THE SCIENTIFIC TRADITION IN INDIA FROM ANCIENT TO MODERN TIMES

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Stemming the tide of brain drain, Professor Narlikar returned to India in 1972 and continued his work on cosmology and astrophysics. Recently he has been engaged in the study of quantum fluctuations in the vicinity of space-time singularities at the origin of the universe. He is a recipient of prizes, medals, and awards, including Padma Bhushan from the President of India.

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INTRODUCTION

WE INDIANS are justifiably proud of our long tradition of culture extending back to recorded history and even beyond if we assume that some of our ancient scriptures like the Vedas were handed down from one generation to the next orally. The word 'culture' is defined by the Oxford Dictionary to mean 'trained and refined state of the understanding and manners and tastes, phase of this prevalent at a time or place, instilling of it by training'. Often, the usage of the combination 'science and culture' suggests that science is something that is different from what is implied in the above definition. In the celebrated quotation (*Īśa Upaniṣad*, 11) :

> *Avidyayā mṛtyuṁ tīrtvā vidyayā' mṛtamaśnute* (Having conquered death by *avidyā*, [he] attains to the nature of immortals through *vidyā*),

the word *vidyā* is identified with knowledge of the spiritual kind and *avidyā* with the scientific knowledge. I will return to this particular quotation towards the end.

I see no reason to set 'science' apart in the evaluation of the 'culture' of a civilization, ancient or modern. For science develops through man's attempts to 'understand' Nature and through his applications of that knowledge for practical purposes. Directly or

indirectly the state of science in a civilization influences it materially and spiritually. The directness of this influence is perceived in the standard of living enjoyed by the members of the civilization, in the way its houses, roads, and monuments are erected, in the way its battles are fought, and in the way the dissemination of information takes place amongst its members. The indirect influence is seen in the thinking of its intellectuals including poets, littérateurs, philosophers, and even religious leaders.

The Scientific Discipline

With all these influences that it generates, science works in a set and disciplined framework which has been both its strength and its weakness. The weakness is highlighted in the following extract from *The Condensed Gospel of Sri Ramakrishna* :

> *Ishan* (to Doctor) : May I ask why you think that God does not incarnate Himself as a human being ? It was only a moment ago you admitted that God may be with form as well as without form, and said that nothing is impossible with God.
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> *Sri Ramakrishna* (smiling) : My dear Sir, the fact is, such a thing is not declared in his books on science. (*Laughter.*) It is not set forth there in so many words that God may come down into this world as a human being for the salvation of mankind. That being so, how can he believe ? (*Laughter.*)
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> Let me tell you an amusing story. A person called upon a friend and reported to him saying 'Haven't you heard the latest news ? Well, I was yesterday passing along the street when down came the house belonging to the Mukherjis with a terrible crash.' The friend cried out, 'Is that so ? But let me consult the newspaper and see if this is true.' He read the newspaper, but there was nothing about the coming down of the house. Upon this, he coolly said to the other, 'I can't put faith in your words. It is not so stated in the paper here.' The first replied, 'But I saw it with my own eyes !' The man still would not believe, and said, 'Well, there is nothing set down in the newspaper about it ; how can I believe it ?' (*Laughter.*)
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> People do not see that science deals only with the conditioned knowledge. It brings no message from the Land of the Unconditioned. Such message has been brought by holy men who have seen and realised God like the *Rishis* of old. It is they alone that are competent to say 'God is thus and thus.' [1]

The limitations on scientific knowledge implied in the above example arise because science cannot deviate from its set pattern of experiment, observation, inference, theory, and prediction. The first two steps generate the source material, the mysteries that science is called upon to unravel. The next two steps come out of the human brain in the form of attempts to answer the challenge posed by the first two steps. The last step is a test of how successful the attempt has been. For it must not only explain the existing mysteries but come out with new results that future experiments and observations can verify. And so the cycle goes on and only the knowledge generated in this fashion is admitted as part of science.

By so limiting his framework the scientist has, however, the advantage of objectivity. The knowledge and understanding achieved by science do not depend in the last analysis on the credibility or prestige of any individual scientist. Even an Einstein may not be

[1] *The Condensed Gospel of Sri Ramakrishna*, Sri Ramakrishna Math, Mylapore, Madras, 1978, pp. 276–7.

believed if his ideas fail to meet the discipline imposed by science. Also the experiments of science are repeatable under controlled circumstances by any competent person—they do not depend on any special powers of a selected individual.

The 'conditioned knowledge' that Sri Ramakrishna refers to in his description of science may, in modern context, be termed as the basic laws of science obtained by the above five-step cyclic procedure. The laws are based on detailed experiments and are quantitatively expressed in the language of mathematics.

I have gone into some details about how science works because it is within this framework that I propose to look at the scientific traditions in India.

The Vedic Times

Science is characterized by a questioning attitude. The 'whats', 'hows', and 'whys' are essential for the scientific culture to take root and prosper. Going back to the Vedic times we do find evidence of this questioning attitude. I give an example from the *Nāsadīya-sūkta* :

Nāsadāsīnno sadāsīt tadānīṁ nāsīdrajo no vyomā paro yat. Kimāvarīvaḥ kuha kasya śarmannambhaḥ kimāsīd gahanaṁ gabhīram. Na mṛtyurāsīdamṛtaṁ na tarhi na rātryā ahna āsīt praketaḥ. Ānīdavātaṁ svadhayā tadekaṁ tasmāddhānyanna paraḥ kiṁ canāsa. Tama āsīt tamasā gūḍhamagre'praketaṁ salilaṁ sarvam ā idam. Tucchyenābhvapihitaṁ yadāsīt tapasastanmahinā'jāyataikam. Kāmastadagre samavartatādhi manaso retaḥ prathamaṁ yadāsīt. Sato bandhumasati niravindan hṛdi pratīṣyā kavayo manīṣā. Tiraścīno vitato raśmireṣāmadhaḥ svidāsīdupari svidāsīt. Retodhā āsanmahimana āsantsvadhā avastāt prayatiḥ parastāt. Ko addhā veda ka iha pravocat kuta ājātā kuta iyaṁ visṛṣṭiḥ. Arvāgdevā asya visarjanenāthā ko veda yata ābabhūva. Iyaṁ visṛṣṭir yata ābabhūva yadi vā dadhe yadi vā na. Yo asyādhyakṣaḥ parame vyomantso aṅga veda yadi vā na veda (*Ṛg-Veda*, X. 129).

Loosely translated into English this reads thus :

> 'At that time (when the universe was not born) there was no *sat* (being) nor was there *asat* (non-being). At that time there was no space nor was there the sky beyond it. Who (then) covered what, where and for whose welfare ? Was the dense fathomless water there ? Then there was no death nor was there the immortal to be distinguished from it. There were no means available to distinguish between night and day. (Whatever existed) was unique and alone surviving on its own. There was nothing else or beyond. There was darkness and living forms covered by it and free of any distinction. The Brahmā was covered by Māyā and appeared later (in a different form) because of penance. The seed from its mind was *kāma* (desire), the inspiration for creation. The wise have thought over it and decided that this was the (first) contact between *asat* and *sat*. This thread was spread between them below as well as above. (From these) some gave seeds that grew. Their power remained here and influence spread there. How did the spread of *sat* come about ? Who can tell this in detail ? Who knows definitely ? Even gods came after the spread (of *sat*). So who can know where the creation came from ? This spread (of *sat*), where it came from, whether created or not may or may not be known to him who presides over the great heavens (who can tell ?).'

We also find evidence of this attitude in Upaniṣads and some of the Purāṇas. Unfortunately this attitude seems to have fizzled out, perhaps largely through the tradition of orally transmitting knowledge from one

generation to another, with no critical discussion between the teacher and the pupil. Even in the *Bhagavad-Gītā*, we find Arjuna asking critical questions in the early stages :

Jyāyasī cet karmaṇaste matā buddhirjanārdana ;

Tat kiṁ karmaṇi ghore māṁ niyojayasi keśava.

Vyāmiśreṇeva vākyena buddhiṁ mohayasīva me ;

Tadekaṁ vada niścitya yena śreyo'hamāpnuyām (III. 1, 2).

(If you hold, O Janārdana, that knowledge is superior to action, why, then, O Keśava, do you engage me in this terrible action ? With these apparently contradictory words you seem to confuse my understanding. Therefore tell me definitely that one thing by which I shall reach the highest goal.)

But later this critical attitude does not remain, although Lord Krishna Himself at the end does not insist that Arjuna follow his dictates : He says, *Yathecchasi tathā kuru* (Do as you please).

Our ancient tradition of accepting guru's sayings uncritically perhaps has not encouraged the scientific discipline. This may very well have been the reason why very few of our ancient manuscripts contain descriptions that would conform to the scientific discipline. I give an example.

As the late M. N. Saha[2] pointed out, almost all the Hindu calendars are based on Vedic traditions, enunciated for example in the *Vedāṅga Jyotiṣa*. Various time scales are found in the Purāṇas, of which the time scale giving the day of Brahmā as 4·32 billion years is intriguing. This duration is derived as made of 1,000 cycles of the four *yugas*, each cycle taking 12,000 divine years, with one divine year equal to 360 human years. The final answer of 4·32 b.y. is amazingly close to the present geologically estimated age of the Earth, 4·6 b.y. Is this a coincidence ? Or did the ancients know about dating the Earth and other astronomical objects whose ages are presently estimated in the 10–20 b.y. range ?

Unfortunately a scientific account is lacking and one must only conjecture. In this context an astronomical interpretation is given by S. R. N. Murthy in an article recently reproduced.[3] Murthy points out that the above time scale and others, shorter and longer, were obtained in the *Sūryasiddhānta* (one of the five *siddhāntas* by Varāhamihira) from the then available information on the rate of precession of the equinoxes. If so, the time scale of 4·32 b.y. is related to celestial mechanics and not to the nuclear age determinations of the Earth and the stars.

As a scientist I am often asked to comment on how much of modern science was anticipated by our forefathers of the Vedic times. Since our ancient literature and mythology contain descriptions of such objects as guided missiles, spacecraft, helicopters, remote sensing, television and radio, and advanced medicines, it is tempting to argue that these inventions of science were known in those times. The argument can indeed be carried further by saying that the conditions of a human society at any given time find their echoes in the literature created by its members ; and so the above literary pieces must indicate the actual existence of the objects described.

For scientific evaluation such an argument can at best serve to provide a prima facie case, not a conclusive proof. The same

[2] M. N. Saha, *Calendar Reform Committee Report*, Government of India, 1955.

[3] S. R. N. Murthy, 'The Age of the Earth According to the Hindu Calendar', *Journal of Geological Survey of India*, XXIII, 441, 1982.

limitations apply to instances cited [4] wherein the philosophical ideas expressed in Vedic literature resemble the conclusions or basic premises from modern scientific fields like the quantum theory, relativity, and particle physics. The important difference to note between literature or philosophy on the one hand and science on the other is that the latter makes quantitative statements and provides prescriptions for conducting experiments that any competent scientist can translate into reality. Unless such evidence is forthcoming the scientist will remain unconvinced that high levels of science and technology were present in the olden times.

So far I have not seen such evidence. For example, Vimāna Śāstra does not provide a manual to enable us to construct an aeroplane. Nor do we have a technical description of how guided missiles were made. It is encouraging, however, that some investigators are going into details to see whether some of the statements in the ancient literature do contain quantitative descriptions.

For example, Bhayyasaheb Pant [5] has discussed some Vedic statements about the Sun and has argued that the modern theory of nuclear fusion as the source of solar energy is contained in them. Impressive though this discussion looks, I have a word of caution. Sanskrit is a flexible language and several meanings can be drawn from a single Sanskrit sentence suitably constructed. Even the learner of elementary Sanskrit knows of such sentences as : *Kāśītalavāhinī gaṅgā* or *Kambalavantaṁ na bādhate śītam**. A language that has delighted readers with literary gymnastics and ingenious multi-meaning phrases unfortunately poses problems for scientific statements which have to be unique-meaning and precise.

The Post-Vedic Traditions

Much more can be said on the difficulties of interpreting the ancient Vedic literature, but the present limitations of space and time prompt me to move to later epochs. Here we do have evidence of the kind acceptable to scientists. I cite some brief instances.

The medical science as contained in the Āyurveda derives much of its inspiration from the *Caraka Saṁhitā* and the *Suśruta Saṁhitā*. Here we have definite specifications of how to identify diseases from symptoms, how to treat the patients with medicines, how to perform surgical operations, and so on. They do satisfy the criterion of a scientific description and invite further interest into their contents.

It is only comparatively recently that social and behavioural sciences became recognized as part of science. Human relations, industrial relations, economic theories, etc. are now taught by experts to students aspiring to control and manage the complex forces that visibly or invisibly shape our society today. Yet many of the practical dicta of today were anticipated and explicitly stated in the *Śukra-nīti*, as the following verses about employer-employee relationship will show : [6]

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[4] *The Tao of Physics* by F. Capra, Boulder, Shambhala, 1975.

[5] *Dirghatamas Ani Surya* by M. B. Pant, published by M. P. Pant, Pune, 1970.

* The first expression can be put in the form of a question by separating *kā* from the rest : *Kā śītalavāhinī gaṅgā* ? (Which part of the Gaṅgā flows coolly ?) The answer is found in the expression itself, *Kāśītalavāhinī gaṅgā* (the Gaṅgā that flows through Kāśī). Similarly, the second expression can be put in a question form thus : *Kaṁ balavantaṁ na bādhate śītam* ? (Who is that strong man whom cold does not torment ?) The answer, again, is given in the expression itself, *Kambalavantaṁ na bādhate śītam* (Cold does not torment one having a blanket).

[6] *Labour Management* by R. G. Rajwade, published by N. R. Rajwade, Bombay, 1984.

Ṣaṣṭhāṁśaṁ vā caturthāṁśaṁ bhṛter-bhṛtyasya pālayet ;

Dadyāt tadardhaṁ bhṛtyāya dvitrivarṣe'-khilantu vā.

Catvāriṁśat samā nītāḥ sevayā yena vai nṛpaḥ ;

Tataḥ sevāṁ vinā tasmai bhṛtyardhaṁ kalpayet sadā.

Yāvajjīvaṁ tu tatputre'kṣame bāle tadardhakam ;

Bhāryāyāṁ vā suśīlāyāṁ kanyāyāṁ vā svaśreyase.

These verses describe how to set up the provident fund and the rules for pension and family allowance. One-sixth or one-fourth of the wages of the employee should be deducted and he should be paid back half or full amount so deducted after two or three years. An employee who has served for forty years should be paid a pension equal to half of his wages, throughout his life. And after his death a family allowance equal to half his pension be paid to his wife, if she is faithful, or to his daughter for her well-being so long as his son is a minor.

From the practical science of human behaviour let us turn our eyes heavenwards, to astronomy—perhaps the oldest of all sciences. Right from the times man began to think and reason, he must have wondered about the Sun, the Moon, and the stars. Here, again, human imagination ran far ahead of his scientific understanding and to assess the scientific achievements of a human society one must carefully extract the scientific kernel from a much larger superstructure found in the literature of the times.

So far as positional astronomy is concerned we do find work of sophisticated calibre in the writings of Āryabhaṭa, Varāhamihira, Bhāskarācārya, and some others in the first millennium A.D. For example, Āryabhaṭa had calculated that all the planets (then known) were on the same meridian passing through Ujjain in the year 3102 B.C. on February 18. This date is traditionally taken as the starting point of Kali-yuga. The correctness of this calculation was accepted later by the French Academy of Sciences, as mentioned in the *Encyclopaedia Britannica.*[7]

Āryabhaṭa in fact was far ahead of his times when he questioned the dogma prevalent in those days that the Earth is fixed amidst a revolving heavens. His *śloka* (verse)

Anulomagatirnausthaḥ paśyatyacalaṁ vilomagaṁ yadvat ;

Acalāni bhāni tadvat samapaścimagāni laṅkāyām (*Āryabhaṭīya,* iv. 9)

clearly states that the fixed stars appear to rise and set because the Earth revolves around an axis just as a man going in a boat sees the fixed (trees) on the river bank move in the opposite direction. Āryabhaṭa's colleagues and successors did not take him seriously, however, and an important result remained unrecognized until Copernicus put forward the heliocentric theory ten centuries later.

Professor John Playfair (1748–1819), commenting on the accuracy of the work of the early Indian astronomers, has observed : 'Undoubtedly the ancient astronomers must have possessed the best instruments probably differing from the modern ones, but fully as powerful.'[8] As late as 1823, the writers of the *Encyclopaedia Britannica* considered Mān Mandir in Banaras to be one of the five most celebrated observatories of the world, the other four being the Royal Greenwich Observatory built by Charles II in 1675, the Paris Observatory built by Louis XIV in 1667, Tycho Brahe's Observatory in the

[7] *Encyclopaedia Britannica,* Second Edition, X, 477, 1823.

[8] K. D. Mathur, 'Indian Astronomy in the Era of Copernicus', *Nature,* CCLI, 283, 1974.

Island of Hven whose construction was begun in 1576, and the Peking Observatory rebuilt by the Emperor Ch'ien Lung. Krishnan Mathur[9] has pointed out that the Banaras Observatory was flourishing at the time of Copernicus and mentions several astronomers in the fifteenth century who were actively engaged in astronomical calculations.

Alas, this activity was the last flicker before the destructive axe of the invaders fell. I will return to this break in tradition later.

Mathematical Tradition

Mathematics has been an important component of Indian astronomy, although it flourished in ancient India in its own right. Although we think of arithmetic in terms of numbers, symbolic words corresponded to numbers in such ancient works as the *Śatapatha Brāhmaṇa* and *Taittirīya Brāhmaṇa*. Thus *kṛta* was used for 4, *gāyatrī* for 24, *jagatī* for 48, and so on. Proponents of Vedic mathematics even quote a verse whose words are supposed to codify 'pi', the ratio of the circumference of a circle to its diameter, to several decimal places.

I find such examples intriguing and somewhat disturbing. The number 'pi' is known today to be a transcendental irrational number whose decimal expansion does not follow a recurring or any other known pattern. Fairly advanced numerical analysis is needed to work out a decimal expansion to several places. If the ancients knew the answer, why did they not leave any record of the method of computing it ?

The discovery of the number zero, its place in the real number system, and the usage of the decimal numerals (which are far more convenient than the Roman numerals which evolved in the West) are valuable contributions of ancient Indian mathematicians whose names unfortunately we do not know.

Square root, ratio and proportion, interest problems, quadratic equations, and trigonometric formulae are some of the mathematical operations used by mathematicians like Brahmagupta, Śrīdhara, Mahāvīra, and Śrīpati. Bhāskara who is known for astronomy as well as mathematics wrote several works of high calibre. His problem book *Līlāvatī* is a delight to read, containing as it does, interestingly presented mathematical problems together with their solutions.

A Break in Tradition

Although India has had scientific traditions dating back to several millennia, there appears to be a break lasting several centuries immediately preceding the last century. After Bhāskarācārya there was no significant work in India either in mathematics or in astronomy. Likewise we find a break in the progress of science on all fronts since about the twelfth century. The modern thrust on science and technology, though highly commendable for a developing country like ours, is largely an implant from the West, seeded during the British rule.

To me this break in tradition is something of a mystery. Nobel laureate Abdus Salam has expressed it in this form. The Taj Mahal and St Paul's Cathedral were built around the same time. Both represent architectural maturity of the highest level. Yet, in Great Britain, this epoch was followed by great strides in science, followed in turn by the Industrial Revolution. In India these developments did not take place. Why ?

Why did the Moguls and other kings who patronized the arts and architecture not support science, as their counterparts did in Europe ? Why did our society which produced literary figures, saints, and philosophers, musicians and artists not produce

[9] ibid.

even a handful of scientists during these crucial centuries ?

Was it because the country was unstable because of wars and foreign invasions ? This could hardly be the reason. Europe had great and small wars, revolutions and repression, in spite of which science flourished there. Was it because the extreme climatic conditions in Europe called for scientific inventions for survival while in India the survival problems were not so challenging ? If so, why did severe droughts and famines in India not prompt research in improvement of agriculture ?

It may well be that our excessive tolerance of hardships and the socio-religious tradition of self-denial were at the root of apathy towards science. Scientific and technological achievements even today tend to be identified with materialistic gains and looked down upon. If therefore this attitude has been at the root of the break in our scientific tradition then it has cost us dearly. A survey of the history of India over the last four centuries shows how the backwardness in science and technology that grew progressively compared to Europe finally cost us our independence.

Albert Einstein remarked : 'Religion without science is blind ; science without religion is lame.' Just as science has a lot to offer to the human society, so does religion. Both play complementary roles ; neither can afford to do without the salutary influence of the other. *Vidyā* and *avidyā* must go forward, hand in hand.

In Ramakrishna's parable about 'go ahead', the wood-cutter was advised by a *Brahmacharin* to explore the forest further. When he followed the advice the poor wood-cutter was richly rewarded.[10] The parable brings out the importance of the search for truth which religion and science both undertake in their different ways. Let me end with the hope that the vast storehouse of religious wisdom of this country will nurture and aid the prosperity of our newly emerging scientific tradition.

[10] *The Condensed Gospel of Sri Ramakrishna*, op. cit., pp. 176–7.

WHAT we [Indians] need . . . is to study . . . different branches of the knowledge that is our own, and with it the English Language and Western science ; we need technical education and all else that may develop industries so that men, instead of seeking for service, may earn enough to provide for themselves, and save something against a rainy day.

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