised model-making (retrieved again through Islamic science) and a technology empowered experimental philosophy, appear to have led to the revolution of the 'distinctively modern' science that Needham talks about. In retrospect, we can say that the centuries around 1600 CE saw a remarkable series of episodes of cultural fusion from East and West, resulting in the scientific (and later the industrial) revolution.

Roddam further states that the Needham question now rephrases itself to ask why the Indian mathematical revolution did not lead to a corresponding 'distinctively modern' scientific one. One reason is that the other ingredients of the scientific revolution - the idea of physical models and the development of technology enabled experimental methods - did not obtain in India. It is also likely that (unlike in Europe) no social, economic, or political pressure for it was felt in India at the time: the spirit of Baconian domination over nature was (and indeed largely remains to this day) alien to a culture that has always respected nature as bountiful rather than regarding it as an adversary. The proposal here is that there were some fundamental philosophical reasons

as well. It is clear from a reading of Eastern and Western scientific literature that, at the very least, there are strong differences between different civilisations in the style in which they build that organisation. These differences appear to reflect deep epistemological differences, in other words differences in the philosophical approach to knowledge. For instance, if we compare two approaches to geometry *Sulba-sutras* (7^{th} century BCE) and Euclid (3rd century BCE), we will find that *Sutras* are basically strings of concise, aphoristic statements, rules, or directions holding a work or subject together (in western literature we could say that Wittgenstein's *Tractatus* is written in the *sutra* style). Euclid, on the other hand, gives a collection of 'theorems' in geometry derived from a set of definitions, postulates ('axioms'), and common notions. Similarly, if we compare the two great astronomers Ptolemy (2^{nd} century CE) and Aryabhata (5^{th} century CE), Ptolemy proceeds with a basic physical/kinematic model in mind. The model is geocentric, and the planets move in epicycles. Aryabhata also uses epicycle, but by splitting planetary motion into a mean and rapid epicyclic fluctuation superposed over it. It is very likely that the basic idea of epicyclic motion was borrowed from the Greeks. But the interesting point is that Aryabhata does not set out or justifies any underlying physical or geometrical model at all, although he is aware of physical concepts relating to eclipses, relative motion, and so on.

The conclusion that Roddam draws from this comparison is that the Greek ideal was to proceed from axioms or models, through logical deduction, to theorem or result; the Indian ideal seems to have been to proceed from observation, through algorithm, to validated conclusion.

Modern Science: Modern Indian science, which has very largely followed the western style, and claims some very significant contributions in both theory and practice, still lacks innovative model making. A fascinating exception would seem to be the work of S.N. Bose, whose formulation of a new statistical model for the kind of particles that have now come to be known as bosons was very much high science in the western spirit. Paradoxically, the Bose model was really the outcome of a counting exercise, a calculation based on combinatorics, a subject with a long history in classical Indian mathematics. Bose implicitly made fundamentally new and path breaking assumptions in deriving his results, but did not seem aware that he had taken an algoristic rather than axiomatic approach to the fundamental problem that he solved. Was this a fusion of the Indian passion for algoristic procedures with western type model making and does it demonstrate that behind very successful simple algorithms may lie simple and profound physical models? But the very rarity of this kind of achievement shows the enduring power of culturally determined patterns of thought. So too does the work of the mathematician Srinivasa Ramanujan, who discovered brilliant new results but could rarely provide 'proofs' for them.

Roddam further asks, “Is it possible that the great pragmatic civilisations of the East misjudged how far the quest for truth might go based on what they considered inadequate foundations? Were their rules of inference too stringent, their pursuit of absolute truth so demanding, that they missed the power and insight that could be gained from what they considered was a less fastidious approach to knowledge - which (again mysteriously) turns out not only to be often 'correct' (as for instance with the heliocentric theory), but also to lend itself to such systematic but astonishing enlargement of scope and power of self-correction? Could this not be part of the reason for the great eastern failure noted by Needham?

Roddam concludes, the epistemological view that a culture takes may well depend on the

physical and intellectual tools that it has. If the phenomenon is too complex and complicated (e.g. meteorology, biology, social science), one is forced, even today, to resort to data analysis to infer patterns, without the aid of axioms or models; if on the other hand, the phenomena are simpler (physics, chemistry, aerospace science), it seems worthwhile to try to construct suitable minimalist models or to discover the most parsimonious set of axioms, so that 'axiomatisation' becomes a worthwhile goal, a feasible approach. Modern science will presumably go ahead pursuing both paths simultaneously. It is, in the final analysis, a question of choosing the most appropriate strategy to tackle any given problem with the physical and intellectual tools that one happens to possess at a given point in time - as we continue with the long history of humankind's attempt to organise the reality of nature.

Let us consider a few other views now.

David Cosandey

Le Secret de l'Occident (The Secret of the West) unveils an economic and political theory about scientific and technological progress. The theory gives the reasons why the scientific and industrial revolutions originated in the West, and not in the Middle East, India or China. It succeeds in explaining the European "miracle" in the 2nd millennium as well as the Greek "miracle" in antiquity. It unravels the causes for the decline and rise of India, China and the Middle East across the centuries. Cosandey's theory can be summarised as follows:

Debunking Traditional Explanations: Cosandey refuses the usual "internalist" explanations for European inventiveness like religion, culture, genetics, climate, third-world abuse, Greek heritage, etc. He says that none of these elements pretend to shed light on long-term European success. He further explains that during some periods of time, China, India or the Middle East led the way in science and technology and this does not fit well with the idea of an inherent religious, cultural, ethnical superiority of the west over the east. One has to admit important changes in those inherent abilities, which remain to be explained.

Economic and Political Theory: Cosandey further explains that for science and technology to advance in a given civilisation, two conditions are required: a thriving economy and a stable political division. That is, a rich and stable state system is needed. Western Europe enjoyed growing trade and manufacturing, and was divided between long-lasting competitive kingdoms, during the entire second millennium - that is why it succeeded the way it did.

In particular, the smart European scientific professional structure, the institutions that allowed scientists to make a living while doing research in universities, royal academies, private mathematical schools, etc, could come to life and survive, thanks to the existence of a wealthy and stable western European state system.

In this context, the XVI-XVII century scientific revolution is interpreted as the outcome of the economic boom and military revolution that western Europe underwent in the same period.

In the case of Middle East, India and China, whenever prosperity and stable divisions were there, scientific knowledge flourished. In all other cases, (political unity, fast-changing boundaries and/or economical doldrums), science recedes. Cosandey further explains that to get a clear

picture, one must consider each period separately.

Coastline Shape Hypothesis: Cosandey explains why western Europe benefitted from prosperity for such a long time? The main cause is the shape of its coastline. The western part of the European continent is the only densely populated area on the Earth boasting many peninsulas, gulfs, straits, inland seas, while still being, for the most part, an interconnected land. Such an articulated coastline enhances trade, because the sea accessibility makes maritime transportation easier. The sea route is much better than river or land transportation. Before modern times, it was safer, quicker, freer and tremendously cheaper. Moreover, an articulated coastline defines naturally limited core areas within which polities can live without much disturbance – Britain, Ireland, Spain, France, Denmark, Sweden, Italy are regions well delimited by the sea. The long-term stable political division stems from that advantage, as the sea is the best possible boundary for a state. In mathematical terms, the quality of a coastline is measured by Mandelbrot's fractal dimension of the coastline. The higher the dimension, the better is the shore articulation. Cosandey made some measurements on maps and obtained that Europe has a fractal dimension of 1.46, much higher than China (1.26), India (1.14) and the Middle East (1.13), which is significant because this figure can only take values between 1 and 2.

David Landes

Landes says, "If we learn anything from the history of economic development it is that culture makes all the difference. . . what counts is work, thrift, honesty, patience, tenacity". Landes explains that culture might include, in addition, such attitudes as willingness to challenge the natural environment, which previously was the realm of the gods; rebel against ancient traditions of how to make things; emulate the customs and techniques of otherwise despised foreigners; and adopt a rational and mechanistic attitude toward the manipulation of natural forces we call "production." These features determine technological creativity, and surely they are part of "culture" no matter how defined. He further explains the tendencies in medieval religion in which nature is subordinate to man and remarks that, while the old legends remained to warn against cosmic insolence (in East), "the doers were not paying attention (in West)".

Karl Wittfogel

Civilisations whose agriculture was dependent upon large-scale waterworks for irrigation and flood control were called "hydraulic civilisations" by the German-American historian Karl A. Wittfogel in his book, *Oriental Despotism* (1957).

Wittfogel believed that such "hydraulic civilisations" – although neither all in the Orient nor characteristic of all Oriental societies – were quite different from those of the West. He believed that wherever irrigation required substantial and centralised control, government representatives monopolised political power and dominated the economy, resulting in an absolutist managerial state. In addition, there was a close identification of these officials with the dominant religion and an atrophy of other centres of power. The bureaucratic network directed the forced labour for irrigation projects. Among these hydraulic civilisations, Wittfogel listed ancient Egypt, Mesopotamia, India, China and pre-Columbian Mexico and Peru. Wittfogel identified the centralised and bureaucratic empire as the one blocking element for eastern science, technology and economic development.

Max Weber's Views

Weber provided the specifics for the argument, with the details of the mechanism by which the belief in a "calling" and in worldly asceticism developed, leading to modern capitalism. Weber argued that these behavioural changes alone could not bring about modern capitalism, as it required an "appropriate set of conditions" in the economic sphere. Weber falters when it comes to explain the ancient Greek boom, the fast growth of northern Italy up to the Renaissance, or the great times in other civilisations (in particular India: 300-700, China: 700 to -200 and 800-1300 CE). He thinks naively that people are, on an average, moved by abstract ideas and not by their interests. Weber's idea seems to confirm that people are likely to believe:

- Simplistic ideas in fields where the mass of information and interconnections apparently makes the problem hopelessly difficult.
- Negative judgements about other people. It is so nice to feel superior.

Ziauddin Sardar

Passion for science isn't restricted to the richer countries of the West. If people think otherwise, it's because colonialism did its best to stamp out every last vestige of indigenous research in the East, says Ziauddin Sardar.

Ziauddin states that science and scientists in developing countries are not much different from their counterparts in the West. There is nothing uniquely Western about the pursuit of knowledge through deductive reasoning. All living cultures, however "backward" they may seem to the European gaze, have an appreciation of logic, reasoning and empiricism. A culture that does not value knowledge *per se* is a rare – and an extinct – beast. Cultural attitudes have nothing to do with scientific progress or lack of it in the developing countries. The assertion that science cannot develop in conformist societies is also false. Consider Japan, one of the most conformist nations, yet with one of the most developed scientific structures in the world. Neither was the European Renaissance unique. Many great civilisations have had their own versions – albeit in the distant past in some cases. We now know that the quantity and quality of science in Islamic, Chinese and Indian civilisations was truly mind-boggling. Historians of science now tell us that there is hardly a culture that has not produced some significant science.

Ziauddin argues that Europe itself learned deductive reasoning and experimental method from Muslim scientists. The European Renaissance would have been inconceivable without Islam: the scientific works of Copernicus were based on the labours of Nasir al-Din al-Tusi, a 12th-century mathematician from Khorasan, Iran. Where would optics be without Ibn al Haytham, a physicist and philosopher from 10th century Basra, Iraq. It's impossible to imagine mathematics today without the 9th century founder of algebra, Al-Khwarizmi.

There are differences between science in the West and the developing world. Some of them are historic; others have to do with the nature of modern science. But by far the most important reason for this difference is colonisation, which destroyed indigenous science. Colonial powers closed down colleges and universities, banned research and outlawed the practice of indigenous science and medicine. In Indonesia, for instance, the Dutch barred local people from higher education right up to the 1950s. Back in the colonising countries, the fruits of colonisation

fuelled European Renaissance and provided the Industrial Revolution with all the capital it needed. Sardar concludes by suggesting that science outside the West is held back by cultural attitudes or lack of willingness to confront authority is to simply repeat the mistakes of too many textbooks.

Our Suggestions

As we have seen above, there are no easy and simple answers to the Needham question. Such social phenomena are multidimensional and therefore multi-causal. We would like to emphasise simply on the negative roles of the Brahmins and the British.

There seems to be a deliberate attempt by the Brahmins to keep science as a monopoly of the Brahmin elite. It was expressed in symbolic form or terse *shlokas* which required detailed commentaries and explanations. The priests considered the natural cause and effect approach to human ailments and their treatment subversive, and the Indian lawgivers were obliged to denounce it as abject heresy. This led to the downgrading of practitioners of medicines in social hierarchy

They also put more emphasis on learning through rote rather than through critical discussion. The worst thing that they did was that they monopolised theoretical and philosophical knowledge and the practical work was delegated to the lesser castes. Even in the Harappan period, we find the metallurgists on the periphery of the settlement and all our artisans were pushed to the lowest rung of the social hierarchy. No wonder, whether it is the weavers or the blacksmith, they were treated as *Shudras*.

As has been shown by Dharampal, Claude Alvarez and A Rahman, Indian science and technology were faring well in 18^{th} century CE when Europe was still going through its Dark Ages. Indians were producing the best steel, doing plastic surgery and smallpox inoculation, and between China and India monopolised 75 per cent of the global industrial production. Even in the 12th-13th century CE, zinc production in Rajasthan was almost on an industrial scale. Our textile industry was highly developed and competitive. It was the colonial rule which practiced a deliberate policy of learning our technologies and utilising them for their own industrial revolution and systematically dismantling all our industries. The consequences of the negative socio-cultural factors generated by the Brahmins and the physical decimation of our science and industry by the British were mainly responsible for our regression. Perhaps, if the British had come a century later, India and China would have continued on their trajectory of industrial and scientific growth and perhaps overtaken Europe in assuring the industrial revolution.

Summary

Needham's question is rather vast and complex to answer. Such social phenomena are multidimensional and therefore multi-causal. The discussion on this question should not be limited only to explain the success of the West and the regression of the East in science and technology over the last few centuries, but also to explain the astonishing stagnation of the West from 300 to 1100 CE (the Dark Ages), and the progress of the East during this period.

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