Synopsis of the History of Chinese Science

Shigeru NAKAYAMA*

Continuous tradition

The Chinese maintained their cultural isolation fairly well in most of the time. Surrounded by high mountains, wastelands and oceans, China is effectively isolated from the rest of the world, save some nearby satellite countries like Korea and Japan, to such an extent that this geographical insulation is largely compelling a long-standing countinuous culture – from the second millenium B. C. down to almost present time – without substantial interruption. This continuity is one of the most outstanding characteristics of Chinese science, forming a striking contrast with the main current of Western scientific development, in which the center of its activity shifted from Babylonia to classical Greece, to the Hellenistic world, to India, to the Islamic world, to the Renaissance Europe and so on. Thus, we find in Chinese science a process of gradual development on a single established traditional line rather than discrete scientific revolutions which were by no means the product of one race or continent and often resulted from active intellectual confrontation with an equally high culture. For science in which intellectual feedback is indispensable, cultural isolation meant a lack of challenge. Perhaps, the chief merit is that this long continuous tradition provides to the modern researchers – seismologists, astronomers and other scientists – invaluable records of uninterrupted observations of eclipses and other portents extending over two millenia.

We can go back to oracle bones of the Yin dynasty (mid fifteenth centrury B. C.) in tracing the evidences of some basic characteristics of the Chinese science. During the Chou period – the Warring States period (the fourth to third centuries B. C.) in particular – philosophic thought appeared – not only the humanism and naturalism of Confucius and Lao Tzu, but also systems like Mo Ti's which attempted to integrate axioms of optics, mechanics and semantics. The Mohist

*College of General Education, University of Tokyo.

Canon contains many germinal ideas of science, but lacked a favourable climate to grow and flourish.

It was, however, in the Han period (second century B. C. to second century A. D.) that the most of basic features of the Chinese science were formulated and became a prototype of what the traditional Chinese would consider to be authentic curricula and topics of research. Most of major scientific classics, which later dominated as standard texts on the Chinese scientific community, were composed by the end of the Han time. The *Chiu-chang suan-shu* (Nine chapters on the mathematical art) in arithmetics and mathematics; *Chou-pi suan-ching* (The arithmetical classics of the gnomon and the circular paths of heaven) in astronomy and cosmology; *Huang-ti nei-ching su-wen* (Pure questions, inner classic of the Yellow Emperor) and *Shang-han lun* (On febric diseases) in pathological and clinical medicine; and *Shen-nung pen-ts'ao ching* (Pharmacopoeia of the Heavenly Husbandman) in pharmacology are most important. Within the government, calendar-making, astrology, medicine and mathematics were given a solid institutional basis.

Institution

The well-founded Chinese bureaucracy is also contributing to the continuity of Chinese scientific tradition. Even at the time of a cultural ebb, the institutions for astronomical sciences and medicine existed at least as a matter of routine and maintained a minimum of tradition as an official duty of civil servants.

Bureaucratic control of learning in China, however, restricted not only the influx of new ideas, but also stunted intellectual growth by absorbing all the talents into administration, a single key to social recognition.

In the earlier days, the higher posts in bureaucracy were monopolized by powerful aristocratic families but from the Sui period (seventh century), civil service examination system was founded and operated effectively until the time of its abolition in the early twentieth century.

Persons of almost any economic or social background were eligible to take the civil service examinations. Hence, the Chinese system of recruiting talents seems at first glance to be more effective and advanced than even modern Western educational institution. However, its main purpose was not the training of prospective research scholars, but the selection of a priviledged few among the many career-seekers. It was, moreover, completely controlled by the government, which was thus able to stereotype all form of learning.

This examination was chiefly a written one, placing a premium on memory and comprehension of classical literature, which was regarded as an indisputable canon beyond criticism. Thus, students did not develop powers of logical analysis. Nor were they stimulated to think along independent lines, as were students in medieval European universities who prepared for oral examinations involving individual disputation.

In comparing the relative status of various scientific institutions within the government, we find, in the T'ang governmental regulations, that astronomical posts were most prominent since both astrology and calendar-making were important imperial functions, while the government had little respect for the status of mathematics. Most of the graduates of the mathematical institute were trained merely to be minor functionaries such as tax-collectors and surveyors.

In the bureaucratic society, generalist administrators were always more highly esteemed than technical specialists. Bureaucrat-scholars outside these technical offices could overrule scientists on matters of crucial scientific problems like calendrical reform. On the other hands, as long as one remains a technical specialist, the promotion of his status were limited and hence, there were always shortage of well-qualified personels in technical offices.

Major scientific principles

There are two principles that throughout history were applied to Chinese astrology, as well as to medicine, alchemy and many other aspects of the Chinese intellectual framework: the *yin-yan* and "five-elements" (or five-forces) principles. The *yin-yang* principle explained all phenomena in the universe in terms of a fundamental dichotomy which corresponded to that of heaven and earth, male and female, and so on. The five-elements principle was used to systematize the relations of things by placing them in the constellation and temporal cycles of natural agents – wood, fire, earth, metal, and water.

The question of when these principles came into being still challenges the historians, but it would be safe to assume that they were formulated and put together about the fourth century B. C. and became established during the second and first centuries B. C.

From their inception these principles were closely related to astronomical and cosmologic thinking. Unlike the Aristotelian counterpart in the West, however, these were prematurely divorced from phenomenal world and had been reputed with the status of the highest metaphysical principles. They were too abstract to apply successfully to explain phenomenal world. As the empirical observational data became abundantly available, calendar-calculators found no longer possible to deal with the framework of their rigid dogmatic notions, and finally gave up totally the attempt to express celestial courses in terms of cosmic cycles. Principles were often placed only in the preface or opening part of their treatises as an ornamental discourse of a cosmologic nature so as to convey an impression of profundity. In medical field, although these principles were employed in classifications and explanations of physiology and pathology, clinical medicine has been less influenced and developed more or less independently on its own empirical merit.

Hence, any new discovery would not create crisis in refusing or replacing these principles with some other new ones. For instance, the report of the discovery of the sixth planet, Uranus, during the Ch'ing period never caused serious panic to violate "five-elements" theory which was considered to manifest "five" planets in the sky. In fact, they were not so committed to phenomenal world as to refutable on account of the contradiction with measurable world.

Together with the lack of rigorous proof, this is the reason why the Chinese science is generally characterized as empirical and practical. The Chinese scientists often showed scepticism or apathy towards the existence of rigorous underlying regularity in Nature and a thorough-going "general conceptual scheme" at all as existed in mechanistic philosophy in Europe. For instance, inaccuracies in predicting solar eclipses were attributed not necessarily to imperfections in scientific technique, but often to the inherent indeterminacy of celestial motions, or to their susceptibility to at least some control by human desires operating through ritual and magic.

Cosmology and astronomy

While basic cosmological ideas appeared in fragmentary form in the oldest classics, the first Chinese treatise on "scientific" cosmology – scientific in the sense of being mathematical and entirely divorced from mythopoeic tradition – is found in the *Chou-pi suan-ching*, which is based on gnomon observations and the conception of heaven and earth as parallel. This was opposed by another important cosmological school, who, obviously closely associated with tthe development of armillary sphere observations; recognized the sphericity of the sky. Cosmologists' debate had been most active during the Han and Six Dynasties period. The controversy, however, dies out and astronomers lost their interest in it, occupying solely with routine observations and calendrical calculations. In the T'ang time the Chinese astronomers' attitude towards this particular speculative pursuit was that "Our business is exclusively calendrical calculations and observations in order to provide the people with the correct time. Whether flat or spherical cosmology is no concern of the astronomers!" While occasional cosmological debates were found among the Sung philosophers, scientific cosmology was long set aside and forgotten in professional astronomy circles until the time of the Jesuits' impact.

Thus, we can scarcely find in the later development of Chinese astronomy any tendency towards a conceptual scheme or a mechanistic model. The approach of the Chinese official astronomers was to represent numerically the course of the celestial bodies, without depending upon a geometrical model. Their final aim was to reduce observations as accurately as possible to algebraic relations. Unlike Ptolemaic astronomy, Chinese astronomy showed no concern for the calculation of radius vectors or dimensions of the universe; for all purposes of measurement, heaven was treated two-dimensionally. On account of considerable developments of eclipse-predicting techniques, it is surprising to note that even the sphericity of the earth was not explicitly recognized among astronomers until the time of Jesuits' visit.

Calendar-making

Perhaps the most striking thing about recastings of the civil calendar in China was their frequency. The Chinese calendar was revised move than fifty times in two thousand years and another fifty unsuccessful proposals are recorded. Two major reasons to explain such repeated efforts are apparent.

1. Among the Chinese the idea prevailed that a ruler received his mandate from heaven. In the early period, therefore, after important changes of individual reign and always after important changes of dynasty, the new emperor was prompted to reform the official calendar in order to confirm the establishment of a new order which a new mandate implied; a new mandate meant a new disposition of celestial influences. This notion was responsible for the subsequent course of development of Chinese calendrical science. Calendrical science enjoyed government sponsorship throughout its history, and had more prestige than other branches of science; it was China's most genuine contribution to exact science. The history of Chinese astronomy is, for the most part, the history of calendar-calculation.

2. In the course of time, however, the political importance of calendar reform dwindled. The restriction of calendar reform to change of dynasty was not strictly observed by the fifth century A. D. In the T'ang dynasty, the motive for calendar revision became simply to correct disagreements of the calendar with observed celestial phenomena. Hence, reforms were carried out whenever a small error was found. This accounts for the frequent revisions in later phases.

The Chinese calendar, from early times until its replacement by the Gregorian calendar in the twentieth century, was a typical luni-solar calendar. The Chinese calendar-calculators were not satisfied with providing a conventional calendar, in which the course of the sun and moon were reconciled, merely for civil use; but they also tried to include the anomalistic motions of the sun and moon. On the other hand a sharp separation of scientific astronomy and civil calendar-making did not take place in China. Its scope was confined to the composition of a luni-solar ephemeris which stood or fell on the accuracy with which it could predict eclipses – the best way to check the validity of any luni-solar calendar. Analysis of planetary motions was rather ancillary to the main problems of Chinese astronomy.

Mathematics

Throughout Chinese history the main importance of mathematics lies in relation to the calendar-making. Unless associated with the work of calendrical composition – a basic concern of the Empire –, mathematics itself could never achieve a high status in the hierarchical disposition of learning within bureaucracy, nor enjoy a high intellectual position in the appreciation of scholars-literati class, but tended to be a mere technique, having few philosophical overtones, for counting-clerks to employ in such minor works of petty-officials as mensuration, tax-collection and book-keeping. Thus, the Chinese way of presentation of mathematical topics were definitely inclined to application, or at least application-conscious. One did not find abstract and systematic proofs reflecting a concern with mathematics for its own sake.

The Chinese had relied on machanical tools in calculating. Early use of counting-rods and later of abacus certainly fascilitated the advancement of numerical solution of algebraic problems. They could handle negative number by using different colours – black and red – of rods as early as the Han time. Numerical quadratic and cubic equations, simultaneous linear equations, the value of circular constant: these were better calculated in the third century China than the rest of the world by use of counting-rod.

The absence of calculation by writing up until the introduction of Western mathematics at the Jesuit time was, however, doubtlessly extreme limitation. Adherence to mechanical tools allowed calculations to vanish without trace, leaving no record of the intermediate stages by which the answer was reached. In ordinary mathematical texts, only problems and final answers were given. This custom could be related to the absence of the idea of rigorous proof in Chinese mathematics.

Geometrical problems were treated only algebraically. Graphical treatment was not found (at least explicitly) in the texts. There is not much to say about trigonometry in the ancient Chinese mathematics, save the Pythagorean relationship was enthusiastically studied as early as in the *Chou-pi suan-ching* in connection with astronomical measurements for which the gnomon was required.

Medicine and the related fields

Chinese physiological theory as it appeared in the *Huang-ti nei-ching* is deeply involved in their characteristic *Naturphilosophie.* According to its pathology, the cause of disease lies chiefly in malfunctions of the circulation of *ch'i* (a sort of pneuma). External *ch'i*s of wind, coldness, hotness, humidity and so on come into internal organs and cause disease. Internally, disturbance of *ch'i* circulation through the five *tsang* (the heart, liver, spleen, lungs and kidneys) and the six *fu* (the gall-bladder, stomach, large intestine, small intestine, bladder and *san chiao,* an imaginary organ) is also the cause of disease. It is considered that the dissection of the human body was being practiced to some extent before the Han time. *Nei-ching* states that "After death the body may be dissected and observations made as to the size of the organs, the capacity of intestines, the length of the arteries, the condition of the blood, and the amount of pneuma."

In Chinese physiological and pathological theories, the brain never played a significant role. Brain was considered to be merely a part of marrows of bones. Mental activity was attributed to the function of the heart, the prince of body. The symptom of disease can be readily detected by the pulse and hence sphygmic treatment was considered to be as important in diagnosis as gross symptoms and case history. Climatic and topographical factors were well taken into consideration, and the body was always treated as a whole. Most unique therapy in Chinese medicine is perhaps acupuncture.

Natural history, chemistry and alchemy existed only in subordinate relation to therapeutics. Presumably, Chinese word *pen-ts'ao,* equivalent to pharmacology, originally meant the study of a medicine for longevity or immortality, and later it was applied for the study of *materia medica* in general, which includes mineral drugs. Unlike the Western counterpart, the Chinese did not try to extract essence out of herbs.

The primary goal of the Chinese alchemy was to find out a recipe to make individuals immortal rather than to prepare authentic noble metal from base metal. The transformation of metals into gold was tried, but in the earliest phase of alchemy, goldmaking was associated with immortality only indirectly; eating off utensil made from the gold was supposed to lengthen life to the point that the thaumaturgic and ritual prerequisites to actual immortality could all be satisfied.

Foreign influence

There are two major foreign cultures which influenced pre-modern China: Indian and Islamic.

Buddhist pilgrims returning from study in India brought home elements of Indian culture and science. We do not find, however, much substantive influence of Buddhism on science despite the fact that Buddhism was the most important and influential imported culture throughout Chinese history.

Buddhism emphasized contemplation and rejected the phenomenal world as illusory. Physical theory and scientific institutions were outside its scope. The Buddhists were concerned with science only as one of the peripheral features of the Indian cultural tradition, transmitted as an incidental part of theology.

With a single exception of I-Hsing, there is no Buddhist monk found in the list of notable astronomers. "Nine upholders" calendar, translated into Chinese during the T'ang period, includes unmistakable influences of Hellenistic astronomy, but it remained outside of the main current of the development of Chinese calendrical science.

Influences were rather found in peripheral topics such as horoscopic art and the custom of week cycle. More Indian influence can be found in medical field. Many Indian medical treatises were translated into Chinese during the T'ang period.

Islamic culture must have imposed some influence upon the science and technology during the Sung period, but no systematic importation was ever attempted. During the Yuan dynasty, when the Mongols established a huge Empire, uniting East and West, cultural traits of both were often mingled. The Chinese gunpowder and papermaking techniques were allegedly transmitted to the West at this period, while Islamic astronomers were employed in the Chinese court and competed with the Chinese native school in precision of predicting eclipses. However, these competing schools never merged, and thus the Chinese astronomy remained virtually independent of any substantial foreign influence.

Such a piecemeal influsion of knowledge could never have led to a conceptual revolution in Chinese science.

The coming of Jesuits

It was the Jesuit time in the seventeenth to mid-eighteenth century when indigenous Chinese science was for the first time substantially affected by another culture. The Jesuits in China generally took a flexible, and sometimes conciliatory, attitude toward the existing social order. They attempted to gain converts indirectly by impressing the elite classes with their superior knowledge of astronomy, then exploiting these groups to bring about wholesale conversions.

Their efforts were rewarded in making some influential converts among the Chinese high officials and succeeded in changing the official calendar from one based on traditional Chinese technique to that based on Tychonic astronomy.

The first generation of the Jesuits, Matteo Ricci, had started to bring in the Ptolemaic kind of astronomy while the second generation of missionaries introduced the core of Tychonic astronomy and pre-Cartesian mathematics. Copernicus was quoted as the discoverer of eleventh sphere and as a skillful observer; no mention of the heliocentric theory appeared until the middle part of the eighteenth century.

While geometrical treatment, the values of parameters and contents were all Tychonian, the way of presenting and arranging calendrical treatises, and also the very purpose of Chinese astronomy, i.e. the composition of a luni-solar calendar and the most precise prediction of eclipses, remained unchanged. Thus, the celebrated slogan of HsüKuang-ch'i, an eminent Chinese collaborator of Ricci, that "Let us melt their (Western) materials and cast them into the mold of the traditional calendar" was firmly carried out.

Introduction of modern science

The second wave of the Western influence came to China during the nineteenth century along with the invasion of Western powers and the missionary activities of Protestants, such as Alexander Wylie. Although the Protestant missionaries followed a similar educational policy toward China as their Jesuit precursors, the Protestants approached commoners rather than high officials, with the latest knowledge in modern science. For instance, John Herschel's *Outline of Astronomy* was translated by Wylie with the assistance of a native Chinese in 1859. At the same time, some less conservative Chinese officials started to introduce the core of Western military technology and its concomitant science by establishing translation bureaus and schools for modern engineering and military arts in order to compete with the military superiority of Western powers. They emphasized the role of surveying and mathematics, in which Western superiority was already recognized by the Jesuit activities. On the other hand, modern medicine was entirely left in the hands of foreign missionaries.

The abolishment of time-honoured civil service examination system in the early part of the twentieth century created a great stimulus among Chinese youth to seek a new nourishment of learning in the Western science, and many of them rushed to study abroad. "Science" became a new fashion of thought to replace old tradition of learning since the second decade of this century.

The present generation of senior scientists were mostly trained in the United States and Europe (some in Japan). Under the regime of the Chinese Poeple's Republic, many students of the generation born in 1930's were sent to the Soviet Union during the time of Russo-Chinese collaboration in 1954-59. Because of the split in ideology, China started pure imbreeding of scientist since 1960.