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THE DEVELOPMENT OF THE SCIENCES IN CHINA FROM THE 4TH TO THE END OF THE 12TH CENTURY *

I. *The Period of the Northern and Southern Dynasties*

UNABLE to bear the oppression of the different races in northern China, the Chin Dynasty transferred the capital to the lower reaches of the Yang-tzū River in 317 A.D., and, thenceforth, the tract along the river came under the rule of the Eastern Chin. At the same time, many different races were in conflict and, at last, in 386 A.D., the Northern Wei Dynasty was established and obtained control of northern China, thus causing the direct confrontation of North and South. The Wei dynasty had existed for about 150 years, but was for some time divided into the East and West Weis ; soon afterwards, Northern Ch'i from Eastern Wei and Northern Chou from Western Wei were established and later still the Sui Dynasty was set up by one of the commanders of Northern Chou, which again brought the whole of China under its authority. In the same manner in 420 A.D. the Sung Dynasty [1] emerged from the Southern Dynasty that upheld the tradition of the Chinese. After the Sung, the Ch'i and Liang Dynasties fell, the Ch'ên Dynasty took control. This latter was overthrown in turn by Sui at the end of the 6th century.

Throughout the long period from the 4th century to unification by the Sui Dynasty, the northern part of China, which had been the stronghold of the Chinese from far back, came successively under the control of the different northern races, and the Chinese themselves migrated to southern China along the Yang-tzū River. Consequently, the cultivation of southern China was remarkably improved and, as the administration in the south was chiefly in the hand of aristocrats in the old tradition, classic studies were continued. Indian Buddhism, first introduced in the time of the Second Han Dynasty, had gradually increased its influence ; large numbers of Buddhists passed through Hsin-chiang province, the translation of various Buddhist scriptures was under way, and huge stone-caves were made at Ta-t'ung and Lung-mên during the Northern Wei Dynasty. All this exerted a great influence upon both north and south and, consequently, the power of Buddhism became greater in China than that of Taoism which had hitherto been dominant. Later, during the Sui and T'ang periods, the influence of Western civilization with Buddhism as its core grew more remarkable. In the north, the land had been devastated by a series of disturbances. With the Northern Wei period, however, the strong agricultural policy was extended, and such excellent technical books on agriculture as *Ch'i-min-yao-shu* were compiled. Needless to say, the Chinese were the representatives of civilization even when under the control of the different northern races and although they carried the cultural tradition to the south, there was a sharp difference between north and south. From the middle of the 6th century, however, unification of the two regions began, and this was consolidated by the Sui Dynasty.

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[1] This Dynasty is different from Sung after the T'ang Dynasty.

A. *Mathematics and Astronomy*

Chiu-chang-suan-shu or *Arithmetic of Nine Sections*, the basic Chinese work on mathematics, was compiled in the Han period, and in 263 A.D. was annotated in detail by Liu Hui of Wei of the Three Kingdoms, who was himself a creative mathematician and the author of *Hai-tao-suan-ching*. Subsequent mathematical works still surviving include *Sung-tzū-suang-ching*, *Chang-ch'iu-chien-suang-ching*, *Wu-ts'ao-suang-ching*, and *Wu-ching-suan-shu*. Except the last two, however, information as to the authors and the date of compilation is vague. The last two are supposed to have been written by Chên Luan of Northern Chou, one of the annotators of the ancient book on mathematics, *Chou-pei-suang-ching*, and the author of books on astronomy. He was a Buddhist priest, but there is no evidence that he was especially influenced by Western civilization. These mathematicians were not so outstanding as those represented by the *Chiu-chang-suan-shu* or *Arithmetic of Nine Sections*, but it is important to remember that the indeterminate equations were first given in *Sung-tzū-suang-ching* and *Chang-ch'iu-chien-suang-ching*.

The most remarkable mathematical works are rather those of Ho Ch'êng-t'ien, Tsu Ch'ung-chih and Tsu Huan-chih, southern scholars

and well-known astronomers. Ho Ch'êng-t'ien devised "T'iao-jih-fa" in order to indicate one synodic month by fractions ; Tsu Ch'ung-chih originated "Chui-shu", a method no longer employed. His work on the circular constant, however, was a great achievement. According to *T'ien-wen-chih* in *Sui-shu,* he calculated the circular constant as $3.1415926<\pi<3.1415927$, with $\frac{22}{7}$ as the rough circular constant and $\frac{355}{113}$ as the exact one. The latter accords with the result obtained by a Danish scholar in the 16th century, but it is not known how he reached this. Tsu Huan-chih, a son of Tsu Ch'ung-chih, was the first man to succeed in calculating the volume of a sphere, and both father and son helped advance the work begun by Liu Hui. Though Liu Hui had already used the idea of limit of an infinite series, Tsu Huan-chih adopted the geometrical method in cubing the sphere and utilized an idea similar to the integral calculus of today. The achievements of these two scholars rank high in the history of Chinese mathematics [2].

In China, the calendar had long been regarded as the symbol of political unification. Just as Gregorius XIII in the 16th century provided Roman Catholic countries with a revised calendar, so the calendar officially adopted by any dominant state was used even by countries only nominally under her control. Though it was usual for a new calendar to be introduced with each change of dynasty, it sometimes happened that calendar reform was undertaken during the same dynasty. The calendar in those days showed solar and lunar eclipses as well as the division of months and days. On the ground, however, that these forecasts of astronomical phenomena were necessarily uncertain, "astronomical tables" were frequently revised and new calendars based upon those tables officially issued. During the period under consideration, many astronomical tables were made and the followings were among the most important.

First, in Northern Liang, in the north-west, Chao Fei devised an astronomical table called *Hsüan-shih-shu,* and the calendar derived from this was in use from 412 A.D. to 439 A.D. A lunisolar calendar was used in China, and before the time of Chao Fei, a "metonic cycle" with 7 leap months in 19 years had been employed, this 19 years cycle being known as a "chang". Chao Fei, however, adopted a method involving 221 leap months in 600 years, and he named this "P'o-chang-fa". He was thus the first to adopt a method of intercalation other than the metonic cycle ; Tsu Ch'ung-chih of the Southern Dynasty followed suit and it became the basis of various methods of intercalation in subsequent astronomical tables.

Ho Ch'êng-t'ien of Sung made the splendid astronomical table called

[2] Yoshio Makami, *The Achievements of Kowa Seki and the Comparative Study of and Relation between Arithmeticians of Osaka and Kyoto and Arithmetical Methods in China* (in Japanese) (Toho Gakuho, Vol. 20-22, 1932).

"Yüan-chia-li" in 443 A.D. and suggested the first day of each month be fixed by true syzygy instead of mean syzygy. Liu Hung of the Second Han period had already discovered the irregularity of the lunar movement, particularly in regard to the equation of motion, and Ho Ch'êng-t'ien tried to incorporate it into the calendar, though without success. The calculation of the new moon by true syzygy or "Ting-shuo-fa" was adopted in the T'ang period.

The irregularity of the solar movement was discovered by Chang Tzū-hsin, the northern astronomer who lived from the end of the North Wei Dynasty to Northern Ch'i and made his observation by "Hun-i", or an armillary sphere, for more than 30 years.

After Ho Ch'êng-t'ien, in accordance with the P'o-chang-fa of Chao Fei, 144 leap months in 391 years were inserted in the astronomical table or "Ta-ming-li" of Tsu Ch'ung-chih, and the precession, first known by Yü Hsi of Eastern Chin, was also adopted. According to Yü Hsi, the numerical value of precession was $\frac{1}{50}$ degree. Tsu Ch'ung-chih, however, amended this into $\frac{1}{47}$ degree. Precession was thereafter frequently used in astronomical tables [3].

As mentioned above, there were some differences between the astronomical tables of the Northern and Southern Dynasties, and from the astronomical point of view, the Southern table was superior. Although some of its features were not exactly theoretical, there were many metaphysical modifications in the Northern table. Ch'ên-wei-shuo, or theory of divination, which had grown stronger after the Second Han period, was favoured by scholars of the Northern Dynasty with the result that it was associated with astronomy. In the north, too, the Buddhists took part in the compilation of the calendar, and, at the same time, there were many astronomers among the Taoists.

During the reign of Huan-ti of the Second Han, a priest, An-Shih, who was believed to be a son of the King of Parthia, translated *Shê-t'ou-chien-ching* into Chinese and introduced the old astronomy of India. Afterwards, *Mo-têng-ch'ieh-ching,* another manuscript version of the same work was also translated into Chinese. According to *Hsü-kao-sêng-chuan,* Ta-mo-liu-chih translated the 20 volumes of Brahminic astronomy in obedience to an Imperial command during the reign of Chien-wu-ti of Northern Chou. Besides these, some books on astronomy and mathematics were also translated during the northern dynasties. *Hui-yüan-chuan* of *Kao-seng-chuan* recounts that Ho Ch'êng-t'ien studied Indian astronomy, but there is no sign of its influence in his surviving astronomical table. Nor is there any trace of Indian influence elsewhere in the field of astronomy, although in astrology, it gradually grew stronger.

[3] Kiyoshi Yabuuchi, *A History of the Chinese Astronomy from Ancient Times to the Sui Period* (in Japanese) (Toho Gakuho, Kyoto, Vol. 12, 1941).

B. *Medical Science and Pharmacology*

Among the ancient books of medical science, *Nei-ching* including *Su-wên* and *Ling-shu* written in the Ch'in-Han period should be noted [4]. This touches chiefly upon fundamental medical science, and explains the functions of the human body by the principles of Yin-yang and by the theory of Wu-hsing, or theory of five elements, and also refers to the causes of diseases. It reveals the theories of physiology and pathology in ancient China, according to which man comes into existence with two spirits of Yin-yang, which symbolize heaven and earth and replenish air and food. The five viscera—heart, liver, spleen, lung, and kidney—not only perform their particular physiological functions but have their special spirits and are the centre of mental activities. Besides these five viscera, there are the six internal organs : gall, stomach, large and small intestines, urinary bladder and "san-chiao".

The book describes in fair detail the anatomical structure and the physiological functions, but deals very little with the nervous system. It argues that disease is mainly due to a disordered spiritual state or the work of evil spirits such as wind, cold, warmth, and heat, entering the body while it is off guard. Finally, it indicates how to diagnose disease by pulse and how to cure by medicine, depletion, acupuncture and moxibustion.

In contradistinction to this ancient work is *Shang-hang-lun*, a clinical study written by Chang Chi, otherwise known as Chang Chung-ching of the Second Han. He divided diseases into two kinds of Yin and Yang according to the degree of pyrexia and each of these into three classes according to the place and condition of the symptoms. "Shang-han" was the principal disease belonging to Yang—a fever marked by intense pyrexia and rigor and including typhoid fever and other infectious diseases. About 200 A.D., when Chang Chung-ching was a child, this fever killed more than a hundred of his relatives and this later decided him to write his treatise.

Wang Shu-ho of the Chin period was a scholar who revised *Shang-hang-lun* and the author of *Mo-ching*, a famous book on diagnostics. He divides the pulse into 24 kinds by its place and characteristics. Huang-fu Mi, who appeared after the time of Wang Shu-ho, wrote *Chia-i-ching* which refers in detail to acupuncture and moxibustion, both specifically Chinese methods of treatment. These were the important books on medical science written in the period of the Northern and Southern Dynasties. In these periods, knowledge of practical cures developed into the basis for medical science in the Sui-T'ang period but no outstanding books represented this period.

[4] Tameto Okanishi, *A Bibliographical Introduction to Medical Science in China* (in Japanese), Vol. 1 and 2 (Kampo, 1952 and 1953). All the surviving books on medical science in the period of the Six Dynasties, including those of Han, were revised by later scholars. Dr. Okanishi made detailed bibliographical investigation on *Nei-ching*, *Chia-i-ching*, *Shang-hang-lun*, etc., in his *Bibliographical Introduction.* He has published the *Catalogue of Books on Medical Science in China* (2 vols.) in collaboration with Dr. Genji Kuroda.

Chinese pharmacology is known as "Pên-tsao" (used from the end of the First Han), the term presumably deriving from the fact that herbs (tsao) were extensively, although not exclusively, employed as medicaments. Significant books on pharmacology include *Shên-nung-pên-tsao-ching* compiled by T'ao Hung-ching (452 A.D.-536 A.D.) and a number of works compiled under the name of "Shêng-nung", the father of medicine. This latter revived the tradition of old pharmacology and revised *Shên-nung-pên-tsao-ching* which listed 365 kinds of medicinal substances representing the days in a year and divided into upper, middle, and lower levels, according to the tradition. According to *Shên-nung-pên-tsao-ching*, the 120 "upper" substances represented the elixir of life, the 120 "middle" substances were for the preservation of health, and the remaining 125 were curative. To these were added by him another 365 which were used supplementarily by noted physicians. The account of this second group was given the name of *Ming-i-pieh-lu*, which was not only a compilation of the old pharmacology but became the basis for subsequent developments [5]. The book refers in detail to the properties of each medicine and explains when, how and where the various herbs should be collected and how they should be prepared and administered.

C. *Agricultural Technique*

From the beginning of the 4th century, northern China was devastated by war, and much land rendered unfit for cultivation, while, on the other hand, many farmers had no land of their own to cultivate. The leaders of the Northern Dynasty had devoted their energies to increasing the population and encouraging agriculture. Specifically, the distribution of land according to age and sex was decided in the 9th year of T'ai-ho (845 A.D.), a sort of nationalization of land, giving a fixed area to each farmer.

In spite of this, however, aristocrats and other influential men owning slaves were able to retain considerable property, so that distribution was not in fact carried out very equitably. Since northern China had relatively little rain, german, millet and ordinary millet were the principal crops, while in the yellow land belt, dry-farming was devised to make the best use of water absorbed into the ochre. *Ch'i-min-yao-shu*,

[5] Shikazo Mori, *About the Medicinal substances appearing in Shên-nung-pên-tsao-ching* (in Japanese) (Silver Jubilee volume of the Research Institute of Humanistic Sciences, Kyoto University, 1954).

compiled by Chia Ssū-hsieh of the Northern Wei explains the technique of this dry-farming. The date of compilation of this book is uncertain, but is thought to be between 530 A.D. and 550 A.D. It is one of the most advanced works on agricultural technique and exerted a great influence on later developments [6]. The technique of aquatic rice cultivation, subsequently of paramount importance, was still in the early stages and is only sparsely treated. German millet is described as the most important food, but after the end of the Northern and Southern Dynasties, the cultivation of wheat increased substantially with the result that many water mills were built on the northern rivers, a method which grew more prosperous in the period of T'ang [7].

After the middle of the T'ang period, the technique of aquatic rice cultivation improved, and not only irrigative devices but new farm implements were invented about this time. Moreover, with the Sung period, a new variety of rice was imported and a wide tract along the Yang-tzū River was developed where conditions were especially suitable for rice cultivation [8]. Although there were plenty of swampy places, the large-scale project of land reclamation by drainage had taken place, and agricultural production increased remarkably. Ch'ên Fu of Sung described the technique of aquatic rice cultivation in detail in 1149.

II. *Sui-T'ang Period*
From the end of the 6th to the beginning of the 9th century

The Sui Dynasty which dissolved the antagonism between the Northern and Southern Dynasties, worked on the excavation for an enormous canal, which, along with the construction of the Great Wall, is considered among the greatest Chinese engineering achievements. Not all the work on this canal connecting north and south, was done during the Sui Dynasty, however ; but by repairing waterways which already existed and by excavating a number of canals which passed through from north to south, it was brought to completion. As a result, not only could rice produced on the Yang-tzū River be transported to the northern capital, Ch'ang-an, but of the advantages being handed down to the T'ang period, the canal played an important role in the unification of all China.

[6] Takeichi Nishiyama, *Study or the Editions of Ch'i-min-yao-shu* (in Japanese). Appendix to the surface-printed *Ch'i-min-yao-shu* in Kanazawa Library, 1948.

[7] Sadao Nishijima, *On the Problems of Mills : a Problem in the History of Agricultural Productivity in Northern China* (in Japanese) *(Rekishigaku-Kenkyû*, No. 125, 1947).

[8] Motonosuke Amano, *The Development of Rice Cultivation Technique in China* (in Japanese) (Toho Gakuho, Kyoto, Vols. 19 and 21, 1950 and 1952).

In the Sui Dynasty, various changes suited to the unified country were introduced. For example, a system of K'o-chü made official position hitherto open only to the sons of aristocrats accessible to the people in general, but it thereby increased the tendency to concentrate studies on the classics of Confucianism, and thus obstructed free research [9]. Moreover, as the Sui Dynasty fell within 40 years, the changes were mainly completed in the T'ang period.

A. *Astronomy and Mathematics*

In the beginning of the Sui period, the calendar was based on the astronomical table partially revised in accordance with the method of Ho Ch'êng-tien, and Liu Ch'ao was the most prominent astronomer of the time. He had acquired a thorough knowledge of the astronomical works in the Northern and Southern Dynasties but his own table was essentially original. He reasoned Ting-ch'i or true seasonal points by accepting the irregularity of the sun's motion discovered by Chang Tzū-hsin, and improved the calculation method of true syzygy. As a result, calculation of solar and lunar eclipses was remarkably improved. As to the value of precession, he improved Tsu Ch'ung-chih's and adopted as accurate a value as once in 76 years. Although the astronomical table was not used in the calculation of the calendar, it provides an example of the tables used in the T'ang period. Ting-ch'i's method was not used until the Ch'ing Dynasty. Li Ch'ung-fêng completed *Lin-tê-li* in the early years of the T'ang Dynasty ; although he based it on Liu Ch'ao's table, he unfortunately ignored precession. He did, however, devise a way of expressing fractions of all astronomical constants by a common denominator and this represented a considerable saving of time in calculation. Other excellent astronomical tables in the T'ang period were I Hsing's *Ta-yen-li*, Hsü Ang's *Hsüan-ming-li* and Pien Kang's *Chung-hsüan-li*. In *Ta-yen-li*, an approximate correct value was found for the irregularity of the sun's motion and the method of calculating the day of true syzygy was improved. While Liu Ch'ao had already developed a method of interpolation in equal intervals for this purpose, I Hsing expanded this to unequal intervals. His method was identical with that of Gauss' interpolation formulae in disregarding the third difference and over [10].

I Hsing also found that the conditions of a solar eclipse varied according to the observation site and devised a method of calculating these differences. When *Hsüan-ming-li*, *Chung-hsüang-li*, etc. were

[9] Ichisada Miyazaki, *Kakyo or K'o-chü*, 1946.

[10] Kiyoshi Yabuuchi, *Study of History of Astronomy in the Sui-T'ang Period* (in Japanese), 1944.

put into circulation, most of the improvements related to the method of calculation, and Chinese astronomical tables founded on the traditional method apparently came to an end in the T'ang period.

Buddhism flourished greatly in the T'ang period and as the country prospered, the visits of Indians and then Westerners increased, with a corresponding increase in the influence of Western culture. At the same epoch Christians of Nestorian faith arrived and made a fairly large number of converts. In the field of science, Indians achieved great success. A number of them occupied high positions in the Royal Astronomical Observatory in China and some even became directors of that institution. Nonetheless, there is no Indian influence apparent in the traditional Chinese astronomical calculation methods and instruments : it is seen rather in astrology. *Hsiu-yao-ching* translated by the priest Pu-k'ung in 859 A.D. is the book which introduced Indian astrology and commentaries based on Indian astrology were added to the calendar. In the T'ang period, too, Sunday began to be entered on the calendar as the word "mi". The word is the phonetic translation of "mīr" in Sogdiana, and it was introduced by Manichee who came to China. In the calendar were rules of conduct prescribed for Sunday according to astrology. And when printing began in the T'ang period, the printing of the calendar was one of the first works. The oldest printed calendar in existence can be assumed without doubt to be the one printed in 877 A.D.

In the reign of Hsüang-tsung of the T'ang period, Ch'ü-t'an-hsi-ta, an Indian, who was appointed director of the Royal Astronomical Observatory, translated an Indian astronomical book into Chinese, and called it *Chiu-chih-li.* It explained calculation by the method of the third period of Indian astronomy [11]. Astronomy in this period, influenced by the Greek, had reached a fairly high level. In India, besides the sun, the moon and five stars, two invisible stars called "Rāhu" and "Kētu" were thought to exist ; all these heavenly bodies were collectively known as "the nine planets", or "navagrāha" ; the translation by Ch'ü-t'an-hsi-ta was named after these planets. It is noteworthy that explanations of the Indian numeral and sine-table, originating in Greece, were given in this book, but they did not exert any influence on existing mathematics and astronomical calculation in China.

Many improvements were made on astronomical instruments in this period, notably an armillary sphere made by Li Ch'un-fêng. In the reign of Hsüan-tsung shadows of a pole and the altitude of the North Pole in the "24 chi" or 24 seasonal points were observed in every district in China. It was known that the altitude of the North Pole differed according to districts, and I Hsing and Nan-kang Yüeh were the

[11] KIYOSHI YABUUCHI, *Studies on the Chiu-chih-li* (in the *Study of the History of Astronomy in the Sui-T'ang Period,* 1944).

first persons to measure the meridian arc of the earth based on these facts. By first selecting a flat area in Honan and then measuring the distance between two points which lay approximately on the same meridian, I Hsing obtained the value of 365.4 Chinese li to a degree of latitude. But he had no clear and accurate knowledge of the shape of the earth and therefore could not go further in trying to calculate the dimension of the earth.

In the field of mathematics, a method of interpolation for astronomical calculation had been originated in the Sui period. The noted mathematicians in the T'ang period were Wang Hsiao-t'ung and Li Ch'ung-fêng. Wang Hsiao-t'ung used cubic equation in his *Ch'i-ku-suang-ching ;* Li Ch'ung-fêng, who won fame as an astronomer, annotated a number of old mathematical books. Schools of mathematics were set up to train special officials and 10 classical mathematical works including Wang Hsiao-t'ung's, were adopted as textbooks. Since examination problems were limited by these textbooks, there was little likelihood of creative mathematicians arising in the school system. Unlike the position in astronomy, there was a strong tendency in mathematics to respect the ancient tradition and hence no new mathematical studies were undertaken.

B. *Medical Science and Pharmacology*

Medical literature in the Sui period is characterized mainly by a complete survey of medicine in the Six Dynasties. Various methods of medical treatment were acquired through experience, developed in the period of the Six Dynasties, and in the Sui period were brought to completion. As a result, the voluminous medical books entitled *Ssū-hai-lei-chü-fang,* amounting to 2600 volumes, were compiled, and at the time represented the greatest body of medical literature in the world. Among works still existing is *Ping-yüan-hou-lun* which was by the Imperial ordinance compiled by Ch'ao Yüan-fang and others in 610 A.D. This not only records symptoms but ascribes illness to five *miasmata* (evil spirits) and various demons. Despite this mystical element it nonetheless gives the impression that clinical knowledge had greatly increased. Though descriptions of medical treatment are comparatively brief and medicinal substances not mentioned, it expounds acupuncture-moxibustion and a sort of calisthenica. The influences of Taoism and Indian medicine are both apparent. Specifically, the theory that there are four elements, each of them involving 101 kinds of illness, derived from Indian medicine.

Ch'ien chin-fang and *Wai-t'ai-pi-yao* by Sun Ssū-miao and Wang Tao respectively are the representative medical books in the T'ang

period and deal mainly with methods of medical treatment. The former was thoroughly acquainted with books on Taoism and Buddhism and since he regarded human life as more valuable than a thousand gold pieces (Ch'ien chin), he named his book *Ch'ien-chin-fang*. In his emphasis on medical ethics he merits comparison with Hippocrates. He was not a man of originality but rather one who took up the methods of medical treatment completed in the Sui period, and gave a full account of the quality, usage and prescription of the substances required for such treatment. Wang Tao was a man of the Hsüang-tsung era, and his book, being compiled on the basis of the earlier *Ping-yüan-hou-lun*, goes into details about prescriptions of medical substances as well as the nature of diseases and pathological theories. Many quotations from Chinese medical books occur in *Isinpô* selected by a Japanese, Yasuyori Tanba, in 984 A.D., and in this regard, it is of value for any study of medicine in the T'ang period since so many of the original works have been lost.

Hsin-hsiu-pên-tsao was written by Imperial command and under the direction of Li Chi, its compilation was completed in 659 A.D., chiefly by Su Ching. It was intended to supplement *Shên-nung-pên-tsao-ching* which was compiled one hundred years earlier.

Since T'ao Hung-ching lived in the southern district, his knowledge of medicinal substances was mainly local but *Hsin-hsiu-pên tsao* added 100 substances to the former book. It is thought that it contained illustrations of medicinal substances, probably in colour, and this shows that writing had become scientific and observation of medicinal substances sharp. This book listed medicinal substances from Arabia and several Western countries, indicating that the import of various products from the West had increased conspicuously. For instance, it mentions theriaca, a well-known drug of which the chief ingredient is opium, then imported from the Near East. In this connection, it is certain that the use of opium as a drug was not then practiced in China.

Some information about T'ang drugs can be obtained from the remains of the treasure at Shôsôin in Nara City, Japan. It is a storehouse in which many valuable articles, mostly mementoes of the Emperor Shômu in the Nara era, are kept, including not only medicinal substances but various utensils, implements, garments, porcelains and so forth. There are many articles brought directly from China, among which those imported from the south or from Persia in the T'ang period are included. The medicinal substances number more than 60, and besides the Chinese products are several introduced from Persia [12]. Further study of this material is being carried out by a number of Japanese scholars at present, and it is expected the results will be published in the near future.

[12] MANZO NAKAO, *About Chinese Drugs in the Storehouse of Shôsôin* (in Japanese) (Manmô, Nos. 67 and 68, 1925-26). The study by some Japanese scholars, written in following sentences, has been made public in 1956 for the title of *The Shôsôin Medicinals*, edited by Yasuhiko Asahina, 1955.

Alimentary therapy had been highly regarded in China from ancient times as can be seen in the list of dietary experts in *Chou-li*. In succeeding years, the Taoists continued to seek the elixir of life by way of diet and, at the end of the T'ang period, Mêng Shên, disciple of the prominent doctor Sun Ssū-miao, wrote *Pu-yang-fang ;* later, Chang Ting of Wu-tai, supplementing it, published *Shih-liao-pên-tsao*. Part of an old copy of this book is in the possession of the British Museum.

C. *Printing and Paper-Making*

Printing originated in China. The art of printing can be traced back to the era of Empress Wu, that is to the end of the 7th century [13]. At first, it was used to meet the massive demands for Buddhist literature, dictionaries and so on, but, about the period of Wu-tai, the sacred books of Confucianism were printed. In the succeeding Sung period, printing became so popular that it was carried out by ordinary individuals as well as by the officials, and it developed until it could run as an independent enterprise. During the years of Ch'ing-li (1041 A.D.-1048 A.D.) an artisan named Pi Shêng invented type made of hardened earth and glue to replace the block printing so far used. The process consisted of fixing type on an iron plate with melted wax and placing sheets on the plate as in block printing. As its technique remained crude, type printing never became as popular as block printing in China, although the use of metallic type was later successful in Korea.

The invention of paper is likewise due to the Chinese, dating back to about 100 A.D. Various materials for paper-making were used, including, according to the writings of the early Sung period, fibers of paper mulberry, bamboo, mulberry tree, etc. It would seem that the use of many different materials for paper-making and increased production was already under way in the T'ang period, and at the same epoch a unique event had occurred in the history of paper-making. In the 10th year of T'ien-pao (751 A.D.) in the reign of Hsüang-tsung of T'ang, when the army under the command of Kao Hsien-chih was defeated by an Arabian army in the Turkistan district, a number of Chinese paper-making artisans were captured. Paper-making factories were set up employing these prisoners and from these the knowledge of paper-making eventually spread over Europe.

[13] KIICHIRO KANDA, *The Origin of Printing in China* (in Japanese) (Toyogaku setsurin, 1948) ; T. F. CARTER, *The Invention of Printing in China*, 1925.

III. *Wu-Tai, Sung Period*

From the beginning of the 9th to the end of the 13th century

The period of Wu-tai succeeded that of T'ang and lasted some 50 years. It was followed by the Sung Dynasty which unified the whole of China and which came into being in 960 A.D. About this time, however, the Liao Dynasty had been formed in the north-eastern district of China, and for some time menaced the Sung Dynasty. No sooner had the Liao Dynasty been overthrown by a joint operation of the Chin Dynasty in the north-eastern district and Sung in the south, that the former attacked its ally and in 1126 A.D. succeeded in capturing K'ai-fêng, the capital city. Consequently, Sung moving its capital to Hang-chou in the south, China was divided into two. Chin established its capital at Pei-ching and occupied the whole stretch of northern China.

It is customary to call the first displacement of central authority of the Sung Dynasty to the south, Northern Sung and its later retreat to the south, Southern Sung. After the rise of the Mongolian race, Yüan took Chin's place, while Southern Sung, losing its power gradually, continued to exist until the end of the 13th century.

It was during the Sung period that Neo-Confucianism emerged and gave an impetus to study of the T'ang period and preceding periods. In this Neo-Confucianism, "Ko-wu-chih-chih" ("after scrutinizing the reason for things, seek after deeper knowledge") was emphasized. Although this precept was purely ideal and although it had never been intended to encourage empirical science, yet the natural philosophical thought which accompanied Neo-Confucianism exercised great influence on medicine. Learning spread with the popularization of printing, and the progress of urban culture was conspicuous, but originality in science was little in evidence except for a number of remarkable technical achievements. In the short time from the end of Sung to the beginning of Yüan, considerable advance was seen in the fields of mathematics and, particularly, medicine.

A. *Astronomy, Cartography, and Mathematics*

Nineteen kinds of astronomical tables, apart from some unofficial ones, were compiled throughout the 300 years of the Sung period, accompanied by as many revisions of the calendar. Even in the Liao and Chin Dynasties, calendars based on Sung methods were used. Most astronomers in the Sung period avoided making new observations of astronomical phenomena but were merely content to modify constants, such as the length of the year, etc. However, as soon as the astronomical phenomena proved to be too much at variance with the existing records, the compilation of new tables became necessary.

The most prominent astronomer of the Sung period was Liu Hsi-sou of Northern Sung. He compiled *Ch'ang-shu* (a kind of chronological table) from the beginning of Han to the end of Wu-tai, and contributed to the compilation of Chinese chronology. About the same period, Shên Kua, whose scholarship was widely recognized and who was conversant in other sciences, wrote *Meng-ch'i-pi-t'an.* In this he pointed out the defects of the existing Chinese luni-solar calendar and became the first proponent in China of the solar calendar, which was, however, adopted only after 1912, under Western influence.

While no remarkable advance was made in regard to astronomical tables, it was in the Northern Sung period that an armillary sphere was constructed, and the position of fixed stars accurately determined. For astronomical as well as astrological reasons, the determination of the positions of fixed stars and the drawing of star charts had been practiced from ancient times in China. In the Sui period, a certain Tan-yüan-tzū composed a long poem, *P'u-t'ien-ko,* in which knowledge of the constellations was incorporated. Among the determinations of the positions of stars in the Sung period, one conducted during the Huang-yu era (about 1050 A.D.) was particularly noteworthy [14]. There still remain minute records of about 340 stars based on these determinations, that is records of right ascension differences which refer to the standard star of 28 hsiu and the north polar distance of these stars, and from the latter it is easy to calculate a star's right ascension. Besides such a star calalogue, a star chart appears in Su Sung's *Hsin-i-hsiang-fa-yao.* It was based on the measurements made during the Yüan-fêng era (1078 A.D.-1085 A.D.) a little later than the Huang-yu era, but it is not known how far the positions of plotted stars are correct, for the original edition no longer exists. In Soochow an astronomical chart engraved in stone seems to have been based on measurements made during the Yüan-fêng era. Many charts were originally drawn for the royal prince by a scholar called Huang Shang, and it is one of these that, during the Ch'un-yu era (1247 A.D.), was engraved.

Mainly for astrological reasons, all heavenly phenomena, beginning with lunar and solar eclipses from olden times, had been observed and recorded. This tradition continued through the Sung period. From these records it was found that a new star (nova—now presumed super nova) was observed in 1054 A.D. and consequently these records are attracting the attention of many modern astronomers. In general, as Chinese records of observation have been kept from remote ages, they can be said to be quite valuable.

[14] KIYOSHI YABUUCHI, *On the Star-Catalogue of the Sung Dynasty* (in Japanese) (Toho Gakuho, Kyoto, Vol. 7, 1936).

Su Sung in his *Hsin-i-hsiang-fa-yao* explained by means of a chart the new astronomical instruments made by himself in the Yüan-yu era (about 1090 A.D.). He was a man of extensive learning and compiled a book on pharmacology, made a water clock, an armillary sphere, and further, by using the water clock as a motor he made a celestial globe with its stellar system revolve, reproducing the conditions of the sky ever undergoing changes. No doubt, this kind of device existed fairly long ago. In the T'ang period I Hsing and Liao Ling-tsan had made it, and further in the beginning of Sung a work by Chang Su-hsün of Shu existed. When Chin captured the capital of Sung in 1126 A.D. and brought back many astronomical instruments and books to the north, the advancement of astronomy in Southern Sung declined.

As stated already, an important survey was carried out in the Hsüang-tsung era, and a little later Chia Tan (730 A.D.-805 A.D.) published *Hai-nei-hua-i-t'u* and other works on geography in the 17th year of Chân-yüan (801 A.D.). Even though the map no longer exists, it is known that it was a full-sized one of 3 "jo" (about 360 inches) in width by 3.3 "jo" in length, drawn on graph paper to a scale of one inch to 100 Chinese li. Not only China proper, but also Tibetan districts were included, and as it was useful to national defence, the author received courteous treatment from T'ang's prince. As to existing maps, these are Yü-chi-t'u and Hua-i-t'u which were carved on stone. These are known to have been carved in 1137 A.D. because of appearance of the words "7th year of Fu-chang" (1137 A.D. is the 7th year of the Fu-chang era of the Ch'i Dynasty which lay between Chin and Sung). Yü-chi-t'u is a map of all China of 3 "shaku" (about 36 inches) by 3 "shaku", and in a scale of one inch to 100 Chinese li. These graph paper maps were originated by P'ei Hsin (224 A.D.-271 A.D.) of Chin and imported into Chia Tan [15].

Little creative study is found in mathematics of the Sung period. The wars of Wu-tai at the end of T'ang destroyed many old books on mathematics, but those which survived until the Northern Sung period were printed and can still be found today. The period between the end of Sung and the beginning of Yüan marked an epoch in Chinese mathematics, and in the north Li Chih and in the south Ching Chiu-shao, Yang Hui, Chu Hsi-chieh took an active part. A method for discovering an unknown quantity by calculating blocks led to the creation of a kind of algebra.

[15] Takuji Ogawa, *The Development of Chinese Cartography: Studies of Chinese Historical Geography* (in Japanese), 1928 ; Shikazo Mori, *Commentary on the Map of the Earth possessed by Rikkyokuan* (in Japanese) (Toho Gakuho, Kyoto, Vol. 11, 1941).

B. *Medical Science and Pharmacology*

Many revisions of and annotations of classical books on medical science were made in the Sung period and a number of important classical books therefore still survive, though not in their original forms. For example, Wang Ping annotated *Huang-ti-su-wên* during the Pao-ying era in the T'ang period. This book was later lost, but another manuscript revised by Lin I and others during the Chia-yu era (1056 A.D.-1062 A.D.) in Sung still exists. Lin I and others also revised and published *Shang-hang-lun* by Chang Chi. Not only were classical books published but also many new books on medical science, and in this respect, as in regard to pharmacological books, the Sung period is preeminent. This achievement was due to the improvement of printing technique and, at the same time, to the active efforts of successive Emperors. It is important to note that of these books on medical science and pharmacology, only a few were the work of specialists and almost all the rest produced by the Confucianists.

Among the principal books of medical science were *T'ai-pin-shêng-hui-fang*, written at the beginning of the Sung period, *San-in-chih-i-ping-chêng-fang* by Ch'ên Yen, which explained the new pathology, and the two hundred volumes of *Shêng-chi-tsung-lu*, which were compiled during the Chêng-ho era, and formed the encyclopaedia of medical science in those days. Much later, during the reign of Hui-tsung, a simple *Ho-chi-chü-fang* was compiled. This was highly esteemed as a handbook for the country doctors and was an index to practical methods of medical treatment. Books specifically dealing with pediatrics and gynecology were first written in the Sung period ; *Hsi-yüan-lu*, a famous book on medical jurisprudence, was written by Sung Tz'ū of Southern Sung in the middle of the 13th century, and medical jurisprudence in general was advanced at that time ; a description of the human anatomy was first made in the Sung period [16].

Neo-Confucianism developed in the Sung period and "Hsing-li-shuo" based upon the natural philosophy appeared. Four famous doctors who lived between the end of Sung and the beginning of Yüan were greatly influenced by this theory. As mentioned above, medical science in the Sui and T'ang periods was based on the experiential curative means established in the period of the Six Dynasties. But with the Sung period, the ancient medical science described in *Nei-ching* was revived, and the four doctors suggested new theories and new curative means. These men were Liu Wan-su of Chin, Chang ts'ung-chêng and Chu Chên-hêng of Southern Sung, and Li Kao of Yüan, and their

[16] Kōzō Watanabe, *General Remarks on the Dissection and Anatomical Figures in China* (in Japanese) (Nihon Ishigaku Zasshi, Vol. 7, 1956).

work was so remarkable that entirely new schools in medical science were established.

As far as the books on pharmacology are concerned, at the beginning of the Sung period, Liu Han and others compiled *K'ai-pao-pên-tsao,* revising *Hsin-hsiu-pên-tsao* of the T'ang period. During the reign of Jen-tsung, new books on pên-tsao were compiled according to *K'ai-pao-pên-tsao.* For example, Chang Yü-hsi and others wrote *Chia-yu-pên-tsao* which described in detail as many as 1082 medical substances, revising old theories and adding many new substances. Together with this *Chia-yu-pên-tsao,* a famous astronomer, Su Sung, made illustrations of medicinal substances and although his book no longer exists, almost all the illustrations had been reproduced in a rather different form in later books, and today are of great value in identifying the Chinese medicinal substances.

As we have seen already, in *Chia-yu-pên-tsao* illustrations and their explanations were given separately, but T'ang Shên-wei and Chên Ch'êng put both into a single volume. They also published *Ching-shih-chêng-lei-pei-chi-pên-tsao* and *Chung-kuang-pu-chu-shên-nung-pên tsao* and *T'u-ching* in 1092. Afterwards, on the basis of these books, Ai Shêng compiled *Ta-kuan-pên-tsao* in 1102 and Ts'ao Hsia-chung *Chêng-ho-pên-tsao* in 1116. In the year when *Chêng-ho-pên-tsao* was compiled, K'ou Tzung-shih wrote *Pên-tsao-yen-i,* in which he eliminated all medicinal substances appearing in older books when their value was uncertain. All the above books were compiled and published in the Northern Sung period, but Wang Chi-hsien's *Shao-hsing-pên-tsao* published in the 29th year of Shao-hsing era (1159 A.D.) in the Southern Sung period and apparently written on the basis of *Ta-kuan-pên-tsao* also merits attention.

C. *Gunpowder and Magnetism*

Gunpowder was first made in China, the chief ingredients being nitre, sulphur and charcoal. Although Tseng Kung-liang first described the method of compounding gunpowder in his *Wu-ching-tsung-yao* in the middle of the 11th century [17], a method of compounding something like gunpowder appears in a book written still earlier by Taoists [18]. At all events, it may be said that from the appearance of *Wu-ching-tsung-yao,* gunpowder became militarily important.

[17] Jin-ichi Yano, *About the Rise of Modern Gunpowder and Firearms in China: Politics and Culture in Modern China* (in Japanese), 1926.

[18] Fêng Chia-shêng, *Invention of Gunpowder and its Propagation* (in Chinese), *(Shih-hsüeh-chi-k'an,* the 5th period, 1947).

It is said that the Chinese were the first to make practical use of the magnet. Of course, in China as elsewhere it had long been known that magnets attracted iron substances, but it was in the Sung period that it was discovered that a magnetic needle points to the north.

In *Wu-ching-tsung-yao* there is a description of Chih-nan-yü or the fish which pointed the direction. This Chih-nan-yü was a fish-shaped piece of wood to which a magnet was attached, so that it pointed north and south when it was set afloat. In ancient China, there was a device called Chih-nan-ch'ê [19], which has been wrongly considered as a magnetic needle, whereas it was not a magnet at all but a contrivance geared to point to the south. Shên Kua's *Meng-ch'i-pi-t'an* explained how to suspend a magnetic needle with a string, and noted that it does not always point due north owing to the declination of the needle. It is likely that a magnetic needle was first used for navigation in China at the end of the 11th or at the beginning of the 12th century [20]. Some scholars claim that it was brought to Europe by the Arabs.

[19] Ayao Kuwaki, *Studies of Chih-nan-ch'ê and the History of the Compass: Studies on the History of Science* (in Japanese), 1944.

[20] Jitsuzo Kuwabara, *On the Bibliography of Ho Jukô* (in Japanese), 1935.

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