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JAPAN

Shigeru Nakayama

The eighteenth century was one of Western recognition of Japan against the Chinese background. During that period, Japanese thinkers became critical of the Chinese scholarship with which they had struggled to keep pace in the previous century; for the first time, Japanese intellectuals from the extreme eastern regions of Asia began to compare Chinese scholarship with the infiltrating Western science. It is extremely interesting to see what happens to a paradigm from one culture – and the scholarly traditions that have evolved around it – when it is introduced into another. In the following pages we shall examine the impact of this transplantation, mainly on three disciplines: mathematics, astronomy, and medicine.[1]

The Jesuits had been evangelizing in Japan since the mid-sixteenth century. Eventually, the Japanese government, considering Christianity a threat to the cohesiveness and integrity of Japanese culture, successfully banned all Westerners from the country with the exception of Protestant Dutch traders,[2] who were restricted to the port of Nagasaki. This ban, which remained in effect until the mid-nineteenth century, was reinforced with bans on Jesuit writings in Chinese in the 1630s and further intensified in the 1680s.

The beginning of the eighteenth century was thus the nadir of access to information on all things Western. Throughout the eighteenth century, a gradual relaxation of the ban brought an awareness of East-West comparisons based on limited sources of available information.[3]

[1] Shigeru Nakayama, *Characteristics of Scientific Development in Japan* (New Delhi: The Center for the Study of Science, Technology, and Development, 1977).
[2] C. R. Boxer, *Jan Compagnie in Japan, 1600–1817* (The Hague: M. Nijhoff, 1936).
[3] Masayoshi Sugimoto and David L. Swain, *Science and Culture in Traditional Japan* (Rutland, VT: C. E. Tuttle, 1989).

SCIENCE AS AN OCCUPATION

Peace prevailed throughout the century in Japan. The economy and demographics remained stable, and the class hierarchy was tightly maintained. The samurai – around 6 percent of a total population of approximately 25–27 million – were at the top of the class structure, and their sons learned the orthodox Confucian classics in clan schools. Commoners were much less literate until village schools evolved toward the end of the eighteenth century with the development of the rural economy.

The samurai class held hereditary stipends that only firstborn males could inherit. Families without sons had to adopt heirs if they were to continue. Younger sons, on the other hand, had to find their own livelihood. Most of them were adopted by other families, and others found occupations outside the old rigid structure in medicine or Confucian scholarship.

There were no clear-cut scientific occupations. Astronomy and medicine were esteemed but offered opportunities only to a few talented men. These fields offered opportunities outside the conventional structure, allowing some to take advantage of a social mobility that was not otherwise available. But attempts were continually made to subordinate men in these fields to the hereditary tradition that governed the rest of Japanese life. It was expected, for instance, that the son of a doctor would eventually be registered as a doctor, regardless of how little aptitude or motivation he might have. The shogunal and fief governments needed talented professionals, however, and governmental authorities often resolved the conflict by advising a professional family to adopt a gifted youngster.

Elsewhere in the Chinese cultural domain, including Korea and Vietnam, scientific professionals were tightly bound to central government institutions through civil service examinations. However, in Japan after the tenth century, as the Chinese-type court bureaucracy atrophied and military power became dominant, these examinations disappeared.

Even during the peaceful Tokugawa period (1603–1869), the shogunal government had no power to impose its recruiting policy on the fief government. During the eighteenth century, the shogunate discussed reviving the examinations, but this was carried out only tentatively in the last decade of the century by testing candidates in Confucian studies from the lower samurai class.

However, an egalitarian examination system was not possible within a hereditary structure. In practice, those who passed with the highest grades received only a prize, varying with their family status, but it did not bring a permanent increase in social status.

Medical examinations began some years before those in Confucian studies. The shogunate, in need of several hundred doctors, gave written as well as oral examinations. They, too, were not intended to change the social status of graduates but to encourage the sons of medical families to study diligently rather than simply claim their sinecures.

To find experts to fill posts in technical fields such as astronomy (there were only ten or twenty such posts), personal references were sufficient.

THE BAN ON WESTERN SCIENTIFIC KNOWLEDGE

During the eighteenth century, woodcut printing flourished. A set of printing blocks could produce around two hundred clear copies, and, therefore, publishing a book with a corresponding potential readership was commercially feasible. By the end of the century, a popular culture of reading evolved to the extent that more than ten thousand copies of a bestseller might be in circulation. During the eighteenth century the center of publishing moved from Kamigata (Kyoto and Osaka) to Edo (Tokyo). Most academic works were written in classical Chinese, whereas popular works used a native style that combined Chinese characters and phonetic kana.

Even as the book trade grew, an official ban severely restricted knowledge of the West. In the 1630s the government banned imports of Sino-Jesuit writings, thus depriving the reading public of information on Western science. In 1685 the censors defaced and destroyed what previously had been two important sources of European cosmology: *Huan yu ch'uan,* written by the Portuguese Jesuit Francisco Furtado (now preserved at the Bibliotheque Nationale, Paris) and the sequel to a Chinese work with Jesuit influence, *T'ien ching huo-wen* (Queries on the Heavens), which will be discussed later in this chapter.

A collection of treatises by Matteo Ricci, *T'ien-hsueh chu hand,* had previously been available in Japan. It consisted of two parts: *li,* catechetical and theological, and *ch'i,* scientific. The latter does not appear to have been strictly censored. The world map compiled by Ricci, and some popular astronomical books that reflected some Western influence such as *T'ien ching huo wen* (Tenkei Wakumon), had escaped the attention of the censors at the port of Nagasaki. These documents, as they spread among Japanese intellectuals, influenced their worldview as well as their cosmology.

Furtado's book *Huan yu ch'uan* is a popular treatise on Western cosmology and cosmography, with the first half covering Christian theology and the second half devoted to scientific matters, as in Ricci's collection and in contemporary popular books. This format implied that the two parts, written by the same author, were distinct but inseparable. When the authorities became aware of this, public access to scientific and overtly religions works was forbidden, and at the beginning of the eighteenth century the Sino-Jesuit treatises were still heavily censored.

The Jesuits, who arrived in China in the seventeenth century, challenged traditional astronomy with their superior parameters and methods of calculation, which became apparent in competitions to predict solar eclipses. It was clear that in astronomy – the foremost subject of a traditional exact science – the criterion of quantitative precision transcended East and West, and observation of celestial phenomena precluded human manipulation. Accordingly, Jesuit astronomers took over the Astronomical Bureau in 1644, won a decisive prediction contest, and quickly carried out a calendar reform that established a largely Western system, the Shih-hsien li. Jesuit control over the Bureau, although challenged several times, survived until the end of the empire.

The Japanese learned about this Chinese reform from imported annual almanacs. Because of the ban on Jesuit works since the 1630s, not enough information could be obtained to reform the Japanese system. Shibukawa Harumi (1639–1715), the first genuine reformer, judged from the crude values of Western parameters given in the popular *T'ien ching huo-wen* that the Shih-hsien calendar was no improvement on its predecessors. Shibukawa followed the great Shou-shih computational system of 1279, which had not been significantly improved before the arrival of the Jesuits.

T'ien ching huo-wen provided Japanese intellectual circles with a standard pre-Copernican cosmological picture, but its sequel was banned at Nagasaki for the official reason that its contents were occult and therefore unhealthy. This volume has long been unknown in China. I had an opportunity to look at the copy in the Seikado Library in Tokyo, a modern acquisition from a Chinese private collector. It contained nothing fantastic. Its history of Chinese calendrical astronomy clearly stated that the Western Jesuits carried out the recent Shih-hsien reform. If contemporary Japanese read this book, the news may have caused great concern and jeopardized Shibukawa's native Jokyo reform, which was based on a purely Chinese model.

We still do not know why the sequel was banned. It is my guess that under the seclusion policy the government and its "Confucian" censors feared that it would convince intellectuals that Western astronomy was superior to traditional Chinese astronomy and perhaps would lead eventually to the belief that Christianity was superior – something that was, after all, the ultimate aim of the Jesuits astronomical activity in China.

In the early part of the eighteenth century, members of the scientific elite in the shogunate consulting bodies began to suspect that the Chinese approach to calendar-making had been replaced by that of the West. Because of this suspicion, in 1720 Tokugawa Yoshimune, the eighth shogun (1684–1751), who was himself eager to collect Western knowledge, ordered specialists in calendrical astronomy and mathematics to carefully examine the banned books that were stored in the shogunal library. Nakane Genkei (1661–1723), a private scholar not previously allowed to see Shibukawa's Jokyo calendar, at Yoshimune's request read the Sino-Jesuit astronomical writings and concluded that they would be useful for the next calendar reform.

The shogunate adopted his recommendations and encouraged elite scholars to study foreign languages, particularly Dutch, which was the sole language used for trade with the West during the seclusion period.

This event, a watershed in the official recognition of Western science, would have shocked those who respected the Chinese model. Because the central government demanded a monopoly on information about the West, it never publicly announced the lifting of the ban. People were still wary of becoming involved with anything related to Western learning. However, for the remainder of the eighteenth century a number of intellectuals perceived that the policy was not being rigorously enforced, and they copied and circulated Sino-Jesuit works. To escape the censors' notice, they often put false titles on the front pages and avoided direct quotation.

In 1726 an incomplete set of the *Li-suan ch'an-shu* (Complete works on calendrical mathematics, 1723), by the great mathematician Mei Wenting, reached Japan. This work was influenced by the Jesuits, but because Mei's work was purely scientific and technical it was much safer to disseminate in Japan. Mei's treatises convinced the Japanese that Western astronomy was superior, and that brought about a further moderation of the ban.

TRANSLATIONS OF WESTERN WORKS

Japanese intellectuals could read classical Chinese writings without difficulty, and Sino-Jesuit publications were likely to be widely read if available; hence the ban. However, because no astronomer had mastered European languages, there seemed little need to ban these publications.

On the other hand, at the port of Nagasaki there were about fifty official interpreters of Dutch, twenty-three of them hereditary. They had enough linguistic knowledge to communicate verbally with Dutch traders and ships' doctors. In the mid-eighteenth century, with the relaxation of the seclusion policy, these interpreters began to study Dutch books and undertake translations. They usually worked at the request of feudal lords who rewarded them well. They translated the few books they received from their foreign contacts. These materials – initially they were generally maps, seamen's almanacs, and other navigators' essentials – stimulated curiosity about Western countries. Eventually, Dutch merchants were asked to import various books by way of Batavia (Indonesia), but these were expensive and limited in subject matter.

The official interpreters were bound by their official duties, and their translations were never intended for publication. Doctors, on the other hand, as intellectuals and men of culture, were more open-minded, independent of government institutions, and eager to publish books that would improve medical practice. Their knowledge of Dutch was greatly inferior to that of the Nagasaki interpreters, but, nevertheless, a few of them obtained Western medical books and began to translate them. The first publication was *Kaitai Shin-*

sho (New Book of Anatomy) in 1773. A pioneer of the project, Sugita Genpaku (1733–1817), managed to obtain official approval in advance for the first published translation of a Western book, and, as the title of his memoir states, this was viewed as the dawning of Dutch learning in Japan. This breakthrough encouraged other physicians and intellectuals to learn Dutch and to investigate Western science. By the turn of the century, a group of physicians and intellectuals formed a society with the aim of exchanging information on Western science.[4]

THE INDEPENDENT TRADITION OF MATHEMATICS

The Western world first became aware of the independent tradition of Japanese mathematics (*wasan*) through the publication in 1914 of *A History of Japanese Mathematics* by Eugene Smith and Mikami Yoshio. Japanese mathematicians had built this tradition on the basis of late seventeenth-century Chinese mathematics and had developed it independently in the eighteenth century. Despite the influence of Western culture on other aspects of life, Japanese algorithms and the Japanese style of writing equations are quite distinct. A number of its characteristic problems did not exist, or appeared later, in the history of Western mathematics.

Reckoners used the abacus or counting rods on a grid. When symbolic algebra appeared after Seki Takakazu (d. 1708), symbolic (as opposed to merely numerical) written calculation (on paper) became possible. *Wasan* has been compared to Newton's and Leibniz's differential and integral calculus; but Seki and his immediate successor, Takebe Katahiro (1664–1739), leading figures in the tradition, showed little interest in solving mechanical problems, the calculation of the area of a circle being a more typical preoccupation. Pure mathematics, in other words, was pursued as a hobby and was not associated with physical science.

In the seventeenth century, mathematicians established the tradition of *wasan* by the practice of "bequeathed problems." Anyone who solved a difficult problem for the first time would write a treatise and would then bequeath a new problem; whoever solved this problem would bequeath another, and so on. This ongoing competition gave the tradition its momentum. Emphasis was placed on problem solving by unusual means and on presenting problems for which solutions were unknown or perhaps did not exist. Mathematicians increasingly valued complexity and emphasized the transformation of systems of simultaneous equations into higher-degree equations.

This ostentation for its own sake prompted Seki Takakazu to introduce an important innovation: the *tenzan* algebra. This was a system for expressing

[4] Donald Keene, *The Japanese Discovery of Europe, 1720–1830,* revised edition (Stanford, CA: Stanford University Press, 1969).

unknowns, previously solved only via numerical equations, in symbols. He also developed a theory of equations that recognized imaginary and negative roots (*daijutsu bengi no ho, byodai meichi no ho*) but rejected them as "sick solutions" – thereby ruling out a theory of imaginary numbers. In *wasan,* as in Chinese arithmetic, problems were presented in the form of questions and answers and often omitted the method of derivation. Therefore, they did not encourage investigation of the basic nature of equations.

Seki was exceptional in investigating the general nature of equations. His orthodox standard for posing and solving problems fits the Kuhnian definition of "paradigm." Once this paradigm was established, "normal science" could follow.

Before the time of Seki and Takebe, mathematicians were concerned with the practical problems of calendrical astronomy: surveying and so forth. The paradigmatic approach ruled out application. Subparadigms appeared in the course of development – for instance, Takebe's *enri* (circle theory) calculus. Ajima Naonobu applied this method not only to circles but also to curves and curved surfaces in general. Wada Yasushi furthered the development of mathematical analysis by compiling tables of definite integrals and applying them to the mathematically infinite and infinitesimal, and so on. All these innovations remained, however, within the *wasan* tradition. There was little discussion of fundamental theories, and practitioners continued to solve increasingly complicated geometrical figures by algebraic means.

Another stimulus for amateur mathematicians came from a somewhat different source. Artists and poets had established a tradition of offering their masterpieces, painted on wooden plaques, for display in the public gallery of Shinto shrines. Mathematicians followed suit, exhibiting a tablet with both problem and answer displayed, usually accompanied by an elegant geometrical diagram for public entertainment. Amateurs seeking acclaim often spent a great deal of money on such pursuits. Thus, mathematicians valued playful competition rather than basic research or application, and intuitive breakthroughs for elaborate problems were regarded more highly than logical consistency or rigor. Indeed, when Euclid's *Elements* first came to Japan, *wasan* experts – noting its figures only – judged it rudimentary and unchallenging.

The Sino-Jesuit treatises had introduced trigonometry, and by the end of the century it was used by astronomers and surveyors. Although *wasan* mathematicians were capable of mastering it, they continued to use their traditional methods, valuing problems arising from their own tradition and not those posed by technical practice. The eccentric mathematical genius Kurushima Yoshihiro wrote, "In mathematics, it is more difficult to raise a problem than to answer it. Only mathematicians incapable of inventing problems borrow them from other fields such as calendrical science."[5]

Because of their lack of interest in practical applications, the nucleus of

[5]Naonobu Ajima, *Seiyo Sanpo* (1779), preface.

Japanese mathematicians did not compete with Western mathematicians in solving practical problems until the middle of the nineteenth century. Unlike other Japanese intellectuals, *wasan* practitioners, as they moved from paradigm creation to the formation of a support group, advanced to new technical frontiers without the need to consult foreign authorities. In isolation they underwent vigorous growth in normal science, largely unaware of the developments in Chinese or Western mathematics. *Wasan* did not substantially influence scholarship in other fields or in cultural matters, although those practitioners who applied their mathematical skills to the practice of land surveying or calendrical calculation were well-versed in the algorithms, formula, and notations of traditional *wasan* mathematics.

MATHEMATICS AS AN OCCUPATION

Seki Takakazu issued a license to teach, and it was developed by his successors into a five-stage system of degrees. This system did not guarantee employment as a teacher but was primarily considered an honor, certifying that a certain level of mathematical mastery had been achieved. Without a solid occupational basis it is difficult to estimate how many people were engaged in *wasan* or to distinguish amateurs from professionals.

There is evidence that even peasants occupied themselves with *wasan* puzzles in the agricultural off-season. Mathematicians were primarily hobbyists, and the traditions existed only in the private sector. Although the shogunate attempted to maintain the occupational hereditary system, it did not consider mathematics worthy of perpetuation through this system.

Only a handful of leading mathematicians were able to support themselves. From the late eighteenth century, a number of them traveled from village to village, visiting amateur groups and enthusiasts and conducting problem-solving competitions, thereby following the practice of other arts such as *haiku* poetry.

PUBLICATION IN MATHEMATICS

Wasan mathematicians circulated their solutions to problems by copying by hand, although the more famous published theirs. Popular mathematical works for general readership were even more widely published. The printing blocks were often cut in an informal running style of calligraphy, which made it easy for the literate public to read. They were bestsellers by Japanese standards, some selling more than several thousand copies.

The literary world did not consider mathematics to be true scholarship, and, from the end of the seventeenth century, mathematics was often classified in book catalogs as a hobby on a par with flower arrangement or the tea ceremony. *Wasan* authors, in an attempt to increase the prestige of their books, invited Confucian philosophers to write prefaces, which usually bore no relation to the technical content.[6]

ASTRONOMY WITHIN THE TRADITIONAL FRAMEWORK

The traditional Chinese approach ("calendrical astronomy") investigated the apparent motion of the sun and moon to construct a method for generating lunisolar calendars. The ultimate test was the precision with which a system could predict solar eclipses. Successive reforms refined parameters for solar and lunar motions by testing them on previous records of solar eclipses. Planetary phenomena attracted relatively little attention.[7]

Throughout the written history of Japan, the Chinese lunisolar calendar had been accepted. From the late seventeenth century onward, the shogunate adopted its own Jokyo system, merely revising the Chinese Shou-shih system of the thirteenth century to incorporate the difference in latitude between China and Japan.

An order of the Shogun Yoshimune in 1720 assigned responsibility for a new calendar reform to Nishikawa Masayasu. He was the son of the noted Nagasaki scholar Nishikawa Joken, Japan's foremost expert on the West. Masayasu was not a professional astronomer, but, assisted by professionals, he undertook a reform based on Sino-Jesuit writings. When Yoshimune died, a family of court astronomers in Kyoto tried to restore the emperor's prerogative of issuing the calendar. This conservative backlash ignored Yoshimune's goal of reform and their Horyaku system, issued in 1754, made matters worse. Masayasu was subsequently dismissed, and his associates could only edit their records for use by a future generation.

Real reform came a generation later in the Kansei calendar revision (1797). It was undertaken by Asada Goryu (1734–1799), a physician and amateur astronomer, and his followers, who had access to most of the Sino-Jesuit treatises.

In astronomy, the new Western paradigm did not replace the traditional Chinese one. Rather, new data and mathematical techniques were simply incorporated into the old framework. This was also the case in China from the seventeenth century onward, with the structure, style, and purpose of Chinese calendrical astronomy unchanged. As Hsu Kuang-ch'i, the high official who had collaborated with the Jesuit Matteo Ricci on several projects, remarked, "We melted down their materials and poured them into the [old]

[6] Shigeru Jochi, "The Influence of Chinese Mathematical Arts on Seki Kowa," unpublished Ph.D. dissertation (University of London, 1993).
[7] Shigeru Nakayama, *A History of Japanese Astronomy: Chinese Background and Western Influence* (Cambridge, MA: Harvard University Press, 1969).

Ta-T'ung mould."[8] Until the mid-nineteenth century, official Japanese astronomers adopted this attitude and even repeated Hsu's slogan in their treatises.

Throughout the eighteenth century, Japanese calendrical astronomy adopted the view that astronomical parameters varied in time. In 1684, the government adopted the Jokyo system, whose originator, Shibukawa Harumi (1639–1715), restored the variable tropical year length of the Chinese Shou-shih calendar. He reasoned that such a minute variation reflected high precision. In reality, however, it provided no gain in accuracy.

Ogiu Sorai (1666–1728), the most influential Confucian philosopher of his time, supported Shibukawa's notion on ideological grounds, commenting in his *Gakusoku Furoku* (supplement to School Rule), "Heaven and earth, sun and moon are living bodies. According to the Chinese calendrical technique, the length of the tropical year was greater in the past and will decrease in the future. As for me, I cannot comprehend events a million years ahead."[9] In Ogiu's dynamic view of nature, everything was subject to change and it was therefore impossible that ancient laws could still hold. Since the heavens were imbued with vital force, the length of the year could change freely, and thus constancy was not to be expected in the heavens. Indeed, only a dead universe could be governed by law and regularity. Since it was precisely the vital aspects of nature that interested Ogiu, he remained an agnostic in physical cosmology.

Lack of interest toward the search for regularities in nature prevailed in the School of Ancient Learning (*Kogaku*), of which Ogiu was the leader. Nature was observed in the light of social and ethical concerns. This moralistic, anthropocentric, and often anthropomorphic view of nature was common among Japanese Confucian intellectuals. Few of them imagined that mathematical astronomy was deserving of attention except to provide an accurate calendar. Hence, the official astronomers' recognition of Western superiority did not immediately influence conventional intellectuals.

The next calendar reform, the Horyaku (1755), replaced Shibukawa's notion of changeable parameters. The value of yearly change was much too large and the discrepancy between observation and calculation, as it increased, was bound eventually to become apparent. This secular variation, nevertheless, was again adopted without reflection in the system that was to follow, with a predictable growth in inaccuracy.

The traditional eclipse records used as benchmarks for astronomical parameters were not supplemented by Western observational records in Jesuit writings. Asada Goryu (1734–1799) collected all the available records, tradi-

[8] Shigeru Nakayama, *Kinsei Nihon no Kagaku Shiso* (Japanese Scientific Ideas in the Eighteenth and Nineteenth Centuries) (Kodansha Gakujutsu Bunko, 1993), p. 70.

[9] *Gakusoku Furoku* (Appendix to the Principles of Learning) (1727).

tional and Western, and tried to represent them all with a single formula of his own. He varied not only tropical year length but also other astronomical parameters in a twenty-six-thousand-year cycle of precession. His approach was purely numerical, and it was incorporated in the next Kansei calendar reform in 1798.

In Asada's time, knowledge of Western astronomy was still limited to Sino-Jesuit writings in Chinese, which made no mention of Copernican doctrines. Toward the turn of the nineteenth century, Asada's pupil Takahashi Yoshitoki (1764–1804) began to study a Dutch translation of Lalande's post-Newtonian *Astronomie.* His was a purely academic interest in the kinematics of planetary motions, although celestial mechanics were still beyond him.

Because calendrical astronomy was an official domain, advisers urged that the shogunate recognize Western superiority. However those bureaucrats employed in astronomy had no authority except in purely technical matters, and they neither intended nor had the power to speak publicly on the merits (or otherwise) of Western science. Their influence in nonastronomical fields was negligible.

An index of Western influence can be taken from the use of the Sino-Jesuit 360 degrees for coordinates as opposed to the traditional Chinese count of approximately 365.25 (the old degree, *tu,* was defined as one day's mean solar motion). Official astronomers working on the Kansei calendar reform (1798) first used the former, after which it spread gradually into general use.

ASTRONOMY AS AN OCCUPATION

Calendrical astronomy was a state monopoly. Issuing the annual ephemeris and reforming computational methods were purely a matter of prestige for the ruling government. In the eighteenth century, although dynastic legitimacy could not be removed from the imperial court in Kyoto, real political power lay entirely in the hands of the military dictator, the shogun, in Edo (Tokyo). Certain astronomical prerogatives were a hereditary right of the Tsuchimikado family in Kyoto, the imperial court astrologers, but only the shogun's astronomers had the actual power to reform the calendar and apply the science. There were eight shogunal families of astronomers, who, like their imperial predecessors, had become hereditary. They and their associates totaled between fifty and one hundred officials. The Tsuchimikado, other families of lower rank, and temporary associates brought the total in Kyoto to less than fifty. Hoping to restore their ancient authority, they successfully intervened at the time of Horyaku reform, but the Kyoto revival was short-lived.

The hereditary astronomers did not require talent or even much skill to calculate the annual ephemeris. They met the greater demands of the two eighteenth-century reforms by acquiescing in the appointment of – or even by adopting – well-qualified individuals. Some fief governments occasionally hired astronomers, usually because the ruling *daimyo* family was interested in the astrological prediction of natural disasters. Some remote areas such as Satsuma, one of the larger fiefs, appointed permanent astronomers and issued their own calendars, but these did not diverge significantly from Shogunal astronomical practice.

PUBLICATION IN ASTRONOMY

As a shogunal practice, astronomy was by no means accessible to the general public. The most important official treatise on the new calendrical system, the product of the calendar reform, was never published. Three manuscripts were submitted to the Shogunal Library, the Imperial Court Library, and the Library of the Ise Grand Shrines, to each of which only a few high-ranking officials had access. The government feared that criticism from the private sector would destroy public esteem for this particular governmental function.

As a result, those who wanted to learn computational astronomy could study only the past system, in particular the Shou-shi calendrical treatise of the late thirteenth century, the highest achievement in Chinese mathematical astronomy and the model for the Japanese calendar until the middle of the eighteenth century. Many illustrated guides and commentaries on this were complied and printed in Japan. The main source for cosmology was *T'ien ching huo wen,* the seventeenth-century treatise that incorporated some Jesuit elements. Again, many Japanese-illustrated versions and textbooks satisfied the intellectual needs of the day, and the needs of the general public were met with yearly almanacs printed and distributed by a network controlled by the hereditary imperial court astrologers.

INTRODUCTION OF COPERNICANISM AND NEWTONIANISM

Because the hereditary astronomers' interest remained confined to the traditional model of calendrical science, the introduction of the core of modern Western astronomy was left in the hands of the official interpreters. The first to become involved, perhaps, was Motoki Ryoei (1735–1794), who invented his own system of transliteration from Dutch to Japanese phonetics, using Chinese characters. We know of no similar activity in China at the time.

Ryoei was interested in translating a history of Western astronomy to add to the margins of large navigational charts. However, he was concerned to learn that Galileo had been persecuted because of his writings on Copernical cosmology. Ryoei realized that this would be a delicate subject in Japan since it was related to the strictly proscribed Christianity, and his translation, drafted in 1771, omitted discussions of the trial of Galileo. However, he found Copernicanism important and interesting, and his later translations gradually revealed details of Copernicanism, a full translation being completed in 1793. Borrowing from Ryoei, Shiba Kokan (1738–1818), an illustrator and popularizer, published many books that disseminated the theory of heliocentricism in Japan.

Shizuki Tadao (1760–1806) was also born into a family of official translators. He left his inherited profession to concentrate on the translation of Western books and was the first Newtonian in East Asia to introduce such concepts as the molecule and force. Because traditional Japanese Confucian learning was not concerned with natural philosophy and was unaware of late Chinese writing on the discipline, in translating Newtonian concepts terminology had to be borrowed from the Ten Wings of the Book of Changes, Buddhist speculation, and neo-Confucian writings. Tadao translated the work of John Keill, the popularizer of Newton, adding a great many comments of his own, some quite original and going far beyond Keill. Not entirely satisfied with Newtonian laws, Tadao attempted to base them on traditional Yin-yang metaphysics. He tried to introduce the inverse-cube centrifugal force or quadruple of distance to explain such phenomena as chemical affinity and plant physiology. Tadao is also known for his nebular rotation view of the solar system – a similar idea later attributed to Kant and Laplace – although, essentially, he applied neo-Confucian cosmogony to the solar system.[10]

PHYSICIANS AS INTELLECTUAL CONNOISSEURS

In the seventeenth century, mainstream Chinese medicine dominated that of Japanese with the exception of surgery, which the Jesuits had introduced in the sixteenth century to meet the needs of endemic civil war.

In the eighteenth century, a new group became critical of scholarship of the physiology and pathology that had prevailed in China since the Chin and Yuan periods. They claimed to be returning to a simpler reasoning that more directly reflected the clinical practice of the ancient *Shang han lun* (Treatise on Cold Damage Disorders, between A. D. 196 and 220) but showed little interest in the more theoretical and speculative *Huangti Neiching* (Yellow Emperor's Inner Classics). This group called itself *Koiho* ("Back to Ancient Medicine School").[11]

The school preferred simple and drastic medical prescriptions as opposed to the great variety of Chinese formulas, some simple and some complex, some strong and some mild, some formed by theory and some by direct experience of drug action, all of which neutralized effects. The Koiho defined their goals in terms of utility, which made Chinese complexity seem more of

[10] Tadashi Yoshida, "The Rangaku of Shizuki Tadao: The Introduction of Western Science in Tokugawa Japan," unpublished Ph.D. dissertation (Princeton University, 1974).

[11] Yu Fujikawa, *Kurze Geschichte der Medizin in Japan* (Tokyo: Kaiserliches Unterrichtsministerium, 1911).

an impediment. Because they wished to tackle disease as directly as possible, they refused to view it as a microcosm. As Yoshimasu Todo (1701–1773), the foremost figure of this school, declared, "Yin and yang are the *ch'i* of the universe, and thus have nothing to do with medicine."[12]

The Koiho were materialists in the sense that they rejected abstraction, trusting only that which was tangible, and thus they developed abdominal palpation, which did not exist in China.[13]

FROM THE ENERGETIC TO THE SOLIDIST VIEW OF THE HUMAN BODY

In Chinese and Japanese medicine, disease was attributed to an imbalance of *ch'i,* which circulated throughout heaven and earth and thus through the human body. It is now considered imponderable and incorporeal energy, but Ch'ing Chinese considered it the material basis of life. This view was close to that of Western humoralists, who believed disease resulted from an imbalance between the humors circulating through the body rather than to a pathological abnormality in a particular organ.[14]

Goto Gonzan (1659–1733), a precursor of the Koiho school, reduced traditional physiology and pathology to a simplistic scheme in which every disease originates in the stagnation of *ch'i* and in which the *ch'i* was a more materialistic concept than the accepted Japanese abstract and incorporeal matter. Goto's successors took a position much closer to that of the solidists than had previously been possible in Japan. Lacking abstract concepts, functional analysis lost its importance, and the Koiho physicians studied the physical organs for their own sake.[15]

In conventional *ch'i* physiology, dissection does not yield meaningful information, as the dead body contains no *ch'i.* Koiho physicians, on the other hand, showed a genuine interest in dissection and their organ-centered approach brought a recognition that the traditional anatomical charts were crude and inaccurate. In 1754 Yamawaki Toyo (1705–1762), a leader of the Koiho school, was the first to examine the corpse of a criminal for anatomical purposes. He questioned Chinese anatomical charts and wrote *Zo shi* (Chart of internal organs, 1759) on the basis of his findings. Yamawaki's achievement was, however, limited to challenging the old scheme of six yin and five yang organs (*wu-tsang liu-fu*) in preference to nine. No interest was shown in the

[12] "Idan," 1795, in *Kinsei Kagaku Shiso* (Ideas of Early-Modern Science), vol. 2 (Iwanami, Nihon Shiso Taikei, 1971), p. 540.
[13] Yu Fujikawa, *Japanese Medicine,* translated from the German by John Ruhrah, P. B. Hoeber (1934).
[14] C. Leslie (ed.), *Asian Medical Systems: A Comparative Study* (Berkeley: University of California Press, 1976).
[15] Norman Takeshi Ozaki, "Conceptual Changes in Japanese Medicine during the Tokugawa Period," unpublished Ph.D. dissertation (University of California, San Franciso, 1979).

investigation of the skull, which was regarded as a reservoir of medullary tissue.

In the East Asian tradition, it made no sense to ask in which organ thought took place because physicians did not think in solidist terms. They attributed every activity, mental or physical, to the fundamental agency of *ch'i,* which permeated the microcosm as well as the macrocosm and which circulated harmoniously in both. Thus, there was no reason to attribute thought as a function of the brain. Thought, imagination, and emotion were functions, not as a physical organ but as a bodywide system of energy circulation.

In 1771, however, Sugita Genpaku and his followers abandoned the Chinese physiological tradition, relying on Dutch anatomy charts,[16] although even they showed no interest in examining the contents of the skull after the decapitation of a criminal. Genpaku therefore found it difficult to translate Dutch writing on the brain, often resorting to guesswork and borrowing from Buddhist terminology in order to coin new words for sensory perception. His confusion created difficulties for successive generations of medical students, who used his writings as a base for the understanding of cerebral function.

Thus, the translation of Western anatomical books was significant not only as the beginning of Western learning in Japan but also for the introduction of the solidist school of thought into East Asian culture. However, it is unlikely that the average eighteenth-century Japanese doctor understood the function of the brain.[17]

Practitioners of Chinese medicine viewed disease holistically, and a given disease was not usually associated with a particular body location since pathological *ch'i* as well as life-sustaining *ch'i* usually affected the whole microcosm. For example, when doctors referred to a cardiac or hepatic dysfunction they were not referring to the physical organ but to a whole-body system of functions that the organ merely regulated and that the disease affected. They also treated the body holistically. To treat a headache, for example, needles were inserted into the foot. This approach did not require precise anatomical charts in the clinic. Unlike the physicians trained in the Chinese method, those surgeons cooperating with Sugita Genpaku discovered a remote ancestry in Western origins. This would explain their openness to a solidistic way of thinking.[18]

When the power of Western anatomical knowledge was first realized by the Japanese, it was naturally assumed that associated therapies would also be more effective, although there was no evidence for this belief. Indeed, therapeutically, there was very little choice between the systems of internal medicine that were evolved in the various advanced civilizations before the end of the

[16] Sugita Genpaku, *Dawn of Western Science in Japan* (Rangaku Kotohajime, 1815), translated by Rytz Matsumoto (Tokyo: The Hokuseido Press, 1969).

[17] John Z. Bowers, *Western Medical Pioneers in Feudal Japan* (Baltimore, MD: Johns Hopkins University Press, 1970).

[18] Harm Beukers et al. (eds.), *Red-Hair Medicine: Dutch-Japanese Medical Relations* (Amsterdam: Rodopi, 1991).

nineteenth century, although European medicine was more drastic and more likely to harm the patient than most.[19]

The traditionalists naturally objected to anatomy, a common response being that anatomy and dissection were irrelevant to the improvement of therapeutic practice. Other objections were based on traditional physiology. Sano Antei, in his *Hi Zoshi* (A Refutation of the Anatomical Charts, (1760), said, "What the *tsang* [the spheres of function and their associated viscera] truly signify is not a matter of morphology. They are constant containers that store vital energy with various function. Lacking that energy, the *tsang* became no more than empty containers."[20] In other words, the internal organs were characterized not by their morphology but by differences in function, defined by their proper *ch'i,* and, therefore, nothing could be learned by dissecting a cadaver, since its *ch'i* did not exist. Because they were based on dissection, the anatomical charts that had caught Toyo's imagination gave no indication of the dynamic functions of the body.

The same point emerges in another criticism of Antei: Yamawaki Toyo's anatomical charts did not demark the large and small intestines. Antei himself did not believe that they were morphologically dissimilar. A physiological difference followed. What made them different was that the large intestine was responsible for absorbing and excreting solid wastes, while the small intestine performed the fluid waste functions. This crucial difference would be undetectable in the dead body. Figure and appearance were significant only in terms of their relation to function. Antei, unlike the Koiho radicals, did not claim to be a pure empiricist. "The observation of two obvious facts is of much less value than groping speculation . . . even a child is as good an observer as an adult";[21] a scholar who did not investigate the connections between form and function was no better than a child.

In spite of such reactions by conventional physicians to the radical Koiho school, the solidist tradition that it had initiated paved the way for Western anatomy. Genpaku took up the study of anatomy because it seemed the most tangible and, therefore, the most comprehensible part of Dutch medicine. A solidist breakthrough resulted from this viewpoint and, at the turn of the century, physics and chemistry were studied by Genpaku's successors. The impact of anatomy challenged the energetics and its functional beliefs not only of medicine but also of natural philosophy, and eventually led to the wholesale introduction of modern Western science.[22]

19 Mieko Mace, *L'anatomie occidentale et l'experience clinique dans la mecine japonaise du XVIe au XVIIIe siècle,* in Isabelle Ang and Pierre-Étienne Will (eds.), *Nombres, astres, plantes et viscères: sept essais sur l'histoire des sciences et des techniques en Asie orientale* (Paris: Collége de France, Institut des Hautes Études Chinoises, 1994).

20 "Hi Soshi" in Koichi Uchiyama, "Nihon Seiri Gakushi" (History of Japanese Physiology), in *Meijizen Nihon Igakushi* (History of Japanese Medicine before Meiji Era), vol. 2 (1955), p. 122–3.

21 Ibid.

22 Wolfgang Michel, *Hermann Buschof – Das genau untersuchte und auserfundene Podagra, Vermittelst selbst sicher-eigenen Genaesung und erloesenden Huelff-Mittels* (Heidelberg: Haug Verlag, 1993).

THE MEDICAL PROFESSION AS AN OCCUPATION

Medical practitioners who began to take on the challenge of Western science constituted the largest scientific profession during the Tokugawa period. Medicine, unlike astronomy, was a private concern and not subject to any form of constraint in terms of response to new ideas. Because there was no public health program at the time, medical practice was essentially a relationship between physician and patient. Each community usually had a private physician or healer. The samurai class had its government doctors and fief doctors, and townspeople and peasants had their local practitioners. Medicine was not a profession, and practitioners did not form organizations or even common ties. They were not regulated by the central government and were not subject to the traditional expectation that physicians should be sons of physicians.[23]

Edo, as the seat of the shogunate, was a center of professional activity. The important schools of medicine were scattered as far as Nagasaki, where a tradition of Western surgery was maintained through access to Dutch interpreters. Osaka, for instance, was famous for its number of physicians, whose patients were mainly from the merchant class. This decentralization made medicine one of the few geographically mobile professions in Japan.

Unlike the medical profession in contemporary Europe, which was well established and able to develop through the universities, Japanese doctors remained marginal. Government appointments were not the only possible source of income for physicians. A doctor hired by a fief government had no more status than other petty intellectual officials (Confucian scholars, astronomers, or interpreters), but private practice could bring a much higher income.

Doctors – unlike official astronomers – were independent of government hierarchy, and, in the period shortly before the modernization of Japan, they were among those most receptive to liberal thought.

Medical practitioners were not licensed. Even those who were able to read medical classics could advertise themselves as physicians. Often, those hoping to qualify as Confucian scholars supported themselves by practicing medicine. The shogunal and fief governments appointed physicians, usually with small stipends, to take care of lords and samurai families. The government often encouraged physicians to adopt a talented young man to ensure a reliable supply of medical practitioners rather than bequeathing a first-born son. Toward the end of the century, as public living standards improved, towns and even small villages supported their own doctors, although most of the peasants found Omyoji (traditional diviners) adequate to meet their medical requirements.

Physicians were usually trained by apprenticeship. A young man wishing to embark on a medical career would become the pupil of a practitioner, living in his house for several years to gain "hands-on" experience. The ap-

[23] Erhard Rosner, *Medizingeschichte Japans* (Leiden: E. J. Brill, 1989).

prentice would then move from place to place to gain clinical experience, finally returning home to set up in practice. The more ambitious would seek medical training as far away as Edo, Kamigata, or Nagasaki (for Dutch medicine). It is difficult to estimate the number of practitioners trained in medicine, but I would estimate it to be in the region of several tens of thousands.

The end of the century saw the emergence of therapists – practicing even in villages. For example, the second son of a village chief, with aspirations of becoming a country doctor, would spend many years as an apprentice to neighboring practitioners and finally return to his native village. He would be expected not only to provide medical services but also to undertake educational and cultural duties.

Young men who showed academic promise but with no conventional prospects were often advised to study medicine to achieve a secure livelihood. Those who studied Dutch medicine as a means to a medical career often became experts in Western learning and, much later in the mid-nineteenth century, were to have a revolutionary influence on political affairs.

Among the intellectual professions of the Tokugawa period, it was only physicians who were able to achieve an independent position: they were able to view the world from new perspectives and thus bring modern (universal) science to Japan. However, their independence was bought at the cost of alienation from the true sources of power in Japan – the samurai governments. Their role was thus limited to that of connoisseurs of cultural novelty.[24]

From the late eighteenth century on, the Rangakusha (scholars of Dutch learning) were mainly free-lance physicians.[25] The more successful tended to live in cities, often with government appointment. In Edo, particularly, doctors met and exchanged information on Dutch learning. In 1794, they started their celebrations of the Western New Year and drank European wine. Some connoisseurs wrote entertainingly on curious aspects of Western culture, and their books became best sellers. Otsuki Gentaku (1757–1827), who published a heavily edited and revised version of the *Kaitai Shinsho,* founded a school of Dutch language in 1789. Most of his students were doctors employed in the public sector, but people of any social status could attend. His school was followed by other institutions of Dutch learning. Motivated by a taste for exoticism (novelty), these scholars were not hindered by feelings of inferiority toward Western science.[26] At the turn of the nineteenth century a few recognized that it provided something that was lacking in the Eastern tradition, namely the natural philosophy that generated modern science.[27]

[24] Takeo Nagayo, *History of Japanese Medicine in the Edo Era: Its Social and Cultural Backgrounds* (Nagoya: University of Nagoya Press, 1991).

[25] G. K. Goodman, *Japan: The Dutch Experience* (London: Althlone Press, 1986).

[26] Yoshio Kanamaru, "The Development of a Scientific Community in Pre-Modern Japan," unpublished Ph.D. dissertation (Columbia University, 1981).

[27] Togo Tsukahara, *Affiniti and Shinwa Ryoku: Introduction of Western Chemical Concepts in Early Nineteenth-Century Japan* (Amsterdam: Gieben, 1993).

MATERIA MEDICA

Materia medica, a practice ancillary to medicine, included the study of substances derived from plants, animals, and minerals, and writings on these subjects were indispensable to practitioners. The government often sponsored these voluminous writings, which formed a large pharmaceutical encyclopedia that followed the pattern of the Chinese classification of drugs – mainly according to symptoms – and provided a rough classification of sources. A Chinese treatise, *Pents'ao kang-mu* (Systematic materia medica, 1596, imported 1607), taxonomically arranged, provided a standard pattern in Japan as well as in China. An important Japanese concern was the comparison and identification with local species of animals and plants mentioned in the Chinese classics. This concern led to a dependence on actual observation rather than on the study of classical works. This not only furthered the trend toward morphological study but also introduced a new criterion of classification according to habitat and environment, such as distinguishing insects living on or in water, and fish living in fresh or sea water, as shown in *Yamato Honzo* (Japanese materia medica, 1708) by Kaibara Ekken (1630–1714).

Most scholars of materia medica were physicians, but in the latter half of the century their interest extended from conventional writings of materia medica toward encylopedic natural history, which added new species without proven medical properties, including materials imported from the West.

CONCLUSION

From the seventeenth century on, when Western knowledge began to produce claims distinct from Chinese learning, Japanese thinkers were critically attentive. The conviction that European technical knowledge was superior brought about a switch to the new model. Yoshimune and his astronomer mathematicians clearly recognized the superiority of Western over Chinese astronomy. As bureaucrats or technicians, their interest in Western science was limited to the precision of astronomical data and methods of calculation, and they did not jeopardize their hereditary posts by entering into the mechanistic philosophy of early modern Western science.

Professional interpreters in Nagasaki, well versed in the Dutch language, became acquainted with the concepts of Western science. They too, as hereditary officials, remained within the boundaries of their duty to translate faithfully. Neither official astronomers nor interpreters wrote for a general readership.

From the late eighteenth century on, many Dutch works on *Natuukunde* (the study of nature) found their way into Japan. They aroused the interest of independent scholars, who set about translating them even though their language skills were inferior to those of the Nagasaki interpreters. The majority of these "Dutch scholars" were medical practitioners who were not necessarily occupationally motivated and were thus able to indulge in dilettantism.[28] By the end of the century their interest extended to anything Western.

Astronomy was the first discipline to bring about the conviction of the superiority of Western learning. The idea that this was also the case in other fields of scientific endeavor first spread among the independent physicians. Although only a few realized the power of mechanistic Western science, and fewer still knew of the Enlightenment, many were professionally interested in Western medicine. Unfavorable comparisons were not usually drawn; the thinking was that East is East and West is West and that curious things were going on in the West that brought interesting comparisons with the Eastern tradition. It was believed that Japanese intellectuals could gain advantages from both.

Later in the century, Western aggression toward East Asia – especially that of Russia – was to become prominent. It was not yet on a scale that prompted a radical reevaluation of the need to change political and technological institutions.[29] This took place after the 1840s, when Western aggression increased, leaving the shogunate face-to-face with advanced Western military technology.

[28] Herman Heinrich Vianden, *Die Einfhrung der deutschen Medizin im Japan der Meiji-Zeit* (Dusseldorf: Triltsch Verlag, 1985).

[29] Shigeru Nakayama, "Japanese Scientific Thought," *Dictionary of Scientific Biography,* XV, pp. 728–58.