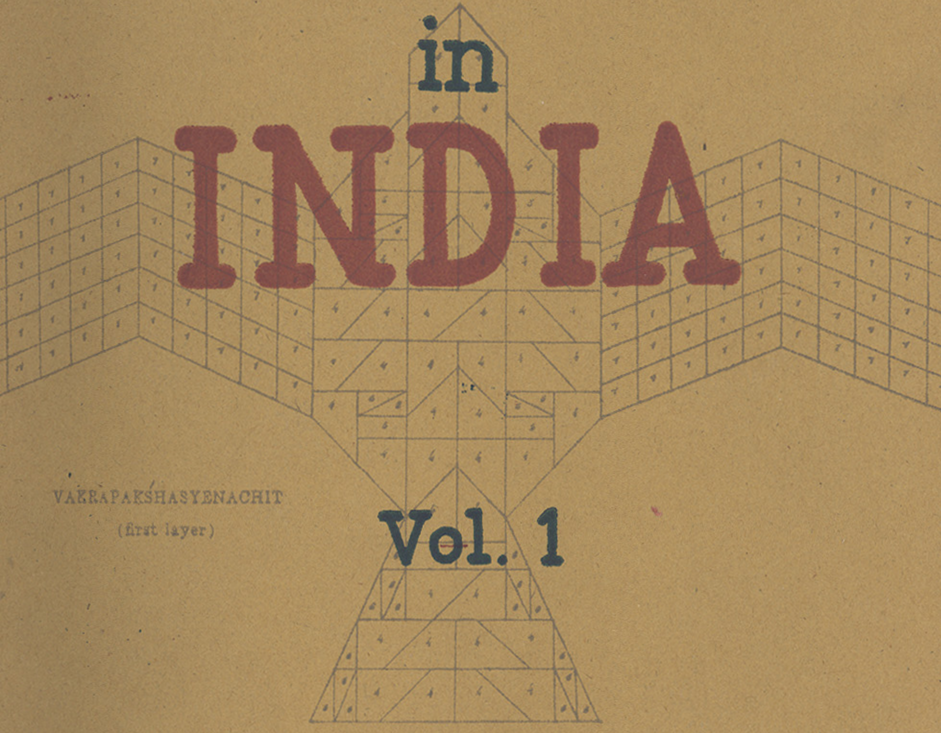
Studies in the HISTORY of SCIENCE in INDIA



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DEBIPRASAD CHATTOPADHYAYA

Studies in the History of Science in India
Volume 1

Studies In The HISTORY Of SCIENCE In INDIA

Volume I

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Th. STCHERBATSKY

INTRODUCTION

The progress of a nation, viewed in historical perspective, does not always proceed along a continuously advancing straight line. At times this progress is arrested, and the reverse process sets in. Though this phase may be more or less temporary, it may sometimes lead to even complete annihilation of the native population from the arena of history and its replacement by the aliens. The historical development of the peoples is checked by wars—external and especially internal—particularly when they continue too long. But, then, they also do some good provided they are followed by spells of peace and order—sometimes on a larger territory than that involved in war. The history of the Indian peoples, as that of no other peoples on earth, for four thousand years of which more or less accurate data are available, is full of such examples of zigzag advance and arrest of culture. We see clearly that during these four thousand years of India's history, in the few epochs when the country was united under one power, was well governed, and was not subject to foreign yoke, it made rapid advances in all directions. The remarkably rich and large territory of the country and the high degree of competence of the people apparently secured the possibility of its rapid progress. And in fact, when in the fourth century B.C., in the course of its aggressive advance on the East, the Greek civilization reached India, it met resistance from the high Brahmin culture which was in no way inferior to the Greek civilization. Alexander's forces were found inadequate for conquering even a small part of Indian territory. The towns founded and the population left behind by him were fast submerged in the surrounding Indian environment, exerting little or almost no influence.

There are, on the whole, two distinct periods in the history of India when large territory of the country was united under one power, was well governed, and was strong enough not only to repel any foreign attack but also to march on the path of progress. The first of these is that immediately following Alexander's invasion; the other—and a more prolonged one—is that from the fourth to the seventh century A.D. During all other periods, India appears to us a picture of disorder, internal discord and weakness as compared to her neighbours, who flowed into her territory in a continuous stream and dominated the country one after another. The Persians, the Greeks, the Scythians, the Turks, the Huns, the Arabs, the Afghans, the Mongols, and then the Portuguese, the Dutch, the French and lastly the British—all avidly strove for the domination of the country, whose legendary riches, high culture and unusual weakness held out promises of rich gain—until the British finally overpowered all the rivals and united the whole country under their sway. ...As also in other countries, nothing in India could withstand the energy of Islam. What happened in many other countries did not, however, happen in India. The Indian culture did not vanish once and for all. What happened in India was something unusual and almost singular in the history of humanity: the national life withdrew within its ancient heritage and preserved itself within the socalled caste structure and in particular alliances of religious character imbued with the spirit of extreme conservatism, culturally absolutely static, inaccessible to any outside influence, and at the same time highly submissive to any power, resigned to any foreign aggression—not having the capacity to show any resistance whatsoever. Under this strict caste system, no progress could have been possible.

CHARACTER OF THE PEOPLE

The scientific achievements of the Indians are closely related to their national character, which has left its imprint on all their work. What strikes most a student of the history of Indian scholarship is the excessive development of the imaginative powers of the Indians. In any work, some imagination is absolutely essential. Not to speak of poetry and philosophy, no hypothesis is possible without imagination. Its exceptional or prominent development, however, becomes a setback : it alienates a person from reality, that is from truth and may lead him so far away that the gulf between fantasy and reality may become unbridgeable. It would be unfair to say that the flight of fantasy in India was absolutely unchecked. Normally, proceeding from a rational basis and developing with inexorable logic, this fantasy works in a known direction along specific lines ; the idea is worked out upto the end till it leads either to a blind alley or to absurdity. The remark made by the leading modern mathematician-philosopher, Bertrand Russell, that one wishing to be a philosopher must learn not to be scared of absurdity, is fully applicable to the Indian methods of work. The Indians never feared carrying things to absurdity if their inexorable logic so demanded. Such disposition of the people, it is clear, made them take up primarily those sciences which were dominated by the method of speculation—the method *a priori*—viz. inference of a result theoretically from some principles established or accepted beforehand on belief. This is why philosophy has been the strongest side of Indian scholarship. This field is still far from being fully known to us. One might even say that the veil has hardly been lifted from the enormous riches of Indian philosophical thought. And nevertheless, we have witnessed what revelation the first light of Indian thought has brought to Europe in spite of its having reached through the prism of bad translations. Schopenhauer's system, as its author himself acknowledged, was much indebted to Indian influence. But the pioneer work in this field is still only in its infancy. The greatest Indian thinkers, Dignāga and Dharmakīrti, are almost still unknown to Europe.

As regards experimental sciences, one cannot say that the Indians did not at all know experiment and observation. On the contrary, they were very good observers. We have highly significant embryos of a majority of experimental sciences during the glorious period of Indian scholarship. However, in this respect, they lag behind other nations, particularly the Greeks. During the period of decadence and difficult living conditions, the experimental sciences completely vanished whereas the favourite contemplation of Indians went on.

PHYSICS

Indian physics represents the transition state from pure philosophical speculation to experimental science. We have a number of theories about the structure and evolution of the material world from the primary substance. From the most ancient times, we find in India a number of cosmogonic systems, gradually passing over from mythological conceptions to distinctive scientific theories. The earliest system that is fit to be called scientific is the Sāṃkhya. According to it, the whole world with all its diversity—everything of the nature of unorganised matter, all the plants and the entire world of animals—everything is basically and essentially material. This diversity includes not only the inert mass but also the active forces and conscious processes, yet all this is derived by evolution from one primeval matter. This system cannot be called fully materialistic, for here the conscious processes do not invariably arise out of the material ones, and a special conscious constituent is assumed to exist separately from matter. This conscious constituent is present in the process of evolution of matter, as it were, but it does not participate in it. By itself, it is absolutely inactive. All psychical processes are the processes of matter and special material forces. But among the constituents of matter, there is one that is akin to the spiritual one and is capable of perceiving and reflecting its static being. This spiritual element can, however, be safely ignored, for it plays no role in the process of evolution of matter. In all other respects, the system is fully materialistic, for the whole complex process of evolution is accomplished by matter from out of its own forces without any outside interference or control of the conscious will. Therefore, in the beginning of the universe, we have only one shapeless, indivisible, unbounded, all-pervading, indestructible, eternal primeval matter which none has created and none controls. But its unity and immobility are caused only by the fact that the forces flowing in it are linked in a state of equilibrium. When this equilibrium is destroyed under the influence of undetermined transcendental causes, the primeval matter is found to have three different constituents—i.e. the constituent mentioned above, which is capable of developing into consciousness; the opposite constituent of inert mass; and the active constituent of forces or energies, under the influence of which the whole process takes place. These energies are conceived as a constituent, which has no mass or weight but has a quantum in every real product of matter. All the three constituents—mass, energy and the conscious—are inseparably linked to each other. The primeval matter is a continuous limitless substance consisting of infinitely small particles of these three inter-acting constituents. The nature of their inter-action is such that one cannot exist independently of the others. Energy cannot exist without mass; the conscious presentations do not occur without energy. The presentation finally obtained, however, depends on the constituent that is predominant. Thus, for instance, a material body in a state of rest shows the predominance of mass; the energy is linked here but the conscious constituent is not at all developed. The same body in motion shows the dominance of the constituent of energy; the mass i.e. resistance is overcome and the conscious constituent is not developed. In a conscious wilful motion, the appearance of energy is due to the predominance of conscious constituent and the presence of the inert constituent is expressed in the overcoming of hindrances. In the primeval matter also, all the three constituents do not come into being, for which it is necessary that here and there one of them should become dominant and thus release a part of the interlinked constituents. The process begins when the individual particles of the three constituents scattered indifferently in the primeval matter, arrange themselves to form a whole under the influence of natural affinity. This results in uneven pressure in various parts of matter, and the single undifferentiated matter yields to various bodies which go on forming gradually—all different from each other.

Unlike in the atomistic systems, evolution does not take place here by the accumulation of atoms. The atoms are there but they are formed later : there are still three stages of infra-atomic development and the atom is not the first one. Every atom has all the three universal constituents of primeval matter. The evolution generally takes place in the matter as a whole ; it is described as the process of transformation of homogeneous, indeterminate and undifferentiated mass into heterogeneous, determinate and organised bodies. In the process of evolution, nothing is added or taken off ; matter can be neither created nor destroyed. The sum-total of matter as a whole—its three constituents—remains constant, if all its states, actual and potential, are taken into account. The elements of matter are in eternal motion, which cannot stop even for a single moment. Any material process—any growth or decay—is nothing but a redistribution of the particles of matter, its transition from past to present, from present to future or from potential to actual state. The redistribution of mass and energy gives rise to all the diversity of material world, plants and animals. The process of evolution of primeval matter begins when its three component constituents are separated from each other. Later, this separation becomes obvious. All the Indian systems are formulated on the basis that matter, fully determinate and cognizable, consists of a number of sensual qualities—of smells, tastes, touches, colours and sounds. We know of no other matter outside these qualities. Therefore, there are five forms of matter corresponding to our five senses. Though they are called earth, water, fire, air and ether, what is however meant by these is only the various agents causing their respective sensations. Thus, in the evolution of matter, bifurcation takes place along two different lines : one—for the products with the predominance of the element capable of forming consciousness, thus giving rise to substances with consciousness and sense organs ; and the other—where inert matter is predominant, and we get its five forms corresponding to five senses. First, matter is formed—though differentiated yet subtle, containing only the capacity of showing the respective qualities. Thereafter, further evolution takes place, when these elements are condensed into real sensual qualities.

This is how this process takes place : at first, in the most subtle rarefied primeval matter, are formed separate points of rotatory motion—whirlwinds of its type—containing potentially the capacity of sound. Then, these points are so condensed that the real atom of ether is formed out of them. This atom having its special energy decomposes under the influence of the same primeval released energy and creates a new centre of new energy, generating the possibility of touch in it, which then forms an atom of matter of touch. The material atoms of fire and of taste and smell are also formed in the same manner. Thus every subsequent atom possesses all the qualities of the previous ones so that the atom of hard matter possesses all the sensual qualities—sound, taste, touch, heat and finally smell.

VAIŚEṢIKA SYSTEM

Other Indian atomistic systems originated from the notion of infinitely small dimension. In the most ancient literature, there are speculations on the infinitely small bodies. The soul, conceived as the body having absolutely no dimension, was at that time considered such an entity. In the Vaiśeṣika system, the atoms are divided into complex—having minimum dimension,—and simple or dimensionless mathematical points. These points, however, have potential qualities—corresponding to the four main senses—on the basis of which they are divided into four categories. In the system, sound and its corresponding element, ether, do not have atomic structure. Ether only fills the empty space between the dimensionless points of simple atoms. In order to form a complex atom it is necessary to have at least six such dimensionless points which, together with ether filling the space between them, form something like a prism. It is only homogeneous atoms of the same category that can form a complex atom ; the heterogeneous simple atoms cannot form anything. Since in simple atoms, the qualities are only potential—in the forms of imperceptible forces—it is necessary that some homogeneous points should arrange themselves in a special compound, which is called creative and is analogous to the chemical one. In matter as existing in the universe, atoms cannot exist freely without combination with others. Any specific quality is always traced back to a compound of two atoms with potential qualities of the same type. The only exception is air which, some scholars opine, is the aggregate of free atoms —which, so to say, do not join the chemical compound. The Vaiśeṣika system did not in any way negate the fact that bodies consist even of heterogeneous atoms having different qualities ; but these so-called extraneous qualities will have only subordinate and secondary importance in the formation of the body. A body consists mainly of matter ; the atoms of other categories only further the main process of formation of the body. The temperature developed in the chemical processes always presupposes the existence of solid so-called earth atoms. Neither air nor water can heat up by itself.

THE ATOMIC THEORY OF THE JAINAS

The theory of the Jainas is distinguished from the Vaiśeṣika system in that the former assumes the existence primarily of the homogeneous atoms only—those of matter, in general. Each atom is an infinitely small quantity and is, by itself, devoid of qualities. These qualities, however, do exist potentially; each atom thus possesses taste, smell, colour, temperature and other special tangible qualities which can cause amalgamation of atoms forming new bodies. For this, mere neighbourhood of the atoms is not enough; more of mutual conjunction is necessary, for which they must have opposite qualities. Two homogeneous atoms cannot blend together. One must be, so to say, positive and the other negative—or, if they are homogeneous, the intensity of one quality must be at least more than twice that of the other. When two atoms of opposite qualities blend together, something like mutual attraction takes place betwen them. If the amalgamation is caused by the intensity of one element, the higher degree of intensity absorbs the lower one. All changes in the qualities of compounds are explained by the nature of their mutual attraction.

THE ATOMIC THEORY OF THE BUDDHISTS

The most interesting atomic theory in India is perhaps that of the Buddhists. They generally started by negating the existence of every eternal substance. They pictured the world as a photoplay consisting of unique flashes of light. Strictly speaking, there is no matter; there exist only forces. At first, it was the existence of spiritual substance only that was denied. This gave rise to a controversy between the Brāhmaṇas and the Buddhists on the existence of soul. The Buddhists, on the whole, were great negaters. They negated the existence not only of God and soul, but also of every substance. The soul was replaced by separate mental elements or ideas and matter by individual forces. The flashes of these forces were not in any way connected with each other; they did not belong to any substance. They were linked to each other in the regular whole of the universe only by the fact that their appearances or flashes were regulated by laws of strict causality. Just as the light of a lamp appears to an observer as a lasting object—in reality, there is a new flash of light every moment—exactly so, all other material elements, i.e. colour, sound, taste, smell and touch are nothing but a chain of recurring flashes. Thus, an atom is nothing but a momentary flash, appearing according to specific laws in relation to all other flashes which the world consists of. But not a single atom like this is ever met in nature. We have in nature only complex atoms, each atom having at least eight parts of which four are of the nature of primary forces, and the other four—of dependent secondary forces. The primary forces are earth, water, fire and air, but what we actually mean by these is the forces of reflection, adhesion, heating and movement. Thus the complex atoms and everything that consists of them possess these four forces. For instance, a flame has a motion, a temperature, an arrangement of particles and a certain elasticity—and because of the presence of these forces in the basic element—the complex atom. Besides these four basic forces, each such atom has four secondary qualities, namely, the atom of colour, the atom of taste, the atom of smell and the atom of touch. Each of these secondary qualities is an individual element, linked to the rest only in the sense that it appears simultaneously—or, in other words, simultaneously flashes out. Here, there should be four basic atoms for every secondary atom. The atom of organized matter, which the living bodies consist of, is still more complex in structure. The whole living body is represented as covered with thin matter, which is compared with the light matter appearing in scintillation, when emanating from a precious stone. It has no weight; it cannot be dissected since a hard object can pass freely through it. After death, it vanishes without leaving any residue; no trace of it is found in the dead body. It also has atomic structure. In the same way, we have secondary atoms of matter, which are living, visual, auditory, and which can perceive the smells, the tastes and the touches. In this case too, each moment of such matter cannot appear without the support of the four basic forces.

MEDICINE

Coming to the field of experimental sciences, it is necessary first to note the advancement of the Indians in chemistry and botany. Both these sciences had practical importance as necessary branches of medicine. The Indians regard medicine as the oldest of the sciences and, in all probability, its sources were borrowed from the Babylonians. The Indian medicine originated from the notion that a body remained healthy if there was equilibrium between the three basic secret fluids, which are there in a human and animal body and are controlled by the normal performance of its functions.

These concepts, on the whole, corresponded to Hippocratic humoral pathology. They were passed on by the Arabs to the medieval Europe where they held sway right upto the beginning of the nineteenth century. But it is difficult to say whether these notions were borrowed by the Greeks from the Indians, or reversely, by the Indians from the Greeks. It is probable that their medical concepts, as those of the other peoples, have been taken from ancient Babylon. In any case, there has been an active exchange of medical knowledge between both the cultured peoples of that time, which is evident from the large number of important prescriptions for various diseases. In fact, these ideas of humoral pathology were only the theoretical side of the affair. They did not at all interfere with accurate observation, not to speak of experimentation. The Indian medical literature gives us a number of fine descriptions of various diseases and of the medicinal effects of various herbs and preparations. However, the specialists in the field opine that Indian achievements are far behind those of the Greeks. The physiological concepts of the Indians are not based on observation, for the Indians were afraid of touching a dead body because of their religious convictions. In this field, they did not have the precise knowledge; the whole picture of human body and its physiological functions were drawn purely on the basis of the theory and the most irrepressible oriental fantasy.

SURGERY

Surgery was the most illustrious aspect of ancient Indian medicine. Since olden days, the Indian doctors were renowned for their surgical operations. In plastic surgery, they had achieved such perfection that the European surgery of the nineteenth century had to borrow some methods from them. Comparatively large number of cases of chopping of noses in punishment for various crimes had made it necessary that a nose be created artificially. Same is the case with the creation of artificial ears and lips. In the field of ophthalmology, the cataract was well-known to the Indians; they had described it in detail and had also given a method for removing it surgically. They were also fully acquainted with and widely applied the most daring operations in cases of abnormal delivery, various methods of laparotomy and enterotomy. The number of sharp instruments used in these cases was 20 and that of the blunt ones—181. It is remarkable that in the decadent period of Indian culture, even surgery fell into decay. Though popular medicine generally continued to exist—and it exists even now along with modern medicine taught in the universities on European model—yet it is evident that the living conditions in the period of decadence were not conducive to its development. The atmosphere heretofore, in which the complicated operations were possible, was no longer there; the complex surgical methods, therefore, gradually fell into oblivion.

BOTANY

The advancement of medicine would have been unthinkable, if the sprouts of two other subsidiary sciences—botany and chemistry—were not there. The rich Indian flora gave rich material for gathering medicinal plants and studying their effects. In the treatises on medicine dating from the ancient period, we find descriptions of about five hundred herbs and their therapeutic uses. We also find various attempts at their classification, but these are very elementary and superficial. The Indian botany of the glorious period did not reach the stage when a scientific classification could be made.

During the later decadent period, when medicine itself started falling into oblivion, there was still less chance of having such a scientific classification. A specific branch of study was that of the toxic means—poisons and various herbs. In the still earlier period, when all was not quiet—viz. in the Maurya period(contemporary of the period of Alexander the Macedonian) when the Maurya dynasty was in power—poison was the usual means of political struggle of various groups in the courts : in the kitchen of every ruler, there always used to be a learned *brāhmaṇa*—an expert in poisonous substances—who was responsible for examining the food prepared for the ruler, so that there was no possibility of any poisonous substance being mixed.

CHEMISTRY

In ancient India, chemistry served medicine on one hand—in the preparation of a number of medicines—and technology on the other—for preparing colours, steels, cements, spirits, etc. Of the metallic medicines, mercury was particularly popular. The Indians could extract and purify mercury and use it for various complex preparations. Its medicinal effect was considered very strong. There was an assumption that it was possible to obtain such a perfect mercury compound that could give not only health but also immortality. The number of various mercury compounds known was as high as 18. There also existed a special school of chemists and alchemists, which endowed mercury with the importance of being the basic element of the universe. The Indians generally had knowledge of other metals and their oxides. They also knew that some of these were chemical compounds. They had various theories of chemical affinity and described practical preparation of various metallic salts. Fine sheets of metal were covered with salts and then heated. The well-known author of the Indian treatise on metallurgy, Nāgārjuna, gives directions for preparation of complex metallic salts and amalgams, and for the extraction, purification and precipitation of metals. He is, however, particularly known for his mercury compounds. Another famous chemist, Patañjali, is known for his invention of a special mixture (called *vidas*) which contained nitric acid. The chemists diligently engaged themselves in the preparation of complex substances from the simple and in the decomposition of the complex into simple ones. Various chemical processes generally described in the ancient treatises are those of extraction, purification, tempering, calcination, powdering, liquefying, precipitation, washing, drying, steaming, melting, filing, etc. Later, all these processes were applied to various metals, using special apparatuses and reagents and heating to different degrees—high, average and low. Though these methods had not been perfected, they did give the desired results, mainly by the use of various strong reagents containing nitric, sulphuric and hydrochloric acids. The method of preparing silver nitrate from the ashes of plants and that of preserving caustic alkali in a metallic vessel so amazed the French chemist, Berthelot, that he doubted the authenticity of the Indian source. He surmised that the prescriptions had probably been borrowed from Europe and inserted in an ancient Indian treatise as a later addition. But it can be easily proved against him that the method has been described in all the earliest treatises; the information on the use of silver nitrate has been taken from the ancient Buddhist literature.

TECHNOLOGY

The progress of chemistry also influenced its practical application in technical production. Various methods for preparing cements had already been known to India since olden days. In the 7th century, a special method was invented for manufacturing cement. Its unusual strength, as seen in the old structures which are still not ruined even in the smallest degree, amazes us. The Indians say that it can withstand destructive influence for a milliard years. In the seventh century, we come across references to various specialists in structure of machines and apparatuses, in preparation of dyes, colouring matter, and also spirits and cosmetics. Three technical inventions have particularly enhanced the reputation of the Indian industrial technology and secured for it such excellence as that of the British industry in the 19th century. It is difficult to form even a slightest notion of the huge commerce that India conducted with the West in the ancient times. Not being in a position to export anything to India, the Roman Empire was economically shattered because of the huge amount of gold that had to be sent to India in payment for the Indian goods. Recently, a storehouse of Roman coins which had in it eighteen man-loads of gold coins was discovered in one place in India. The flourishing of this export trade was due to the superiority of Indian technology. Two of these three main inventions were the fast red dye prepared from a combination of madder with alums ;

and the blue dye extract prepared from indigo by a method which is analogous to modern chemical processes. Because of these inventions, India started meeting the demand for dyes of the whole cultured world of that time. In this respect, it had the same position at that time as that of Germany after the invention of aniline dyes. The third invention was an advanced method for tempering steel—which gave the so-called damask-steel to the middle ages.

MATHEMATICS

The greatest progress that the Indians made was in the field of mathematics, especially algebra and arithmetic. They have to their credit such achievements that were much in advance of those of the Greeks and are close to the modern European science.

In the field of geometry and astronomy, on the other hand, they were far behind the Greeks, and that is why they were strongly influenced by the latter. Since it is widely believed that Pythagoras borrowed his mathematical knowledge and his whole philosophy from India, it appears that this influence was reciprocal in the early stages. The famous Pythagoras-theorem was known to the Indians in the most ancient, the so-called Vedic age. But in the 2nd century A.D., we already see clear traces of Greek influence. The Indian astronomy was built up completely under Greek influence—borrowing from the latter everything right upto the whole range of terminology which was not even translated. In the 8th and 9th centuries, the Indians became teachers of the Arabs. The Indian astronomers were invited to the court of the Caliph in Baghdad. The Arabs then passed on the knowledge so acquired to the European West. Like all other sciences, the glorious period of Indian astronomy and mathematics dates from 5th-7th centuries—the time of the great Indian astronomers, Āryabhaṭa (5th cent.) and Varāhamihira (6th cent.). Their works were translated also into the Arabic language and are studied even now by the special school of Indian astronomers, which continues to exist despite a totally different modern European astronomy taught in the universities. After 7th century, like all other fields of Indian life, astronomy too has its period of decadence—a static period—all under the influence of the same political conditions and war to which everything else had fallen a victim. Nevertheless, pure mathematics—algebra and especially arithmetic—continued to develop even in these difficult times. After the 11th century, however, with the complete disappearance of Buddhism from India, the leading mathematicians also disappeared.

The last well-known astronomer and mathematician, Bhāskara, lived in the 11th century. In this field, the Indians were apparently found to be more gifted by nature than all other peoples of the past. This special natural disposition of the Indians resulted in the amazing development of mathematical art. They invented a system of calculation by figures, to which values were assigned—depending upon their relative position alongside other figures. The Indians then passed on this indisputable invention of theirs to the Arabs and, through them, to the whole civilized world. The most important step in this system of figures was the invention of *zero* which we come across in the 5th century. It was, in all probability, invented a little earlier, but was, like all other Indian inventions, kept a secret—confined to the special school of scholars only. In the beginning of the 18th century, when the Russian system of education came in contact with the Tibetan system in Trans-Baikal, the system of figures was surprisingly found to be the same in both of them. Coming from India, this system completed a full cycle of migration and returned to India from the opposite end. As compared to all other nations, the Indian mind devoted much more attention to figures. This is seen from a study of Sanskrit where there are, from the olden times, special words for much higher numbers (this is not so in the languages of other peoples) in addition to the general Indo-European words for denoting "hundred" and "thousand". In the most ancient epic, *Mahābhārata,* we find special words for denoting such numbers as hundred-thousand-billion.

Archimedes is known to have studied the problem whether the symbols available with the Greeks would be found adequate if it were necessary to count the particles of sand which our planet consists of. For the Indians, this would have been the least difficult, for there are words in Sanskrit language which can denote the highest numbers. Thus, it is not merely a matter of chance that the concept and the symbol of *zero* together with the whole decimal system of figures were invented in India and not anywhere else. Comparing the Indian mathematics with all other Indian sciences—physics, atomic theory, psychology, epistemology, metaphysics—we find that the Indian mind always approached the concept of maximum value from all aspects, irrespective of whether the value was intensive or extensive, and that it was this train of thought that ultimately found expression in the invention of *zero* for denoting the concept which had already been prepared and worked out from all angles. One of the later Indian mathematicians defined the value of *zero* as follows (his words are, of course, applicable even to the earlier period of Indian mathematics) :

> If we go on decreasing the divisor successively, the quotient will correspondingly go on increasing. If the divisor is reduced to the maximum possible limit, the quotient also increases to the maximum. But so long as the latter has some specific value, however high, it cannot be considered to have increased to maximum limit, for one can still find a higher value. The quotient is, therefore, an undefined value, and is rightly called infinite.

This is also the modern mathematical concept of maximum value. With its establishment, the transition of Indian science to the field of higher mathematics was completed. We find the same train of thought even in the field of physics—in the atomic theory. In the ancient Indian systems, an atom was regarded as the minimum possible value. But so long as it is still a specific value, it cannot be regarded as the minimum. The

Buddhist and Brahmanical systems, therefore, considered an atom a complex molecule—the result of the action of infra-atomic forces. Such infra-atomic forces are real mathematical points; they are infinitely small and have neither dimension nor time nor value. The real atom is formed by their special integration. We come across a similar course of thought in Indian psychology which states the complex character of even the simplest thought. If in a thought, there is no generalisation, no synthesis of past and present, or of the individual and the whole, it is totally empty—the so-called pure thought, which does not contradict any object, every object being the result of synthesis. Thus every thought, howsoever primitive, is the result of the synthesis of elements which have no psychic content or where the content is infinitely small. This thought is called emptiness, or *zero;* both the concepts are denoted by the same Sanskrit word—*śūnya.* The Indian epistemology and metaphysics both use the concept of maximum value as the point of departure in the formulation of their systems. In this connection, it is not surprising that the Indian astronomy was familiar with the principles of differential calculus. This information took the British astronomers by great surprise. But, after additional data were placed before them, they had to acknowledge that the method employed by the Indians in the 12th century for finding out the longitude of the planets was closely similar, if not identical, to the formula employed in modern mathematical astronomy.

The Indians differentiated between the velocity of a planet measured roughly and that measured accurately. They had special technical terms for denoting velocity during a small indefinite interval of time. The difference between finite time and indefinite or infinitely small time is also mentioned. The Indian astronomers had a special term for denoting a particular small unit of time, approximately equal to 1/34000th part of a second. For calculating the so-called momentary motion of a planet, i.e. the motion during a mathematical moment, Bhāskara compares the successive positions of the planet. For this, he regards the velocity of the planet as constant during the respective interval of time, which is thus not more than 1/34000th part of a second approximately but may be even less. This momentary motion is, therefore, a differential concept—the differential planetary longitude. It is thus clear that the concept itself of the momentary motion and the method of determining it were known to Bhāskara; he can, therefore, be acknowledged as the predecssor of Isaac Newton in the discovery of the principle of differential calculus.

In Sanskrit, the scientific exposition was almost always in metric form. For almost every concept, therefore, it was necessary to have a number of synonyms so that the word, most befitting to the verse, could be selected. All the mathematical concepts and figures have a whole mass of synonyms, determined on the basis of some associations. For instance, the word for "eye" denotes the figure 2, and the word for "season"—the figure 6. In one of our earliest sources, *zero* has been called emptiness, that is, it is denoted by the same word (*śūnya*) which, almost in the same period, has been used in one of the Buddhist systems for denoting the concept of limit with regard to the relativity and changeability of the whole empirical world. In this source, *zero* is still not denoted by a circle but by a point. But among the many synonyms used for denoting *zero*, the word *ambara* which means "sky" or "empty space" became more widespread subsequently. Probably this is how *zero* came to be represented by a circle—empty from inside.

Though the progress in the field of mathematics—especially calculus—continued in India somewhat longer than that in all other sciences, this too nevertheless came to an end. No more distinguished mathematicians are found after the 12th century—the period following the Muslim conquest. However, the Indian achievements in this field are acknowledged as highly significant. The Indians are rightly considered the direct predecessors of J. Lagrange. The Indian arithmetic enumerates six simple arithmetical rules. Raising to the second and third power and taking square-root and cubic-root are included in simple rules. Of the higher mathematical rules, the Indians were familiar with the summing up of arithmetical series, geometrical progressions, irrational square-root, solving of definite and indefinite equations of first degree right upto the solving of indefinite equations of the second degree. At this point, their achievements came to an end ; their direct successor here is J. Lagrange, who had to discover again and develop this process further. Thus, in the field of mathematics, the achievements of the Indians are the greatest as compared with those of the other ancient peoples. It is to them that the whole civilized world is indebted for the invention of our system of figures—so unjustly called Arabic. It is high time that their real name—the Indian—is restored to them. From what has been stated above, it is clear that these achievements were not merely a matter of chance, but had been worked out by incessant hard work in all provinces of abstract thought.

By thus reviewing the history of India, we see that it had its epoch of cultural progress, which, however, was soon arrested under the effect of unfavourable historical conditions. Undoubtedly, we are at present at a sharp turn in the history of Indian scholarship...

[Translated from Russian by H.C. Gupta]