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Ming Classification on the Eve of Jesuit Contact

By the time the Jesuits arrived in Ming China, many Han Chinese literati were debating an appropriate theory of knowledge. The debate often took the form of claims that morality (*zun dexing*) took precedence over formal knowledge (*dao wenxue*) or vice versa. The focus of the debate in Ming China was on the investigation of things and the extension of knowledge (*gewu zhizhi*). Ming literati invoked a sense of urgency in their encyclopedic efforts to reconstruct the textual lives of things at a time when the meaning and human significance of natural and man-made objects as commodities for the many betrayed the ideals of moral cultivation for the few.[1]

The Jesuits tried to reshape this research agenda by mediating between what they thought was China and their West (*Taixi,* i.e., early modern western Europe). They would add precision to the Chinese notion of investigating things and extending knowledge by exposing Ming literati to European classification schemes, forms of argument, and the organizational principles for all specialized knowledge, i.e., *scientia*. They never grasped, however, that what was happening in Ming China, namely the commoditization of things into objects of material value, was also sweeping through western Europe. Mexican silver dollars coming to China were the first steps of disenchantment about the moral investigation of things for the Chinese.[2]

Ordering Things through Names

Under Mongol rule during the Yuan dynasty, medicine as a profession became increasingly attractive when physician families were exempted from taxes and corvée labor as an occupational group. Some literati-physicians also linked investigating things and extending knowledge to medicine as a classical term to denote the technical learning of the latter. As the only eminent Yuan physician initiated in the direct line of Cheng-Zhu (Cheng Yi and Zhu

Xi) teachings, Zhu Zhenheng (1282–1358), for example, associated medical learning with classical studies. In his most famous work, titled *Discussions Based on Investigating Things and Extending Knowledge* (*Gezhi yulun*), Zhu also opposed Song standardized government medical prescriptions that had been drawn from an empirewide collection of Northern Song (960–1126) medical texts for the Imperial Pharmacy.[3]

In the *Discussions,* Zhu asked Yuan literati to acknowledge medical learning as one of the key fields of study that complemented moral and theoretical teachings by demonstrating the practical uses of the latter. Zhu's work had drawn on Liu Wansu's (1120?–1200) *Direct Investigations of Cold Damage Illness* (*Shanghan zhige*), which had also appealed to the ideal of investigating things (*gewu*). "Cold damage" disorders (*shanghan*) included influenza, common colds, and typhus or typhoid fever. In the late eighteenth century, the editors of the Qianlong emperor's (r. 1736–1795) Imperial Library favorably cited Zhu Zhenheng's claim that medicine was one of the concrete fields that informed the "investigation of things and extension of knowledge."[4]

Overlap between medicine and the investigation of things was often mentioned in late Ming writings. For example, the literati physician Yu Chang, a secondary provincial graduate of 1630, prepared a medical case book. In his 1643 preface, Yu presented the methodology of the Great Learning as the epistemological basis for his efforts to gain an impartial understanding of the root causes of a particular medical problem: "The achievement of sincerity resides in the investigation of things and the advancement of knowledge. Drawing distinctions [in this sphere] requires more rigor than the [legal] dichotomy of fraud versus honesty." According to Yu, investigating a case of illness was like investigating things. The key was to advance one's knowledge one item at a time until the proper diagnosis became clear.[5]

When the Catholic convert Wang Honghan learned about the Western anatomy introduced by the Jesuits in the late Ming, he equated Catholicism with ancient literati classical learning. In addition, Wang likened the "great physician" with the "great literatus," and stressed that study of the two traditions necessitated "exhaustively fathoming principles and investigating things." To "classify studies and clarify principles" (*gexue mingli*) was the way of the physician and the literatus. Although Wang accepted the Galenic tradition of anatomy as part of the Song-Ming investigation of things, he also turned to the Chinese therapeutic tradition for lessons in how to cure illnesses.[6]

Ordering Antiquities and New Findings

The investigation of things was conceptually also applied to the collection, study, and classification of antiquities, as in Cao Zhao's (fl. 1387–1399) *Key*

Issues in the Investigation of Antiquities (*Gegu yaolun*), which was published in the early Ming and enlarged several times. The work originally appeared circa 1387–1388 with important accounts of ceramics and lacquer, as well as traditional subjects such as calligraphy, painting, zithers, stones, bronzes, and ink slabs. It became an exemplar for late Ming antiquarians.[7]

The 1462 edition prepared by Wang Zuo (palace graduate of 1427) was considerably enlarged and included findings prepared by several members of the official Ming dynasty naval expeditions led by Admiral Zheng He (1371–1433) taken to Southeast Asia and the Indian Ocean from 1405 to 1433. Ma Huan's (fl. 1413–1451) *Captivating Views of the Ocean's Shores* (*Yingyai shenglan,* 1433), for example, had described the twenty countries the fleet visited and included detailed accounts of Yemeni towns such as Dhufar and Aden in southern Arabia.[8]

In addition to such descriptions, Wang Zuo was particularly interested in ancient bronzes, calligraphic specimens, and native curiosities. He also added native imperial seals, iron tallies, official costumes, and palace architecture to the collection. In his preface, Wang added, "Whenever you see an object, you must read all about it in the repertories, study its provenance, classify its quality, and judge its authenticity." Archaic-looking fakes produced by clever craftsmen for the Ming market of cultural commodities posed significant financial dangers for literati.[9]

Unlike the impact sixteenth-century oceanic discoveries allegedly had in early modern Europe, the new information the Zheng He fleets brought back to Ming China from southeast and south Asia in the fifteenth century did not challenge the existing frameworks of orthodox knowledge. Donald Lach has argued, for instance, that the early modern European world "underwent a transformation in the sixteenth century which produced in observers a sense of mild shock, wary fascination, or deep wonderment." Lach acknowledges, however, that many scholars "remained oblivious to the rents in the curtain obscuring the East." Those who were alert to the new findings realized that neither classical nor Christian learning in Europe could encompass the latest information, unusual artifacts, and geographical discoveries or duplicate the more advanced technical arts of India and China in textile manufacture and porcelain production.[10]

More recently, however, Michael Ryan, following Lucien Febvre, has argued that the newly discovered lands and new peoples registered little impact on the values, beliefs, and traditions of sixteenth- and seventeenth-century Europeans. We might add that the overwhelming intellectual influence in sixteenth-century Europe came from classical Greek manuscripts sent to Europe from Constantinople in 1453, and not from oceanic voyages. Similarly, Ryan rejects Lach's view that new forms of cultural relativism emerged in Europe. Instead, Ryan has examined how these new worlds were incorporated into a European lexicon by asking how European contemporaries interpreted their world. Their use of categories, such as ancient paganism as a transhistorical framework to classify the cultures of the new worlds, enabled them to domesticate exotic peoples within the frame of Graeco-Roman pagan antiquity.[11]

Europeans understood other peoples in light of familiar genealogies, which minimized the impact of new worlds by conceptualizing new worlds within the terms of the old one. In 1669, John Webb (1611–1672) contended that after the biblical deluge Noah's son Sem and his people had entered China. Athanasius Kircher (1601–1680), a Jesuit scholar who thought China a derivative of Egypt, thought that Cham was the better choice. The Jesuits maintained that all people in the world descended from Noah's three sons (Sem, Cham, and Japheth). Europeans usually regarded Sem as the ancestor of Asian peoples. When Chinese converts translated the Jesuit argument that the earliest Chinese were of foreign origin, however, this provoked an attack by critics of the Jesuit in Qing court circles in 1664 and led to the martyrdom of the converts.[12]

Ryan has contended that the new worlds were discovered by the Europeans, which implies some sort of ownership of their discovery. Later, however, literati in Ming China also discovered and incorporated the world of Europe introduced by the Jesuits. If the discovery of the new worlds in early modern Europe coincided with the recovery of the ancient pagan world, then an alternative, a parallel, and a contemporary assimilative process occurred that we can call the Chinese discovery of the West (*Taixi*), not to mention the European discovery of China. Moreover, after the Jesuit arrival in Ming China, literati who welcomed them prepared parallel but opposite narratives to place "Western learning" within the boundaries of China's classical antiquity.

A century prior to the Jesuit arrival, Ming literati had widely applied their paradigm for investigating things and extending knowledge. The approach had enough authority to allow the compilers of the *Key Issues in the Investigation of Antiquities,* for instance, to domesticate the new materials brought by the Ming navy from the Indian Ocean within a traditional focus on encyclopedias and their already established range of classifications. The fifteenth and sixteenth centuries in China were certainly not "centuries of wonder." Leaving out the "discovered" and their reception of their "discoverers," however, produces only a one-sided historical narrative. Moreover, the Chinese had been learning about the Old World via Islam in central Asia and Persia all along and had never experienced isolation as the Europeans had.

Any claim that most Ming literati, when compared to their European contemporaries, engaged in a subjectivist and idealist discourse about things is off the mark. Indeed, Mark Elvin has misread his sources to contend that

Wang Yangming and his sixteenth-century followers led most Ming literati away from the precocious intellectual promise of objectivist science and natural studies in Song times. In Elvin's view, the pervasive influence of Wang Yangming was one of the three key factors (the others were filling in of the south China frontier and the closed-door policy of the dynasty), that had doomed Ming China to failure in its global competition with early modern Europe.[13]

Moreover, the popular encyclopedias outlined below make it clear that Ming compilers of encyclopedias never took literally Wang Yangming's efforts to find the principles of bamboo through meditative techniques. We need to address the roots of these practical compendia of things, affairs, and phenomena, which were printed as a wide variety of "daily use" compendia of the 1590s. They contrast sharply with the high-minded claims of the Yangming schoolmen that the principles of all things were innate in the mind.[14]

Natural Studies in Yuan-Ming Encyclopedias

During the Yuan and Ming dynasties, compilers constantly added material to Southern Song compilations, but the military dislocations of the period from 1350 to 1450 yielded a dramatic downturn in the numbers of such publications at the same time that the Chinese population declined significantly. The *Expanded Records of a Forest of Matters* (*Shilin guangji*), for example, was a Southern Song compilation that scholar-printers added to during the Yuan dynasty. By 1330–1332, the edition had forty-three divisions, which included heavenly correspondences, the calendar and time, topography, plants and fruits, bamboo and trees, musical harmonics, Daoism, Chan Buddhism, mathematics, tea, wines, liquors, etc. In contrast, the original *Expanded Records* had only seventeen divisions, which generally focused on government and essay questions from the civil examinations.[15]

The Yuan encyclopedia, *Complete Collection of Classified Affairs Essential for Those Living at Home* (*Jujia biyong shilei quanji*), was a precursor to late Ming encyclopedias that focused on customs, practical learning, home rituals, sericulture, health, etc. The 1301 preface to the *Complete Collection*, for instance, called it a "guide to local clerks' learning," and like Ming daily use compendia (*riyong leishu*) it focused more on the audience of lower clerks who served in yamens in cities and the countryside.[16]

The production of such daily use compendia spread more widely from the coast to the hinterlands. Late Ming publications for a popular audience centered in Fujian province, especially in the interior county of Jianyang. A noticeable increase occurred in printed works on agriculture, health, medicine, and mathematics for social groups in traditional Chinese society who were classically or functionally literate, that is, literati, artisans, and merchants. This publishing upsurge in the sixteenth century should be understood in light of a similar expansion during the Southern Song. In other words, the publishing of popular encyclopedias from the Song to late Ming increased, although there was a significant dip in the early Ming.[17]

Jianyang editions were criticized during the Wanli reign period (1573–1619) for their poor paper and for their use of softwood to carve woodblocks in order to sell editions quickly. They remained widely popular, however, as part of an expanding print culture, which took advantage of a decline in printing costs and book publication expenses. Such savings were due in part to a more efficient division of labor in the production of woodblocks for printed books and because the sea route for Jianyang editions from Fujian in the southeast to other regions, particularly the prosperous Yangzi delta, proved cheaper.[18]

The classification system for daily use compendia published in the late Ming typically ranged in content from twenty to over forty major categories. Those that appeared most frequently in late Ming practical handbooks were astrology, topography, medicine, mathematics, dream interpretation, nourishing life, sericulture, writing skills, legal matters, and plants. The encyclopedias published in Jianyang encompassed a wide variety of books, including household manuals, quotation dictionaries, and collections of anecdotes, but their common feature was their topical arrangement as "household handbooks" and manuals for everyday life. We can identify seven types of late Ming daily-use compendia: (1) general works; (2) works oriented to the civil service; (3) reference use (phrase dictionaries, letter writing, etc.); (4) literary collections; (5) sources for looking up names and people; (6) collections of stories and anecdotes; and (7) primers for children.[19]

Based on this synopsis of the classifications and bibliographic locations for natural studies used since medieval times in the Dynastic Histories, Imperial Library, and in official and private encyclopedias, we cannot identify a single, unified field of traditional natural studies before the Jesuits arrived in China. Although the four classifications (*sibu*) were usually in effect, they were often superseded by Song-Yuan-Ming popular compendia. Nonetheless, we will see that among late Ming and early Qing elites both the "wide learning of things" (*bowu*) and "investigating things and extending knowledge" (*gezhi*) were becoming a common epistemological frame for the accumulation of classical and practical knowledge.[20]

Ordering Pharmacology through Names

Biographies of Li Shizhen (1518–1593) have noted that the pharmacologist-physician had at the age of fourteen *sui* (Chinese added one year after the first new year) passed the preliminary county civil examinations held at his home province of Hubei. Assuming approximately 1,000 candidates per county for local qualifying examinations, Li was one of some 1.2 million literate local candidates. After he failed three times in the provincial examinations, like 95 percent of the candidates empirewide, Li never advanced further. As he came from a family whose patriarchs had been medical practitioners and - studied pharmacognosy for several generations, Li Shizhen turned to medicine for a livelihood. His father served in the Imperial Medical Academy and had written treatises on diagnosis, smallpox, the pulse, ginseng, and the local mugwort.[21]

In terms of classical literacy, i.e., mastery of the orthodox canon, dynastic histories, and encyclopedias, Li was by 1535 one out of some 35,820 licentiates within an approximate population of 100 million. Beginning in the fifteenth century, each stage of the Ming civil service selection process eliminated the vast majority of candidates, most, like Li, at the local and provincial competitions. A vast constituency of failures, like Li Shizhen, sought alternative careers in teaching, medicine, preparing legal plaints for others, etc., where they could use their classical skills as scholars and writers.[22]

An unexpected consequence of the empirewide civil examinations was the large number of classically literate men who as a writing elite also formed a significant reading public. In addition, literate women in elite lineages were by the late Ming exchanging poetry and educating their male and female children with equal facility. Such large numbers of classically literate men and women created an audience of some 5 million readers and their families, that an author of a popular Ming work, such as a practical digest, pharmacopoeia, or novel, could potentially reach.[23]

Li Shizhen was not directly influenced by the 1590s daily use compendia discussed above, but he was aware of the dubious quality of such earlier works. His magnum opus, the *Systematic Materia Medica* (*Bencao gangmu,* 1596), and the effusion of encyclopedias and classified pharmacopoeia in the late Ming represented improvements. An ample number of classically literate men and women, and a large audience for practical manuals, compendia, and popular fiction, created the market that late Ming printers in south China sought to profit from by selling a wide assortment of works by men such as Li Shizhen in the late Ming. Chŏson Korea, Tokugawa Japan, Le Vietnam, and the overseas Chinese communities in southeast Asia were additional markets for Ming and Qing editions of such compendia.[24]

Li Shizhen completed the final version of his *Systematic Materia Medica* in 1587. By 1590 he lined up a printer in Nanjing for the complete project. The first printed version appeared posthumously in 1596. Subsequently, the huge work sold out rapidly enough that eight reprints were issued in the seventeenth century alone, three of them by 1602. The *Systematic Materia Medica* was quickly transmitted to Tokugawa Japan via European traders. The first Japanese edition came out in 1637. Scholars in Europe began to take notice of Li Shizhen's work in the middle of the seventeenth century, and the French Jesuit academic Jean-Baptiste du Halde (1674–1743) cited it extensively in his 1735 geographical and historical account of the Manchu empire. In the late eighteenth century, the 1655 edition of the *Systematic Materia Medica* was included in the Qing Imperial Library.[25]

If we place Li Shizhen's *Systematic Materia Medica* in its medical and pharmaceutical context, we find that Li worked tirelessly on a revised materia medica that would correct the errors of identification, classification, and evaluation that had accrued in the standard Song dynasty series. In particular, Li's generation of physicians, like their Jin and Yuan predecessors, were dissatisfied with Northern Song materia medica.[26]

Unlike the Ming, the Song Bureau of Medicine, for example, had collected thousands of medical formulas that led it to publish and distribute formularies beginning in 1107–1110. The latter were based on compound medicines packaged for sale in the government dispensaries. Revised many times, these formularies were reprinted for wide use. Liu Wansu and Zhu Zhenheng, among others, had been critical of these recommendations because they found the system rigid and not effective in treating illnesses in the thirteenth and fourteenth centuries.[27]

From 1556, Li traveled widely in major drug-producing provinces, gathering comprehensive information on mineralogy, metallurgy, botany, zoology, and drug formulas. Over the span of three decades from 1552 to 1578, Li took into account some 40 pharmacopoeias by various authors, 361 medical works, and 591 classical, historical, literary, and encyclopedic works. The medical works were further divided into some 84 cited in earlier pharmacopoeia and the 277 Li cited for the first time.

The nonmedical works were from historical, canonical, technical, and literary sources, as well as from dictionaries and encyclopedias. Of these, 151 texts had been used in earlier accounts; 440 were cited by Li for the first time. Among the 932 titles, including the 792 described above, which Li cited as sources in his detailed bibliography, 36 percent were medical and pharmacological works, while 76 percent were quoted for the first time in the materia medica literature.

Hence, the first innovative aspect of Li's work was his addition to the materia medica literature of much data about drugs and diseases new since the Song dynasties. He incorporated, for example, the medicinal uses of maize and the sweet potato, New World crops introduced from the Spanish Philippines in the middle of the sixteenth century. He also reported on the emergence of a new disease, syphilis, which he traced back to the late fifteenth century in Guangdong province, but which may have had a New World origin.

Li Shizhen argued in his "Conventions" to the *Systematic Materia Medica* that the ancient headings in earlier canonical works on materia medica had been mixed up and that their true meanings were lost. Because Li saw his efforts in terms of a revisionist, tripartite research agenda that included first research and correction, then analytic procedures, and finally synthesizing procedures, recent historical accounts have described Li Shizhen as not merely a pharmacist-doctor but also a botanist-naturalist.[28]

The structure of previous works on materia medica had been based on the ancient classifications in the *Canonical Materia Medica of Emperor Shennong* (*Shennong bencao jing*), which became a classic after it was compiled circa the first century B.C. or A.D. Although the work was subsequently lost, its three-part distinction between minerals, plants, and animals was appropriated in later pharmacopoeias because of its canonical status. Drugs, for example, were classified from a therapeutic point of view into three grades. The *Canonical Pharmacopoeia of Emperor Shennong with Collected Commentaries* (*Shen bencao jing jizhu*) by Tao Hongjing (456–536) introduced a second partition in the materia medica literature. Based on the three natural grades of minerals, plants, and animals, Tao distinguished each of these categories by subdividing them into several subgroups with no attempt at rigorous taxonomy.

Completed in 1496, a century before Li Shizhen's work was published, Wang Lun's (fl. ca. 1456–1496) *Essentials of Materia Medica* (*Bencao jiyao*) distinguished between ten different sub-groups: (1) herbs, (2) trees, (3) vegetables, (4) fruits, (5) grains, (6) minerals, (7) quadrupeds, (8) birds, (9) insects and fish, and (10) humans. Chen Jiamo's (b. 1496) *Enlightenment on the Materia Medica* (*Bencao mengquan*), which was published in Li Shizhen's youth, had followed Wang Lun's model with a few modifications in the order of Wang's ten subgroups. For example, Chen made plants first (herbs, trees, vegetables, fruits) and humans second in the order.[29]

By the time Li Shizhen turned to materia medica issues, there was a clear sense that past classifications, like Song official prescriptions, had become problematic, both because of accumulated confusions in the historical record and because of a good deal of new information that had to be added based on experiences with illnesses more common in south China. In addition, Li Shizhen's organic pharmacology continued the Song-Yuan-Ming condemnation of ingesting poisonous substances, which had been associated with the traditions of external alchemy in medieval times, favoring natural herbs and less harmful minerals.[30]

In his "Conventions," Li further declared the need to reorganize the existing knowledge of drug products. He did this by hierarchically ordering the material into 16 sections, 60 categories, and 1,895 kinds. Li's use of categories as an independent structuring device was somewhat less innovative, but he did improve on earlier efforts to develop a classificatory scheme. Li Shizhen paid attention to the ecology of living things from which drugs were derived. His taxonomic order combined rubrics that were indifferent as to habitat, physical characteristics, and use.

Items were organized by their morphology and their qualitatively defined physical configurations of *qi*. To the latter, Li applied the five evolutive phases as divisions for dynamic processes or static configurations. The fire phase, in particular, was reconceptualized in Li's *Systematic Materia Medica* as an independent medical category, which represented one of the configurations of *qi* affecting the body. In this regard, Li was building on Song and Jin conceptual developments that prioritized the focus on fire within and without the body as an important heat factor in the maintenance of health and the prolonging of life (*yangsheng*).[31]

Li's sorting of plants was sometimes determined by the following categories: the habitat of plants; their morphological aspects; whether they were wild or cultivated plants; their therapeutic aspects; culinary and medicinal aspects; and the agricultural categories for grains. His taxonomy was, however, often still based on subjective judgments, medically overdetermined, and not on botany. Hence, the criteria for his categories were not exclusively naturalistic.[32]

Moreover, Li Shizhen reclassified the entire materia medica record, which revealed Li's concern with the "investigation of things." His approach also stressed the problem of nomenclature (lit., "rectification of names"), as the main entry in his classifications. Another subentry explained the names of things themselves. The structure of Li's entries in the *Systematic Materia Medica* were presented as explanations, corrections, and clarifications in the "Conventions." They provided late Ming physicians and scholars with a broad reservoir of practical medical knowledge.[33]

Accordingly, Li Shizhen's materia medica enterprise was also a scholarly project: "Although this is what doctors have called medicine, in examining and explicating their principles I have actually practiced what we literati scholars call the 'study of the investigation of things.' This can fill the gaps in the *Progress Toward Elegance* [*Erya* dictionary] and those in the commentaries on the *Poetry Classic*." Appealing to the Ming tradition of investigating things, Li contradicted in practice Wang Yangming's claims about what constituted careful research concerning the external world. Li Shizhen had little patience with any effort to employ meditative techniques to fathom the principles of a plant such as bamboo. He was too busy concerning himself with its natural history, nomenclature, and medicinal aspects.[34]

Li's materia medica and the many daily use compendia of the late Ming are a better guide than the work of Yangming schoolmen to the evolution of the investigation of things as an epistemological principle for precise scholarship before the influx of Western learning via the Jesuits in the seventeenth century. Earlier accounts that have paid attention primarily to the moral philosophy of Wang Yangming have misrepresented the intellectual complexity of pre-Jesuit natural studies in Ming China.

Like Li Shizhen's *Systematic Materia Medica,* late Ming digests cited a wide variety of books, manuals, dictionaries, and literary collections, although they did not strive for Li's standards of scholarly rigor. Their common feature was their increasingly complex topical arrangements, which were accompanied by new knowledge and more information about things. Such works were widely printed in south China by printers when lower printing costs made cheaper editions accessible beyond the classically literate elite.

Collecting the Collectors

The Ming scholar-merchant and Hangzhou bookseller Hu Wenhuan (fl. ca. 1596), like Li Shizhen, prefigured the Sino-Jesuit dialogue concerning the investigation of things and European *scientia* in the early seventeenth century when he compiled and published his widely circulated *Collectanea for Investigating Things and Extending Knowledge* (*Gezhi congshu*) in the 1590s. This collection of books, published as a set, embodied a repository of classical, historical, institutional, medical, and technical works from antiquity to the present in China. The collectanea also contributed to the growing late Ming literature of material culture. Its wide dissemination in Ming-Qing China and Japan, in many editions from Hu Wenhuan's Hangzhou and Nanjing print shops, marks it as a very influential and thus representative work. It did not have the scholarly pedigree of the *Systematic Materia Medica,* but Hu's *Collectanea* affords us a unique window onto more common divisions of knowledge. Hu had successfully commoditized classical learning in an age of Ming connoisseurship.[35]

Although provincial informants mentioned two hundred sets of the *Collectanea* in the 1780s, the compilers of the Qianlong Imperial Library catalog criticized its unevenness, looked down on Hu's profit-oriented marketing of several editions, and only summarized its content in the official catalog. It was not included in the library. Nevertheless, its extensive circulation in many published forms allows us to access a representative world of pre-Jesuit natural knowledge and lore. Analyzing its subject matter allows us to go beyond Borges's and Foucault's ahistorical musings about quaint Chinese encyclopedias. The *Collectanea for Investigating Things and Extending Knowledge* presented a cumulative account via a collection of books of all areas of knowledge important to a literati and nouveau riche audience before the Jesuits made their presence felt in Ming literati circles in South China after 1611.[36]

Because Hu Wenhuan also had wide-ranging interests in medicine and popular religion, some versions of the collectanea contained a broad scope of illumination texts and esoteric writings, which I will discuss. In addition to addressing the collectanea in light of its many variant editions, I will also analyze its initial, pre-Jesuit focus on early lexicons and natural histories, which overlapped with classical learning and natural studies during the late Ming. The smaller, more orthodox version of the collectanea thus parallels the distancing of the queer and supranormal in some Song encyclopedias of the tenth century.[37]

For example, the Northern Song *Materials of the Taiping Xing Guo Era [976–983] for the Emperor to Read* (*Taiping yulan*) did not include unusual phenomena or paranormal novelties from medieval times. Moreover, the compilers declined to present grotesques; strange plants, animals, and minerals, and odd countries that appeared in the *Expanded Records of the Taiping Xingguo Era* (*Taiping guangji*), which focused on popular religion.

The taxonomy informing the *Materials of the Taiping Era* was more representative of highbrow literati tastes, which were reproduced in the Song genre of jottings (*biji*). The latter were generally about fictional, historical, or textual material that were preserved by their authors as odd notes. Earlier interests encompassing natural phenomena and supernormal topics in jottings had waned. Thereafter, most jottings were about recollections of court events, celebrated fellow officials, and experiences in the civil service.[38]

On the other hand, even though the *Expanded Records* was less consonant with orthodox encyclopedias, its contents were representative of lower-brow literati and echoed the nourishing of life (*yangsheng*) traditions that permeated popular religion and medical discussions on prolonging life and achieving immortality. This dual track of Song encyclopedias was never mutually exclusive, however, and the creative tension between them continued in later Ming collections of books published as a set, such as Hu Wenhuan's *Collectanea*.[39]

The Life of a Late Ming Scholar-Printer-Collector

We glean from Hu's many prefaces to the works he collated a sense of his life and work as a scholar-printer. His grandfather and father were both Hangzhou collectors and printers, and many of Hu Wenhuan's reprints came from his family's cultural traditions. Between 1592 and 1597, Hu wrote some forty-nine prefaces for works he compiled and published. Hu and his staff assembled some five hundred works in his Hangzhou and Nanjing print shops, which made their way, selectively, into the enlarged versions of the *Collectanea for Investigating Things and Extending Knowledge* and other collectanea that Hu printed.

Hu Wenhuan had several colleagues who shared his bookman's interests and helped compile his works. In addition to collation, they provided prefaces and encomia in Hu Wenhuan's series. One of them, Zhang Lun, was also the teacher in the Hu family school, which indicates that he was well versed in classical learning and that like Hu he was a licentiate who had not advanced further on the examination ladder. Another colleague, Chen Bangtai, helped in printing the books. Hu's family printing shop in Hangzhou became known as the "Hu-Chen Great Print Shop," which suggests Chen's importance to the enterprise.[40]

Hu himself was a Nanjing imperial school student, who had likely purchased his licentiate status to enable him to compete in local qualifying examinations. Like Li Shizhen, then, Hu Wenhuan had attained a high level of classical literacy and literary ability, but also never attained a higher provincial or metropolitan degree. By the late Ming, of the 50,000 candidates empire-wide competing triennially for some 1,200 provincial degrees, fewer than 3 percent would succeed. Because most like Hu Wenhuan, never became provincial graduates, the Ming dynasty required licentiates to keep taking biennial renewal examinations to maintain their special legal status. Like most such students, Hu did not attend his assigned school. The rolls of local official schools were increasingly filled with candidates who had repeatedly failed higher examinations and had nowhere else to go.[41]

Hu used two studio names, one known as the "Hall of Writings Brought Together" (*Wenhui tang*) in Hangzhou and the other called the "Office of Thoughts of Retirement" (*Sichun guan*) in Nanjing. His other sobriquets, such as "Penetrating the Arcane" (*Dongxuan*), also suggest his sympathies with the esotericism associated with popular religion. As the southern capital of the Ming, Nanjing was an important publishing center in the Yangzi delta, along with Hangzhou and Suzhou. Consequently, Hu also relied on the Nanjing book market for many of his editions, although they were mainly published in Hangzhou. Hu's range of focus, from orthodox classical texts to esoteric medical writings on nourishing life (*yangsheng*), were tied to his examination studies and his weak health as a youth.[42]

In addition to books and texts, Hu Wenhuan also collected antiques and musical instruments. He was interested in tea as a cultural phenomenon, as well as wines and perfumes. The financial benefits from his printing enterprise, based on selling many different series of his printed works or individual volumes from the collection, enabled Hu to maintain the lifestyle of a literati scholar with wide cultural interests, even though he had failed to gain an official appointment. By the late Ming, merchant and literati collectors like the Hu family grew and diversified. Hu Wenhuan finally received an appointment in 1613 and served as a low-level county official in Hunan province, first as a magistrate's aide and then as an administrative clerk. While Wenhuan was away, the Hu publishing enterprise diminished.[43]

In sum, Hu was a merchant-scholar of wide-ranging literati interests, and the large-scale collectanea that he compiled, collated, and printed before 1613 preserved many rare texts for his Ming contemporaries, though his editions were later criticized for their poor quality.[44]

A Highbrow Version of the Collectanea

The contents of the more classical versions of the *Collectanea for Investigating Things and Extending Knowledge* ranged from aspects of heaven and earth to classifications of birds, animals, insects, fish, grasses, foodstuffs, architecture, and tools. A classicist frame of reference informed Hu's systematic collection of data from native sources concerning China's natural resources, the arts, and manufactures (see also Chapter 6). The portions dealing with these high-minded themes reveal Hu's efforts to republish and cumulatively build on previous works that focused on natural phenomena, names and their referents, and affairs and things.

The earliest printing of Hu's more orthodox versions included forty-six works that we will focus on first. Later, enlarged editions of 180–200 or more works were compiled by Hu in order to sell more sets of the collectanea for profit. These editions somewhat resembled the Northern Song *Expanded Records of the Taiping Era* as a repository of popular and religious lore, although the latter was not just a collection of texts available for purchase. Starting with annotations of the *Progress Toward Elegance* dictionary and the *Explication of Names* (*Shiming*), the initial edition of forty-six works emphasized a comprehensive account of etymologies and word definitions that would shed light on the golden age of antiquity, a period of enlightened governance. The "rectification of names" (*zhengming*), a perennial literati concern, was a passionate aim.

Overall, the collectanea emphasized a broad learning of phenomena (*bowu*), one of Hu's main classification categories, which encompassed natural and textual studies within a humanist, esoteric, and institutional agenda. Missing, however, was the sense of methodological unity to the investigation of things and the extension of knowledge that Zhu Xi and his Song-Ming followers had prioritized. Hu was content to introduce the lexicographers together in one place without any guidelines for synthesis or analysis.[45]

Hu's *Collectanea* represented one of a large number of late Ming collections of books published as a set that were aimed at elite and popular audiences. Their contents incorporated information on natural history and lexicography to fill the gaps in meaning that had opened between visual things and written words in classical learning. Scholars working on pharmacopoeia and medicine, such as Li Shizhen, were also concerned that the language used to designate things-phenomena-affairs had by the sixteenth century become increasingly muddled. Historical accounts of phenomena were presented as a genealogy of glosses, a sort of textualized natural history, but the order had accrued chaotically. Names for plants, animals, etc., in terms of kind, species, attributes, and uses needed reordering, i.e., rectification.

Although it did not pursue the methodological rigor that informed the Li Shizhen's *Systematic Materia Medica,* Hu's *Collectanea,* nonetheless, contained a repository of works from ancient to contemporary times, which in its initial printing presented the classical ordering of knowledge and its later recapitulations. The collection embodied the problems rather than the solutions. Overall, late Ming collectanea and encyclopedias sought to restore all the words that had been lost or muddled since antiquity through a meticulous reexamination of "things." Composed in the classical language of elites but accessible to low-level licentiates and clerks, Hu's collection of the collectors allowed him to describe and order things, phenomena, and affairs.

The extant genealogy of classical glosses was the first step in capturing the common affinity of things through the language in which they were historically represented. The late Ming collectanea became a textual site for refashioning and reproducing the findings of past sages, worthies, scholars, seekers of immortality, monks, masters, and commoners. It served as a genre for "collecting the collectors" through texts and diagrams, which drew on the intellectual lineage of things, phenomena, affairs, and esoterica dating from the ancients.[46]

Just as Li Shizhen engaged in a reformative agenda of observing, analyzing, recognizing, and naming plants for medicinal purposes, others reviewed the classical search for why things were the way they were (*suoyi ran*). By delimiting and filtering the visible structure of things drawn from a wide variety of sources, Hu's *Collectanea* derived its classical respectability from the traditions of orthodox classical learning. When the Jesuits presented an alternative natural history in an Aristotelian conceptual language (= *scientia,* i.e., "specialized knowledge") for the structure of the world, their description of the visible world was translated by their Chinese collaborators in the language of the late Ming theory of knowledge, namely investigating things and exhaustively mastering principles.

Lexicons in the Collectanea for Investigating Things and Extending Knowledge

Available since the Han dynasty, the *Progress Toward Elegance* dictionary contained glosses for the names of things in early classical texts. The compiler was not the observer, but the secondhand entries of cryptic glosses identified anything from grammatical terms in language, labels for kinship relations, technical language for palace architecture, and names of utensils and tools to the names of musical instruments. Since antiquity, elegance in language had corresponded to elegance in material life.

In addition, the *Progress Toward Elegance* extended its classifying vision to the natural world. One of its nineteen subjects explicated astronomical, calendrical, and climatic terms. Four sections included glosses for geographical, topographical, and geological items. Finally, two sections covered the names of plants (i.e., grasses, herbs, vegetables, trees, shrubs), and five sections presented words for insects, fish, fowl, and wild, domestic, and legendary animals.[47]

As a classical dictionary, the *Progress Toward Elegance* was not written by a botanist or paleontologist. Yet its search for orderliness through understanding ancient names was a serious effort to know about things through an assessment of words. When the medieval commentator Guo Pu (276–324) annotated the dictionary, for instance, he noted in his "Preface" that it was a comprehensive compilation of theses. He added that it was the "unconfused basis for a broad learning of things."

The *Progress Toward Elegance,* Guo concluded, was the handiest contemporary source for names (= "definitions") of birds, animals, and plants. It was also a valuable source for names of curiosities and words in different dialects, based on "reliable and verified sources." The compilers of commentaries and follow-ups to the *Progress,* which Hu Wenhuan also included in his *Collectanea,* addressed the discourse of names, things, phenomena, and affairs. Mediated through the classical language, an amorphous natural history emerged. The allegedly well-constructed classical language for reality gave the reader access to the verbal structure of the visible world.[48]

The stature of the *Progress Toward Elegance* was enhanced during the Wei dynasty (220–264) when it was attributed to the sagely Duke of Zhou by the *Expanded Elegance* (*Guangya*), which was the third work included in the initial printing of Hu's *Collectanea*. Later classicists often accepted this attribution and contended that Confucius had said the *Progress Toward Elegance* was a window on ancient Zhou governance. Because of such attributions, the *Progress Toward Elegance* rose in the ninth century to the status of a Classic. Consequently, from the late Tang to the end of the Song, scholars treated it as a canonical text even though few accepted the claim that the Duke of Zhou was its author. Nevertheless, when the Qing Imperial Library was completed in the late eighteenth century, the *Progress Toward Elegance* was classified under the "classics" and given eminence of place as the paradigmatic work in etymology.[49]

Other Song classical works such as Lu Dian's *Adding to Elegance* (*Piya*) linked the *Progress Toward Elegance* as a classical collection of glosses to the *Poetry Classic*. Lu noted in his "Preface" that the civil examination essay was not used before 1056 and that prior to that candidates for public office had relied on poetry questions in the civil examinations to gain a name for themselves. As a by-product of such preparation candidates had a greater knowledge of the flora and fauna enumerated in the *Poetry Classic*.[50]

Lu Dian was paraphrasing Confucius' famous injunction to his students in the *Analects* that through study of the *Poetry Classic* they could become "more acquainted with the names of birds, beasts, and plants." Lu described how after 1077, when the examination essay took precedence over poetry, everyone mastered "classical techniques" while traditions of belles lettres declined. As a result, knowledge of the names of natural things diminished. Lu Dian clearly pointed to the importance of the *Poetry Classic* for natural knowledge.[51]

In his observations added to the heavens section of the *Progress Toward Elegance,* Lu Dian included sections on thunder and lightning. Citing ancient and medieval sources on how rain produced thunder, Lu Dian explained thunder in terms of the concatenation of yin and yang: "Thunder is the yang part of yin." He then cited the medieval work by Yang Quan *On the Principles of Things* (*Wuli lun*) to the effect that "an accretion of wind produced thunder." From this perspective, the fundamental cause of lightning was thunder and not vice versa as in modern accounts. Hence for lightning, Lu Dian noted that when "yin and yang intercept each other and dazzle, this is the same [configuration of] *qi* as thunder, which when released produced bright light."[52]

Based on traditions that thunder emanated from heavenly *qi,* while lightning came from earth's *qi,* Lu noted that thunder belonged to the fire phase, and that the bright light was the lightning while the sound was thunder. In conclusion, Lu cautioned that although related in terms of yin-yang and the fire phases, one should still see thunder and lightning as separate phenomena. Lu added that when the ruler decided court cases, such cases were seen as "counterparts of heaven" and that if there were occurrences of lightning and thunder, these were taken into account.[53]

Hu Wenhuan included his own work on the *Poetry Classic,* in which he repeated that knowledge of the names of birds, animals, herbs, and trees was important for understanding the *Poetry Classic*. Hu's views reflected what was in late Ming commonplace in civil examination policy questions on "broad learning" (*bowu*). In a 1597 provincial examination, for instance, the Shuntian examiners asked several thousand candidates for civil office to address why Confucius had focused students on "names and things" and not just "principles and nature."[54]

In a 1593 preface to one of his works, Hu replied to critiques that his research was redundant or too nitpicking: "If one says that Master Zhu [Xi] brought together [all knowledge about the *Poetry Classic* in his "Collection of Commentaries"] and that I have split it all up, then what good is erudition?" In effect, Hu revived focus on the "things-phenomena-affairs" mentioned in the *Poetry Classic,* which displaced Zhu Xi's efforts to bowdlerize the more sensuous love poems in the classic. The charge that Hu was splitting up knowledge, however, was an indication that his printing of works dealing with things, affairs, and phenomena no longer sustained an overarching methodological unity, which had informed the Song appeal to universal knowledge. In his scholarship on the *Poetry,* Hu collected items of information. He was not searching for universal principles.[55]

Perhaps because it was already widely available, Hu Wenhuan did not include the second century *Analysis of Simple Graphs as an Explanation of Complex Characters* (*Shuowen jiezi*) in the many printings of his collectanea. A paleographic dictionary of ancient writing forms, the *Analysis of Simple Graphs* frequently informed the lexicographical content of Hu's collectanea, however. Nor did Hu's first collection of books published as a set embrace important Tang and Song works on phonology, although he included Ming works on poetic rhymes, including two by himself. Overall, the lexicographical focus in this version of the collection stressed etymology over both phonology or paleography as the means to recover ancient glosses. This endeavor reflected late Ming trends in classical studies that stressed etymology and paleography, which were later superseded by Qing dynasty phonology.[56]

Early Natural Histories in Hu Wenhuan's *Collectanea*

Chinese naturalists represented the physical world through an historical array of entries about things, phenomena, and affairs (*bowu*). Several works were included in Hu Wenhuan's *Collectanea* that resembled natural history in the classical period in the West, when a dividing line between animate and nonanimate objects was not yet decisive. A biology did not yet exist among the Chinese or the Jesuits, although we can identify aspects of a vitalism linked to *qi* and nurturing life (*yangsheng*) in Ming-Qing medical discourse, which was bounded by a classical concern with the structure of the visible world expressed as a theory of words about things.[57]

Like their classicist counterparts in Europe, the authors of Chinese "natural histories," whose works were included in the first printing of Hu's *Collectanea,* sought to identify and classify natural phenomena through language. The first such natural history that Hu Wenhuan included was the hoary *Classic of Mountains and Streams* (*Shanhai jing*), annotated by Guo Pu. Guo was a "master of esoterica" (*fangshi*) who had annotated several archaic texts included in Hu's *Collectanea* that dealt with anomalies and natural phenomena. Guo's official biography in the *History of the Jin Dynasty* noted that he was a student of classical techniques, whose broad studies (*boxue*) included the five phases, astrology, techniques for prognostication, warding off calamities, and turning back misfortunes.

The *Classic of Mountains and Streams* was a composite compiled over several centuries, which can be described as a *descriptio mundi*. Ascribed by some to the sage-king Yu the Great, it described the earth in terms of concentric rectangles with a central territory, four seas encompassing the central lands, and a great wilderness. Because it also contained valuable information about mountain spirits, popular medicine, divination and other mantic arts, often incorporated in later texts, it was at times classified simply as a handbook of anomalies and prodigies, in addition to a historical geography. Han dynasty scholars regarded it as a window on ancient portents and foreign customs. The Ming bibliophile Hu Yinglin (1551–1602), a Zhejiang contemporary of Hu Wenhuan, described it as the ancestor of oddities in Chinese literature. This view foreshadowed its derisive inclusion under the "idle chatter and gossip" (*xiaoshuo*) subcategory in the late eighteenth-century Imperial Library catalog.[58]

Guo Pu's preface to the work opened by noting that most scholars before him had seen the text as a "strange and unconventional collection," that everyone had doubts about. For Guo the key issue in interpreting the work was first to be clear about what an anomaly was:

> With respect to a correspondence phenomenon, when people called it an anomaly, they did not know why it is anomalous. When they did not call it an anomaly, they did not know why it is not. Why? Something is not anomalous of itself. It must await our [assessment] before it can be anomalous. Anomaly ultimately resides in us, not the thing.

Because an anomaly was apparently odd to us but not in and of itself, an assessment of a thing, phenomenon, or affair, according to Guo Pu, was based on our prejudiced judgments drawn from our unbalanced experience: "We observe based on what we habitually see, and we regard as strange what we have rarely heard about. This is the usual screen for human feelings." Moreover, because oddities reflected our assessment of them more than anything inherent in phenomena, any strange things recorded in the text of the *Classic of Mountains and Streams* were difficult to explain away simply as anomalies.

Guo concluded that such records probably reflected ancient, everyday references that no longer corresponded to today's habitual designations for things. In effect, Guo Pu was protecting the phenomena in the *Classic of Mountains and Streams* from thoughtless derision. However odd such records appeared to us today, they had to be taken seriously as ancient accounts of actual things, phenomena, and affairs. Guo later prepared a work containing over 250 appraisals of the famous illustrations that by the third century A.D. were included in the work but later lost.[59]

Next in the collectanea, Hu Wenhuan included two works on birds and beasts. First came Zhang Hua's (232–300) annotation of *Shi Kuang's Broad Classic of Aviary* (*Shi Kuang qinjing*). The work allegedly dated from the Zhou dynasty (ca. 1045–221 B.C.) and opened with 360 categories of birds. Priority was given to the male phoenix as the chief example of feathered types of animals. Like Guo Pu, Zhang Hua was a medieval master of esoterica, famous for his knowledge of underground and remote realms, skilled as a diviner, and informed about spirits and exorcism. The *Classic of Quadrapeds* (*Shoujing*), which followed, included mention of auspicious animals. Neither work was a zoology per se, though each contained descriptive accounts. Rather, they were repositories of curiosities, prodigies, and wonders and thus outside the realm of normal explanation.[60]

Two later works in the initial printing of the *Collectanea* were "records of anomalies" (*zhiguai*) that dated from the Han through the Song. The *Classic of Spirit Marvels* (*Shenyi jing*) of the Later Han dynasty was completed circa the late second century, and a later Jin commentary attributed to Zhang Hua was added. The religious tenor of the work, including the veneration of sacred texts, linked it to the increasingly porous cultural and religious boundaries of orthodoxy and esoterica, which Chinese literati could comfortably straddle up to the Song dynasty. The *Record of Accounts of Strange Things* (*Shuyi ji*) was allegedly prepared during the Liang dynasty (502–556), although the compilers of the Qing Imperial Library catalog saw it as a Tang forgery because it contained anachronisms.[61]

A preface to the *Record of Accounts of Strange Things* dating from circa A.D. 503 indicated that the author had accessed a library of 30,000 chapters when he prepared his work, which allowed him to include a great deal of stories about anomalies. In addition, his work was informed by an interest in a broad learning about things. The "Afterword" composed in 1044 by Ye Fang defended the *Record* and defined oddities as "matters that were unheard of." It linked the focus in the work to the "broad learning of the scholar," thus making writings about anomalies perfectly respectable, a claim that was contentious among Song literati, who distanced themselves from the records of anomalies genre.[62]

Perhaps the most representative texts of early natural history included in Hu's *Collectanea* were those that focused on "broad learning of things" (*bowu*). Zhang Hua's *Treatise on Broad Learning of Things* (*Bowu zhi*) and Li Shi's Song dynasty *Continuation* (*Xu bowu zhi,* ca. 1150) were included. Other such Song dynasty works in Hu's collectanea were:

- *Record of the Origins of Things and Affairs* (*Shiwu jiyuan*), compiled by Gao Cheng circa 1078–1085
- *Discussions on the Formation of Heaven and Earth and the Myriad Things* (*Tiandi wanwu zaohua lun*) by Wang Bo (1197–1274)

Several works from the early and middle Ming were also printed:

- *Origins of Things* (*Wuyuan*)
- *Origins of Things Old and New* (*Gujin yuanshi*)
- *Examination of Ancient and Contemporary Things and Affairs* (*Gujin shiwu kao*)

Zhang Hua had prepared a table of contents with thirty-nine topical headings for his *Treatise* (see Table 1.1).

Of particular note in this classification list are the highlighted items #17, "nature of things" (*wuxing*), #18, "principles of things" (*wuli*), and #19, "categories of things" (*wulei*), which used terminology that would later be refracted first by Jesuit and then by Protestant missionaries—with the help of their Chinese collaborators—to refer to late medieval and early modern scientific fields.[63]

The Jesuit translation for physics into Chinese (= *cha xingli zhi dao,* lit., "observing the nature of principles of the Way) was used in Giulio Aleni's (1582–1649) *A Summary of Western Learning* (*Xixue fan,* 1623). *Physica* or *physiologia* (= *xingxing xue*) appeared in the *De Logica* (*Mingli tan,* lit., "Chats on the principles of names," 1631), which was compiled by Francisco Furtado (1587–1653) and Li Zhizao (1565–1630). Similarly, the modern translation for physics (= *wuli*), despite its late nineteenth-century Meiji Japan lineage, could also trace its genealogy as a technical term back to Zhang Hua's *Treatise*.[64]

In general these works stressed each human event, object-implement, or natural phenomenon in terms of a teleology of their usefulness to humans and presented a genealogy of discovery that traced each item back to the appropriate sage, ruler, or scholar in antiquity. In his preface to the *Record of the Origins of Things and Affairs,* dated 1448, Yan Jing linked all myriad things and affairs to their principles, which could be investigated by studying their origins:

> The myriad things, which fill heaven and earth and extend from antiquity to the present, always have matters changing within them. Things

Table 1.1. Table of contents for Zhang Hua's *Treatise on Broad Learning of Things* (*Bowu zhi*).

1. Geography	14. Unusual insects	27. Debates on *fangshi*
2. Earth	15. Unusual fish	28. Corrections of names
3. Mountains	16. Unusual plants	29. Corrections of texts
4. Waters	17. Nature of things	30. Corrections of geography
5. General topography	18. Principles of things	31. Corrections of ceremonial rites
6. Peoples in five directions	19. Categories of things	32. Corrections of music
7. Product	20. Medicines	33. Corrections of sumptuary display
8. Foreign countries	21. Medical discussions	34. Correcting names of utensils
9. Strange peoples	22. Food taboos	35. Correcting names of things
10. Unusual customs	23. Pharmaceutical arts	36. Information about anomalies
11. Unusual products	24. Stagecraft	37. Historical supplements
12. Unusual beasts	25. *Fangshi*	38. Miscellaneous words, part 1
13. Unusual birds	26. Medicinal foods	39. Miscellaneous words, part 2[a]

a. *Bowu zhi, juan* 4–5, in GZCS. See also Campany, *Strange Writing,* pp. 49–52, Roger Greatrex, trans., "Bowu Zhi: An Annotated Translation" (Stockholm University Ph.D. diss. in Oriental Studies, 1987), and Hervouet, ed., *A Sung Bibliography,* p. 343.

> have myriad variations, affairs have myriad transformations. No matter or thing is without a principle and an origin. If one does not fathom the principle [involved], then there is no way to complete the knowledge in our minds. If we do not research the origins [of a thing or matter], then how can we unravel and fathom its principle? Therefore, sagely studies give priority to investigating things and extending knowledge. Literary scholars value broad inquiry and wide learning. But a scholar [*Ru*] would be embarrassed by failing to know even one thing.[65]

The meaning of the title for the *Record of the Origins of Things and Affairs* assumed an overlap of natural things, phenomena, and human affairs with a stress on the investigation of things and exhaustively mastering principles. Its scope ranged from large (heaven, earth, mountains, streams) to small (birds, beasts, herbs, trees), to subtle (the arcana of yin and yang), and to the manifest (the institutions that use rituals and music). This spectrum moved from natural to social phenomena. The sources for each item were cited in chronological sequence to elaborate a particular item and set its origins in human terms. Further discussion was otiose.[66]

Luo Qi's 1474 preface for his *Origins of Things* opened with discussion of the sages as the creators of implements. He was critical of earlier works for not excluding patently absurd items. Within his arrangement of 18 categories, Luo included 239 total items. The afterword explained that the aim of the *Origins* was to explain the things of heaven and earth in relation to changes in human matters.[67]

The *Examination of Affairs and Things from Antiquity to the Present* by Wang Sanpin included an institutional account of historical geography (*dili*), as well as general information required for classical literacy and civil examination preparation. In addition, Wang's brief history of "numerical correspondences" (*shuxue*), later a term for mathematics in the nineteenth century, was linked to the *Change Classic* (*Yijing*) and the naturalistic process of the formation of things based on yin-yang and *qi*. In his 1538 preface, Wang Sanpin noted that he had added material to Song accounts.

Wang presented naturalistic explanations for the phenomena of wind and lightning based on yin-yang and *qi* that added some precision to Lu Dian's earlier analysis in the *Adding to Elegance*. Lu Dian had cited *On the Principles of Things* to the effect that "an accumulation of wind formed lightning." Wang Sanpin, on the other hand, explained this by contending that "the yang that is within cannot escape, and its resounding blows produce lightning. . . . When yang is outside," Wang continued, "and cannot get inside, then it swirls around without stopping, forming wind." Similarly, Wang cited Song dynasty accounts on rain: "When earthly *qi* rise and heavenly *qi* fall, they form the vapors of steam and form rain."[68]

A Theory of Cosmology and Natural Change

Although Wang Bo's work was presented before the *Origins of Things* and other such compendia on "things" and "origins," we can conclude this discussion of early natural histories with a work that dealt with the theoretical issues inherent in this genre of entries about things, phenomena, and affairs, namely, Wang's ambitiously titled *Discussions on the Formation of Heaven and Earth and the Myriad Things*.

Wang Bo had opposed Zhu Xi's interpretation of the passage in the Great Learning on the investigation of things and extension of knowledge. Nevertheless, he was in substantial agreement with the spirit of Zhu Xi's investigation of things to fathom principles. Wang, like Zhu, articulated a holistic, structural account of natural processes, which enabled literati to explain in theory the production of all things. In his preface to Wang's *Discussions,* Zhou Yong summarized this all-encompassing view of the cosmos and its naturalistic evolution:

> The Great Ultimate is principle [*li*]. Yin-yang is *qi*. Heaven and earth are forms. Talking about them in aggregate, when a form is endowed with a certain *qi*, principle is complete within that *qi*. Talking about them disaggregated, then what is above form [i.e., principle = Great Ultimate] and what is below form [i.e., *qi* = yin-yang] are bound to differ. The Great Ultimate originally contains yin-yang. What moves becomes yang; what remains quiescent becomes yin. If something is alive, then all of it [i.e., yin and yang] is alive at once. One cannot speak [of this simultaneity] as something occurring before and something else after.[69]

Zhou placed Wang Bo's account of the "shaping of all things" (*zaohua*) within the theoretical framework of what in Song times was referred to as "studies of principles" (*lixue*) associated with Zhu Xi and his followers. Wang Bo, according to Zhou, had "pushed back to the origins of all things and illuminated the mysteries of the shaping of things, and was truly adequate to elaborate studies of principles and provided wings [i.e., commentary] for 'this culture' [i.e., the classical teachings preserved by Confucius]." In Zhou's view, Zhu Xi's "Learning of the Way" was not simply a moral vision of philosophical principles. It was also a theory of the principles of natural change.[70]

Wang Bo's work represented an extended essay on the cosmology of phenomenal beginnings that created all things in the world through the interaction of *qi*, form (*xing*), and materiality (*zhi*). The shaping of all things presupposed, however, the more paramount status (*ling*) of humans in the cosmos. Wang was not unusual in this claim that humans were the rulers of birds and beasts, and that, therefore, things in the world were classified, encyclopedically and otherwise, as secondary to humans and subject to their vital needs.[71]

Wang Bo's own account in the *Discussions* stated the pre-Jesuit theoretical vision informing natural history in late imperial China, which Europeans would challenge in the late Ming:

> Originally, before the beginnings of distinctions, there was the Great Change, the Great Origin, the Great Beginning, and the Great Simplicity. The Great Change occurred before *qi* was manifest. The Great Origin was the beginning of *qi*. The Great Beginning was the beginning of forms. The Great Simplicity was the beginning of material. When *qi*,

> forms, and materiality were not yet mutually separated, then we call this chaos [i.e., undifferentiated]. Chaos refers to the myriad changes [involved], chaotic without a beginning of separation. When chaos was already separated out, then heaven and earth opened out. When heaven and earth were distinguished, then they produced two models [i.e., yin and yang]. The light and clear floated up and became heaven; the heavy and turbid congealed and became earth.[72]

Without citing his source, perhaps to disguise its unorthodox status, Wang Bo was paraphrasing classical Daoist cosmology in the *Book of Master Lie* (*Liezi*), a work that he thought was written much earlier but today would be dated circa third century A.D. The *Book of Master Lie* included the following passage under the heading of "Heaven's Fortune" (*Tianrui*):

> In the past, the sages conformed to yin-yang to unify heaven and earth. If what took form grew out of the formless, then from what did heaven and earth grow? Therefore it is said: 'There was the Great Change, the Great Origin, the Great Beginning, and the Great Simplicity. The Great Change occurred before *qi* was manifest. The Great Origin was the beginning of *qi*. The Great Beginning was the beginning of forms. The Great Simplicity was the beginning of material. When *qi,* forms, and material were not yet mutually separated, therefore we call this chaos [i.e., undifferentiated]. Chaos refers to the myriad things when there was mutual chaos without a beginning of separation. It was invisible, inaudible, and unobtainable. Therefore it was called the Change.'[73]

Borrowing from a classical Daoist text was still acceptable during the declining years of the Southern Song, even when appeals to orthodoxy became more strident. Moreover, the overlap between the orthodox cosmology of the Learning of the Way and that of Master Lie indicates how closely tied classical learning and natural speculations had become. Wang Bo used this classical if unorthodox theory of the "shaping of things" to explain, precisely, natural phenomena (*ziran,* lit., "so of itself"). At times, Wang correlated phenomena based on numerological regularities, but more often his cosmological concepts were used to explain natural events.[74]

We have noted that the medieval *Adding to Elegance* and Ming *Examination of Ancient and Contemporary Things and Affairs* explained lightning and thunder by the concatenations of yin and yang. Zhu Xi had explained lightning in conversations with his students by criticizing the popular notion of a thunder spirit. Like Lu Dian and Wang Bo, Zhu also stressed the mutual rubbing and grinding of yang versus yin *qi* that produced lightning and thunder when *qi* was condensed and exploded. Nevertheless, Zhu also considered the anomalistic aspects of *qi* in light of thunder as auspicious or ominous. For Zhu, during a thunder and lightning strike the *qi* condensed into a sort of thunder ax that possessed spiritual powers. Zhu tied that thunder and lightning to the appearance of spirits and the manifestation of devils (*guishen*).[75]

For the same phenomena, Wang Bo explained that when yin and yang rubbed and ground against each other, their interaction exploded into sparks of lightning. Wang Bo's Southern Song account added more materiality to the swirling winds than earlier accounts and left out the popular understanding of the thunder ax. Nevertheless, the common denominator of these explanations, whose dates range across almost a millennium, was that rain, clouds, thunder, and lightning resulted from interactions between yin *qi* and yang *qi*.[76]

From Orthodoxy to Esoterica

In addition to his interests in classical lexicography and natural history, Hu Wenhuan also compiled and printed a wide range of works based on his broader interests in Chinese religion, which extended to popular Daoism, Buddhism, and medicine. Nourishing life (*yangsheng*) was an important theme in Chinese classical medicine and internal alchemy. The goal was to achieve the ancient ideal of bodily regeneration and longevity through internal moral discipline. Likewise, the focus in Ming publications emphasized "multiplying descendants" and "nurturing life." By linking meditative exercises, sexual discretion, and ingestion guidelines, Ming scholar-printers found a rich vein of readers when they tapped into teachings that historically were concerned with the sexual arts of the bedroom (*fangshu*) and stressed love, fertility, and health in light of the body's potential for producing offspring.[77]

This aspect of Chinese interest in the natural world grew out of the need to maintain the harmonious functioning of the human body, avoiding both excesses and wasting of the body's natural vitality. The *Basic Questions* (*Suwen*), one of the two best-known works in the medical corpus known as the *Inner Canon of the Yellow Emperor* (*Huangdi neijing*), for example, had emphasized the goal of human longevity. There the ruler was advised to cultivate serenity, detachment and nonstriving in order to "guard one's essence and spirit within." Such medical regimes were paralleled by early claims in the classical literature that an imperishable metal (gold) could serve as an elixir and that the attainment of earthly immortality was also possible using herbs of immortality. Such recipes for nourishing life (*yangsheng*) became a major focus in late Ming collectanea and encyclopedias.[78]

The goal of various techniques of breath control was physical immortality in an imperishable body, which was nurtured like an embryo through yogic disciplines. As an inner alchemy (*neidan*), such bodily transformation was comparable to how an alchemist brought an elixir to maturity in a matrix of lead (*waidan*). Older alchemical writings were later reinterpreted in light of the physiologic procedures associated with popular breath control and the meditation techniques introduced by Buddhists in medieval China.[79]

Alchemy from the start had medical overtones because the art of making elixirs of immortality represented a natural process for creating perfected substances that could be ingested or internalized. Alchemical treatises accordingly presented chemical operations as metaphors for cosmic and spiritual processes. The extraction of silver from lead (*waidan*), for example, reflected the emergence of a perfected self (*neidan*). Internal and external alchemy were complementary and regularly practiced together until the eleventh century, when adepts largely abandoned external alchemy.

Events, like things, fit into a cyclical pattern of natural processes. The life cycle of birth, growth, maturity, decay, and death paralleled the cycles of day and night, the seasonal changes, and the calendrical cycles of cosmic change. Yin and yang as dualistic, dynamic concepts were applied to spatial relations that were changing or in equilibrium. The five evolutive phases provided a parallel division of cycles or configurations of change for organizing natural phenomena. The eight trigrams and hexagrams from the *Change Classic* (*Yijing*) were also associated with the production of elixirs.[80]

In Hu Wenhuan's time, the unconventional literatus Yuan Huang (1533–1606) drew on two chief views of fate in Ming public and private life: (1) a system of merit and demerit that human agents could influence; (2) a framework of meaning beyond human influence. Ming literati such as Yuan increasingly regarded merit accumulation in the moral realm as homologous with cultural prestige and worldly material benefit. Later a Cheng-Zhu follower, Lu Shiyi (1611–1672), initially used Yuan's personal *Ledger of Merit and Demerit* (*Gongguo ge*) and titled his own work as *Chapters on Investigating Things and Extending Knowledge* (*Gezhi pian*).

The late Ming debate between moral purists (typically followers of the Learning of the Way), who thought fate was beyond human influence, and those like Yuan Huang, who favored merit accumulation among elites for success in civil examinations and among commoners for personal self-improvement in daily life, had become important enough to contest in official circles such as the civil examinations. Elaboration of a moral vision for those in late Ming society such as Hu Wenhuan, who aspired to social mobility and material success, was not so easily controlled in an era of social and moral flexibility, however.[81]

Yuan Huang also reinvigorated the traditions of inner alchemy by drawing on the psycho-physical model of the body, which informed traditions of outer alchemy. In such representations, the body became the crucible where the gross material of physical life could be refined and purified through human discipline. Yuan recommended the know-how to ensure that a fertile body was properly disciplined by sexual and spiritual exercises and by diet and pharmacy. This flawless body manifested the powers and pleasures of sexual function and the possibility of sagely transcendence and bodily immortality achieved through the procedures of inner alchemy.

By mastering the techniques of sexual hygiene, meditation, breath control, and bodily visualization, an adept could produce an elixir out of his or her own body. Yuan Huang emphasized the moral management of the seminal essence and breath through the three primary psycho-spiritual-material vitalities of the body, *qi,* and psyche (*jing qi shen,* lit., "essence, psycho-physical configuration, and psyche"). An adept could link the refinement of the body's essence, purification of one's *qi,* and the self-transcendence of the psyche to the inner cultivation of an immortal embryo. In a perfect state of emptiness, the circulated vitalities of the body would assume an increasingly concentrated and ethereal form.

This life-affirming overlap of sex, cultivation, and male fertility for nourishing life appealed to elite and popular audiences of men and women. Charlotte Furth has described how the Ming ideal of inner alchemy required moral cultivation and enlisted the sexual drive for the inward goals of classical sagehood, a short step, we might add, from a concept of the sublimation of the affects into spiritual ideals. Male sexual powers in particular were associated with the reproductive function. Consequently, late Ming versions of nourishing life that appeared in popular daily use compendia published separately or in collections focused more on human health and longevity than on the utopian quest for immortality. Inner alchemy was popularized as the moralization of health in Ming cultural life, and the goal of individual fertility displaced human longevity as the goal.[82]

Other Editions of Natural Lore: Expanded Versions of Hu Wenhuan's Collectanea

The 1609 version of the *Collectanea for Investigating Things and Extending Knowledge* was likely the most authoritative edition because it contained the only datable preface by Hu Wenhuan and a general table of contents of 140 works in the collection. Hu's preface presented fourteen categories of works that he and his staff had collated from the early and later masters and the hundred lineages of classical learning:

1. etymology
2. philology

3. poetic ability
4. literary criticism
5. astrology
6. geography/topography
7. astronomy/harmonics
8. penal laws
9. low-ranking officials
10. medicine and prognostication
11. Buddhism/Daoism
12. border peoples/foreigners
13. fauna
14. flora

Except for the lexicons and natural histories, which had appeared as a separate edition, Hu's division of categories for the 1609 edition of his collectanea generally reflected those that we have previously described in the daily use encyclopedias of the 1590s.[83]

Like many Ming scholar-printers, Hu mixed and matched the contents of his editions to sell more copies of his printed works. He also changed several original works to conform with his own printing needs. The Qianlong editors of the Imperial Library project found this aspect of Hu's editions especially egregious as they castigated him for his blatant profit-seeking. The editors made clear in their 1780s critique of Hu's massive *Collectanea* that they also disapproved of his inclusion of works on natural history (*bowu*) because such accounts represented writings previously classified as fictional accounts.

In addition, the editors noted that the version of Hu's collectanea that they reviewed contained 181 works divided into 12 classifications. At least four of these dealt with natural events:

1. classics/commentaries: fifteen works
2. unofficial histories: twenty-one works
3. officialdom: twelve works
4. legalists: twelve works
5. lessons/admonishments: fourteen works
6. masters and others: eight works
7. respect for life: eighteen works
8. seasons/agriculture: eight works
9. crafts: ten works
10. virtuous/praiseworthy: seventeen works
11. fictional works: eleven works
12. arts collections: thrity-five works[84]

What is interesting here is that Hu Wenhuan's publications on poetry, literature, the arts, nourishing life, etc., were added to the earlier, smaller versions of the collectanea, such as the version with forty-six classical works summarized above.

Later, many were also included in Hu Wenhuan's other major collectanea known as the *Famous Works of All the Scholastic Lineages* (*Baijia mingshu*), which can be dated to 1603. The preface by the Hanlin academician Zhu Zhifan (b. 1564) made it clear that Hu's *Famous Works* was also a comprehensive library of works stressing poetry, astrology, astronomy, flora and fauna, medicine and the arts of longevity, in addition to the more classical themes of philology and technical glosses on things and affairs. In his preface, Zhu Zhifan used the term for investigating things and extending knowledge (*gezhi*) to suggest the overarching unity Hu Wenhuan applied to such works, which linked the *Famous Works* collection to the *Collectanea for Investigating Things and Extending Knowledge*.[85]

Each collectanea contained many of the same works that Hu Wenhuan compiled or wrote himself. In the late sixteenth and early seventeenth century, Hu Wenhuan compiled and published more than five hundred works in Hangzhou and Nanjing. Moreover, the various editions of the *Collectanea for Investigating Things and Extending Knowledge* and *Famous Works of All the Scholastic Lineages* that have circulated over time are almost all different in content.[86]

Using works from earlier editions of the *Collectanea*, Hu Wenhuan published the *Famous Works* as an alternative way to present his collection of books. In effect, he had combined in his collectanea Ming works that were similar to two types of Song encyclopedias—the *Materials of the Taiping Xing Guo Era for the Emperor to Read* and *Expanded Records of the Taiping Xing Guo Era*. Other, smaller collectanea that Hu compiled also included many works from his two major collectanea (see Table 1.2). The *Collectanea for Prolonging Life* (*Shouyang congshu*), for example, contained a series of Ming works in which we see a nascent vitalism, or a philosophy for nourishing life, which was representative of similar currents in late Ming digests and collectanea.[87]

Late Ming Statecraft, Mathematics, and Christianity

Most of the collectanea and practical compendia common in the late Ming were produced by lower-level gentry-literati or scholar-printers. In contrast to Li Shizhen's *Systematic Materia Medica* and Hu Wenhuan's *Collectanea,* the scholar-official Feng Yingjing (1555–1606) while in jail compiled an important encyclopedia titled the *Compendium of Practical Statecraft in the*

Table 1.2. Other collectanea compiled by Hu Wenhuan.

- *Secret Works for Investigating Things and Extending Knowledge* (*Gezhi mishu*), with thirty-seven of the forty-six works on lexicography and natural history in the original edition of the *Collectanea of Works Investigating Things and Extending Knowledge.*
- *Collectanea for Prolonging Life* (*Shouyang congshu*), which dealt with some sixteen to twenty-three medical texts associated with "nourishing life," many of which were included in the larger versions of the *Gezhi congshu* and *Baijia mingshu.*
- *Broad Review of Original Roots* (*Yuanzong bolan*), with thirty-one works mainly dealing with "nourishing life," which were also included in the *Gezhi congshu* and *Baijia mingshu.*
- *Comprehensive Collection of Maps and Works on the Great Ming Dynasty* (*Da-Ming yitong tushu*), with nine works that were included in the larger versions of the *Gezhi congshu* and *Baijia mingshu.*
- *Origins of Things Old and New* (*Gujin yuanshi*), with three works, all of them natural histories that were included in the original version of lexicographies in the *Gezhi congshu.*
- *Four Authorities Authors on Music, Calligraphy, and the Arts* (*Youyi sijia*), including four works.[a]

a. See Wang Baoping, "Zhongguo Hu Wenhuan congshu jingyan lu," pp. 19–25.

August Ming Dynasty (*Huang Ming jingshi shiyong bian*), which was published in 1604 with a 1603 preface by Feng. A palace examination graduate in 1592, Feng was jailed for four years beginning in 1601, while serving as an assistant surveillance commissioner, for refusing to allow a eunuch tax collector in Huguang free rein in accumulating revenues in the name of the emperor.[88]

Also jailed with Feng was He Dongru (fl. ca. 1589), who was a prefectural judge in Huguang and had also resisted eunuch tax demands on miners in the area. Together they discussed the political chaos of their time, and each resolved to compile works while in jail that would stress statecraft policies to help ameliorate the dangers of their time. They advocated a return to the policies of the first Ming emperor, who had unified the empire after the anti-Mongol conflagrations in the middle and late fourteenth century. Feng Yingjing's *Compendium* thus returned to the repertoire of statecraft techniques and moral policies derived from the *Rituals of Zhou* that had informed politics in the early Ming.[89]

In addition, Feng Yingjing had befriended Matteo Ricci and taken an avid interest in the Christian religion and the Western studies that were associated with it. It is said that Feng would have been baptized had he not died prematurely, just two years after his release from jail. The Christian impact on

Feng's *Compendium of Practical Statecraft in the August Ming Dynasty* was made implicit in the opening chapter, which comprised the first Ming emperor's own official writings. Under the cover of an annotation to the emperor's orthodox evocation of classical doctrines, namely that "the sages and worthies had the mind-heart of a gentleman," Feng interpolated a discussion of an "enlightened antiquity" when "the spirituality of a unified mind served the spirituality of the minds of ten thousand people."[90]

Feng then turned to a discussion of the "Lord on high" (*shangdi*) and his rectifying power to discern right from wrong, a comforting lesson for a man jailed by a corrupt eunuch. The affinity of human spirituality with such a power, Feng contended, carried over to the founding emperor, who had been endowed with the requisite spirituality to sustain his reign. This reference to the Lord on high, a term that Ricci and the early Jesuits had settled on as a translation for *Deus* because of its ancient provenance in the *Documents Classic,* was permissible in Feng's notes because the first Ming emperor had himself used the term in his discussion of palace sacrifices. Feng regarded this reference as the "origins of the emperor's methods of the mind." Building on this imperial precedent, Feng could then claim that "we are all the Lord on high's people." Feng's rhetorical appeal to spiritual salvation was manifest: "How much heaven must love me as a person to enable me to suffer the pain of the world."[91]

Feng's *Compendium* was composed as a statecraft digest and not as a Christian tract, however. Its focus on imperial governance incorporated sections on officialdom, ritual studies, musical studies, archery, calligraphy, and arithmetic, in addition to sections on orthodox studies. Feng's inclusion of arithmetic and mathematics in the compendium was intended to correct excessive stress on belles lettres, which had emerged during the Ming, particularly since the eight-legged examination essay became a literary rage in the late fifteenth century. Here, too, we discover Feng's contact with Ricci and European studies because the arithmetic that Feng detailed in his digest was drawn from the *Systematic Treatise on Computational Methods* (*Suanfa tongzong*) by Cheng Dawei (1533–1606), which had been published in 1592–1593 and quickly emulated as *wasan* (Japanese mathematics) for practical computations in Japan.[92]

Cheng Dawei's *Systematic Treatise* comprised a collection of 595 difficult arithmetic problems. Designed as a general and practical arithmetic using the abacus, rather than more cumbersome counting rods (*chousuan*) used to solve higher-degree equations during the Song and Yuan dynasties, Cheng's work was widely disseminated before the Jesuits encouraged the Kangxi emperor's interest in it later in the seventeenth century. Cheng's *Treatise* reflected the arithmetic language of Ming merchants, who were the key guardians of the *Computational Methods in Nine Chapters* (*Jiuzhang suanshu*) tradition.

One of the "Ten Mathematical Classics," the *Computational Methods* was compiled between 200 B.C. and A.D. 300, with later commentaries added to it. Some regarded it as the most important work in the mathematics canon. It was also the model for mathematical language and the pattern for computation since medieval times, when the official canon was used at the School for Dynastic Students during the Sui and Tang dynasties to teach mathematics.[93]

The oldest known edition of the *Computational Methods in Nine Chapters* dated from the thirteenth century, however. Because the latter was not fully reconstituted and reprinted until the eighteenth century, Cheng Dawei's *Systematic Treatise on Computational Methods* represented the best available late Ming work in the *Nine Chapters* tradition for arithmetic problems and their numerical solutions. Some of Cheng's problems were later adapted into a more classical style for literati in Ricci's arithmetic, which was based on European and Chinese sources.[94]

Matteo Ricci's 1614 *Translations of Guidelines for Practical Arithmetic* (*Tongwen suanzhi*), compiled with Li Zhizao's (1565–1630) help, adapted its arithmetic from Clavius' *Epitome Arithmeticae Practicae*. It was also based on arithmetic from the Yuan and Ming periods. Hence, Ricci's treatise on European arithmetical knowledge added problems from the *Systematic Treatise on Computational Methods* by following the Chinese arithmetical tradition. Although Ricci introduced the Western pen-and-paper approach to arithmetical calculations, overall his *Translations* did not go beyond the limits of the Chinese traditional mathematics.[95]

By including portions of Cheng Dawei's *Systematic Treatise,* Feng Yingjing's statecraft digest incorporated a definitive arithmetic in which problems, rules, and solutions were composed in verse with rhyming formulas for teaching arithmetical terms, computation with the abacus, and multiplication tables. Feng added that although the Duke of Zhou had in antiquity developed the *Computational Methods in Nine Chapters,* its arithmetic had not developed the relational features for computing the sides of a right triangle (*gougu,* lit., "base and altitude") that were later found in the *Sea Island Computational Canon* (*Haidao suanjing*) by Liu Hui at the end of third century A.D. Feng added that Westerners such as Matteo Ricci had mastered the computational procedures, i.e., geometry and trigonometry, necessary to measure long distances in fields by mastering similar right triangle procedures.[96]

Feng's interest in more advanced mathematics, which went beyond the simple arithmetic of Cheng Dawei's *Systematic Treatise,* indicates that the Jesuits were dealing with literati already concerned about the need to develop more expertise in mathematics. This is shown by Feng's inclusion of earlier Ming right triangle studies in his section on mathematics. A generation earlier, for example, the literatus Tang Shunzhi (1507–1560) prepared a series of essays on triangles and segments of a circle that were essential in geometric calculations, which Tang precociously called "studies of measured amounts" (*jihe xue,* i.e., magnitude or quantity), a term later selected by Ricci and his Chinese collaborator for the late Ming translation of Euclid's geometry.

Before the arrival of the Jesuits, Tang Shunzhi had distinguished between new and old computational methods, a division that would reappear in later discussions of Western learning. His essays preceded by several decades the earliest Jesuit transmission of medieval and Renaissance mathematics to China. The latter were essential to integrate ancient classical theory with contemporary technical expertise in order to reform the Ming calendar.[97]

Feng Yingjing's stress on practical problems in mensuration involving right triangle calculations in his digest also occurred before Ricci's translation of Euclid's *Elements of Geometry* was completed. Moreover, problems in late Ming calendar reform that we will address in Chapter 2 increasingly contributed to the Ming reception of early modern European mathematics and computational astronomy. Consequently, Feng Yingjing's *Compendium* foreshadowed late Ming and early Qing literati and imperial court interest in European trigonometry, trigonometric tables, and logarithms. It also prefigured statecraft collections that were compiled by convert-officials such as Xu Guangqi.

Collecting Things in Texts

The proliferation of late Ming daily use compendia—many of which Hu Wenhuan's *Collectanea* prominently contained—reflected a widening audience for information about things, phenomena, and affairs of all sorts. The accruing knowledge of things and affairs among Ming scholars was still subsumed within the moral and philosophical frameworks that informed the orthodox literati classification of the natural world and drew on the classical repertoires of knowledge outlined above. These repertoires notably included medieval masters of esoterica such as Zhang Hua, who were central to the late imperial definition of a cumulative knowledge of things and phenomena. Although the classical lexicons and natural histories were the beginning points, the knowledge in ancient canonical texts and their commentaries were insufficient.[98]

Literati deployed things in digests and the collectanea by presenting chronological or topical presentations of past glosses about them. Things, events, and anomalies were displayed textually and sometimes pictorially. In time, words as glosses, that is, the textual lives of things, took precedence over any analysis of the things signified. As a result, natural studies became a venue for Chinese textual scholars who were fascinated with the etymologies of the words. Sages had created such words to encompass phenomena. Hence, they were also important as a genealogy of items in the classics. Unlike early modern European scientific culture, where natural history was increasingly displayed as concrete items in a museum, the array of entries about things included in Hu Wenhuan's collectanea of early lexicons and digests converted natural phenomena into words in a text that needed to be decoded primarily through the analysis of language.[99]

Paula Findlen has described the new attitudes toward nature as a collectable entity and new techniques of investigation that informed natural history in early modern European scientific culture. The first science museums were repositories of technology, curiosities, and wonders that built on Pliny's encyclopedic definition of nature in his *Natural History* as everything that was worthy of memory. Europeans coped with the empirical explosion of materials that the wider dissemination of texts, increased travel, voyages of discovery, and more systematic forms of communication had made possible by establishing private museums, which became state-sponsored institutions from the eighteenth century onward. Such museum collections became symbols of prestige and power, and collectors entertained the image of knowledge without end more widely in the seventeenth century.[100]

Paula Findlen focuses on the linguistic, philosophical, and social matrices that gave museums a precise intellectual and spatial configuration. Museums became a venue to experience nature. From the sociology of collecting and its cultural logic, we can see that in late imperial China this sort of collecting and classifying knowledge about things occurred within the pages of collectanea and encyclopedias. Just as the museum was firmly set in the premodern European encyclopedic tradition of catalogs and the vocabulary of collecting, so the daily use compendia of the late Ming were sites of classically derived knowledge where individuals of privilege and learning earned the right to collect and classify the world. Others could participate in such collecting by reading about things in the texts that they purchased or borrowed.

Hu Wenhuan's merchant-scholar-printer status in Hangzhou and Nanjing publishing circles allowed him to participate in highbrow activities at the same time that he published works for profit aimed at popular audiences. The first increased the classical prestige of his collecting and reprinting information from lexicons and natural histories. Hu elevated his own curiosity about things and phenomena to a virtue that was entirely appropriate for gentlemanly behavior. Likewise, Li Shizhen's much more analytic work on pharmacopoeia approximated the role of the collector of natural objects—or information about them—as parallel to the Learning of the Way scholar who investigated things, or someone who collected objects.[101]

If the museum became a site of encyclopedic dreams and humanist sociability in sixteenth-century Europe, collecting information about things in the late Ming was not yet a prelude to display (in museums) or manipulation (in laboratories). Li Shizhen certainly shared the naturalist's agenda. Moreover, his pilgrimages to collect medicines and herbs were done through fieldwork and perusing texts. His natural studies remained focused on remedies. Secondarily, he was fascinated with the etymologies of terms for living things, which could then be applied via the investigation of things to classify appropriate medicines. Ming collectors of encyclopedias (such as Hu Wenhuan) never expressed a penchant for purely experiential knowledge obtained in the laboratory, although medical men continued to produce empirewide a rich plethora of medicines and accessories for traditional Chinese healing. Li Shizhen did so as well.[102]

In early modern Europe, gentlemen enriched their collecting experiences by increasing the presence of animal skeletons and fossils in the museum. The new culture of experiential demonstration transformed the museum into a site of medical knowledge, within which competition over the control of knowledge between apothecaries and physicians-professors ensued. Nevertheless, the modern category of natural science had no formal meaning for the European naturalist in the sixteenth century any more than it did in the late Ming. To compare the historical context for early modern scientific culture in Europe and natural knowledge in late Ming collectanea and digests, we need to problematize the historical teleologies that turn the past purely into prologue.[103]

Collecting as a research agenda rearranged the boundaries of natural studies in Europe, but the coexistence of the old and new, the occult and the demonstrable, in early natural history was as prevalent in Europe as in the late Ming. Even after the Jesuits arrived in Ming China, no one there or in Europe singled out and privileged natural science. Later in the seventeenth century, via Bacon, European scholar-gentlemen dismantled older forms of natural philosophy in favor of a new empiricism. Galileo, Descartes, and Newton transformed such high-minded empiricism into the concrete beginnings of physical science in Europe after the Jesuits arrived in China.[104]

Efforts to normalize the marvelous in Ming China turned the collection of information about things into a form of classical knowledge gained through encyclopedic research, which defended itself using the rhetoric of orthodox moral cultivation, i.e., to investigate things and extend knowledge. Rather than microcosms of nature, collections of early lexicons and Ming digest created textual museums for their theater of marvels. Hu Wenhuan's efforts in the 1590s to collect the collectors within a single collection of books published as a set was not unique. His economic resources allowed him to produce and publish several collectanea he deemed appropriate to place under the general heading of investigating things and extending knowledge (*gezhi*). His initial reconstruction of the ancient lexical texts allowed him to use them as an orthodox base for enlarged editions of his *Collectanea,* which included domains of knowledge that exceeded the boundaries of the official canon.

When the military dust settled after the final Manchu victories in the 1660s, Ming loyalist scholars from the Yangzi delta such as Gu Yanwu (1613–1682) and Huang Zongxi (1610–1695) took their predecessors to task for their naiveté concerning classical controversies such as the Old Text and stone versions of the Great Learning. Chen Que (1604–1677) in particular singled out this controversy and criticized late Ming scholars for their credulity and lack of the textual expertise needed to recognize the dubious stone version as an obvious forgery. In general, the focus on the investigation of things in the early Qing shifted from a pathway to sagehood to a more rigorous methodology for extending all knowledge, whether moral, textual, or worldly. The Jesuit appeal to *scientia* in China was received by literati in the midst of a sea change in classical learning from the Ming to Qing dynasty.[105]

Seventeenth-century Chinese collections and digests drew on Zhu Xi's scholarly eminence, when investigating things and extending knowledge (*gezhi*) became a popular phrase among literati and the Jesuits in their discussions of the proper approach to the diversity of knowledge. In the late nineteenth century, literati and their Protestant missionary collaborators chose Zhu Xi's terminology to translate modern science into Chinese as the study of investigating things and extending knowledge (*gezhi xue*). In opening remarks for the inaugural spring 1876 issue of the *Chinese Scientific Magazine* published in Shanghai, Xu Shou (1818–1882) as cofounder commemorated Zhu Xi's gloss for the investigation of things as an eloquent statement of the universal search for the knowledge of all "principles underlying things and affairs" (*shiwu zhi li*). The naming of science in this way, Xu Shou declared, would empower Chinese to master the practical fields of modern science.[106]

II

Natural Studies and the Jesuits

2

The Late Ming Calendar Crisis and Gregorian Reform

For Chinese emperors and their officials, the mandate of heaven since antiquity measured their cosmological, political, and historical worth. The emperor as the "Son of Heaven" was ritually responsible to establish a system of computational astronomy, which made an accurate calendar a realistic goal for his government. Relying on an accurate astronomical system for a mathematized cosmos, the emperor could disseminate an official calendar.[1] The first record of an articulated astronomy bureau (hereafter, "Astro-calendric Bureau") with clearly delineated duties occurred in the *History of the Later Han* (A.D. 25–220; *Hou Hanshu*).[2]

The *Documents Classic* (*Shangshu*), one of the original Five Classics, contained a famous injunction by the legendary Emperor Yao to regulate the calendar so that celestial events could be predicted. To order the empire, literally, "all under Heaven," Chinese and non-Chinese dynasties required technical mastery of heavenly and atmospheric events such as nonperiodic stellar novae, solar halos, and meteors and meteorites, in addition to periodic lunar and solar eclipses. Celestial events that imperial officials could not predict, as well as earthquakes, famines, etc., were portents that potentially pointed to the emperor's lack of virtue.[3]

In addition, an accurate calendar organized specific economic, political, and religious rituals to demonstrate authority over the agrarian cycle, affirm the cosmic order, and normalize relations with other rulers. The calendar's astrological and ideological significance made its imperial compilation and promulgation a critical ceremonial duty. The symbolic power of the calendar to order daily life via timekeeping affirmed the effectiveness of the dynasty in place, especially a conquest dynasty such as the Yuan under the Mongols and later the Qing under the Manchus. The calendar first and foremost mattered politically, and its impact on the agrarian cycle of seasons was secondary.

Mathematical astronomy (*lifa*), never an abstract study for its own sake, was the key to preparing calendars and horoscopes. Once a computational system was in place—that is, most of the time—the annual work of calendar making involved the lowest-ranking officials, computists with minimal skills. The bulk of the effort of bureau officials went into mathematical astronomy and the observation and interpretation of omens.[4]

Astronomical prediction, astrological interpretation, and the auspicious performance of daily tasks and ceremonies in court and at home presumed an accurate lunisolar calendar. Both the dynasty in power and the people at large were concerned with the dates of events, actions, and rituals. It was fortuitous for the Jesuits who began arriving in Ming China in the 1580s that their order had been involved in resolving one of the major calendrical problems bedeviling the Church in Europe, namely the controversy over the date for the movable feast of Easter.

Pope Gregory XIII (1502–1585) had appointed the German Jesuit Christoph Clavius (1538–1612), a leading mathematician and churchman, to the Gregorian reform commission. Clavius ascertained the proper date for Easter, originally derived from the Jewish Passover, with the promulgation of the Gregorian calendar in 1582. The Gregorian reforms occurred before the Copernican heliocentric controversy climaxed in 1616, but astronomers such as Clavius were already aware of Copernicus's challenge to the geocentric model of the solar system. The earth was a planet in Copernicus's system, and it orbited around the sun with the other planets, as well as rotating daily on its own axis. This brouhaha between the Church and astronomers later affected the Jesuit's role as transmitters of European astronomy to Ming and Qing China.[5]

In Ming China, the remarkable astronomical advances of the Yuan dynasty's Season Granting astronomy system (*Shoushi li*) of 1280, which was repromulgated by the Ming dynasty after 1368, was a major factor in the stability of the calendar until the 1580s. The very success of the Yuan calendar in predicting celestial events, conversely, produced an entrenched complacency in the Astro-calendric Bureau. Fortuitously, the Jesuits, whose main base of activity was in Japan, arrived in south China. Michele Ruggieri (1543–1607), for example, entered Macao in 1579 and initiated a Chinese mission in 1582. Versed in Renaissance mathematics, Ruggieri introduced European mathematics, mechanical clocks, and prisms to gain favor among local elites near Guangzhou. He was joined in the Jesuit residence by Matteo Ricci (1552–1610) in 1583.

Ricci had studied law in Rome and mathematical astronomy under Clavius at the Collegio Romano. Since 1581, one year before the Gregorian calendar was promulgated, he had been in Macao. Many of Ruggieri's and Ricci's initial conversions were "via the door of Mathematics." Moreover, when Ricci arrived in Beijing for the first time in 1601, he brought with him a number of books on mathematics, and he remained in contact with Clavius while in China. Later, when he realized the seriousness of the Ming calendar problem, Ricci hoped the court would employ Jesuits to correct the calendar. Equally important, he realized that the Astro-calendric Bureau offered a place for foreigners in the court bureaucracy, with access to the top.

Ricci's goal was to curry favor with the court and literati elites to gain their tolerance of Jesuit efforts to convert both elites and commoners. The success of some Jesuits such as Ricci in Beijing allowed Jesuits in the field to gain Christian converts openly. Less transparent, however, were their attempts to inscribe precise mathematical predictions of the periodicity of repeating celestial events, such as eclipses, with a vision of time that dated events linearly from creation.[6]

Consequently, when after three hundred years of use the discrepancies between the Yuan-Ming lunisolar calendar and the solar year became astronomically and politically significant, the Jesuits were well equipped to participate in calls for calendar reform during the Wanli reign (1573–1619) because of the legacy of training in mathematics with emphasis on astronomy, that Clavius had established in Rome. The curriculum at the Collegio Romano was copied in Jesuit colleges all over Europe, including the Portuguese College of Coimbra, where the Jesuits who were sent to China received their final training. They were worthy technical adversaries for the hereditary Muslim and Han Chinese officials entrenched in the Astro-calendric Bureau. The battle over the correct time was more than a technical rivalry, however.[7]

Development of the Ming Astro-calendric Bureau

Because the official production of the calendar provided the institutional venue for the development of Chinese astronomy, monographs on astronomy and astrology were regularly included in the dynastic histories. Afterward such information was also added to some medieval and late imperial encyclopedias and gazetteers. Technical knowledge of the heavens mattered for the government, which is why the calendrical advantages and astronomical models demonstrated by foreigners, such as the Indians, Muslims, and Jesuits who were hired by the court, were incorporated into the Tang, Yuan, and Ming-Qing calendars. Moral cultivation was rhetorically preeminent for literati, but understanding the calendar was an important aspect of the classical tradition and thus pertinent to them.[8]

Although rural life was unaffected by the inevitable calendrical errors that ensued from the anomalistic motions of the sun and moon, the official calendar in China was always linked to celestial phenomena. The goal of those who designed computational systems was to represent accurately the periodicity of heavenly bodies. The astrological interpretation of heavenly patterns (*tianwen*) was based first on accurate observations and secondly on the contextualized sociopolitical interpretation of observable celestial events.

The luni-solar calendar in place combined solar years and lunar months. Since twelve lunar months amounted to only 354 or 355 days, it was essential periodically to add leap months, or intercalary months, to maintain an average of a little over 365 days in a tropical year. Officials were needed, in addition to their more demanding tasks, for calendar maintenance and occasionally for minor modifications. The designers of computational systems marked the divisions of the tropical year, projected the locations of the five visible planets among the stars, and predicted solar and lunar eclipses. Such expertise enabled others in the bureau to base ceremonial dates and interpretations of anomalies on accurate information.[9]

The bureau was a midlevel agency in the Ming government. Under the courts of Imperial Sacrifices and Imperial Entertainments in the Ministry of Rites, it was essentially a service organization. Dates for important events and ceremonies performed by the court or high officials required an accurate calendar. Otherwise, the political consequences for the court, and hence for the Bureau, could be volatile. Located between the court and the bureaucracy, the Astro-calendric Bureau was on par with the Imperial Academy of Medicine, the Office of Transmission for Official Documents, and the Directorate of Imperial Parks. It had less prestige than the Hanlin Academy, whose academicians often served dual roles as grand secretaries within the imperial household and as high officials within the Ministries of Rites and Personnel.[10]

The first Ming emperor simply appropriated the Yuan dynasty's Season Granting system—calling it the Grand Concordance astronomy system (*Datong li*)—and similarly took over its Astro-calendric Bureau intact to assert imperial legitimacy. Now called the "Directorate of Astronomy" (*Qintian jian*), the Astro-calendric Bureau continued in Nanjing with segregated Islamic and Han Chinese sections. When the third Ming emperor moved the metropolitan government to Beijing in 1414–1415, which he made his official capital in 1421, an auxiliary Astro-calendric Bureau remained in Nanjing until the end of the dynasty. Although complete with accurate versions of Yuan instruments, its importance declined.

A separate Islamic office was eliminated in 1398, but its Muslim personnel were incorporated into the main bureau to provide an accurate Islamic calendar for the many Muslims in China, many of whom had been invited by the Mongols to serve the Yuan dynasty.[11] The Ming bureau maintained the four divisions of the Jin-Yuan bureau: astrological interpretations, timekeeping, Islamic methods, and mathematical astronomy (*lifa*). The Islamic division and its Muslim calendar in China echoed the Nine Governors System of the Tang, when Indian calendrical officials had served in the bureau.[12]

Expertise in the Ming Astronomical Bureau

The staff in the Ming Astro-calendric Bureau was responsible for general observations and specific predictions that were divided into five general duties: anomaly observation, eclipse prediction, calendar compilation, auspicious time and place selection, and timekeeping. The equipment and computational tables they employed were similar to the sophisticated observational tools that had been employed by the Yuan bureau under Kublai Khan after 1280 and by the Mongol Ilkhans at the Marâgha Observatory in Persia until 1305:

- An armillary sphere comprised of three layers of uniformly revolving rings representing the fundamental celestial circles or spheres. A sighting tube in the plane of this ring pivoted around the center to make observations and measure distances on the spheres.
- The “simplified instrument” served the same purpose but with fewer parts. It consisted of two rings, and the siting tube was fixed to the center to allow it to align with any celestial object. Its simplicity, based on equatorial coordinates until the Jesuits introduced ecliptic coordinates, made it a mainstay of Yuan-Ming astronomy.[13]
- Yuan dynasty gnomon (shadow-casting instrument) to determine the solstices when the sun’s shadow produced the longest or shortest times of daylight.
- A water clock for timekeeping, namely, the three-chamber inflow type clepsydra.[14]

Although the Mongols used Islamic methods for planetary computations, Kublai also used other scholars skilled in Islamic star studies, such as the Persian Jamal al-Din, in his Astro-calendric Bureau. Jamal al-Din and others came to the Mongol court in 1267 with diagrams of an armillary sphere, a parallactic ruler, a sundial-gnomon, an astrolabe, a terrestrial globe, and a celestial sphere. Initially, the Yuan Astro-calendric Bureau was divided into three parts, with Jurchen, Islamic, and Chinese offices, although there were Han Chinese in each office. Kublai also adopted the traditional Chinese ban on the private ownership of astrological texts and private practice of astrology but as usual made no attempt to enforce it.[15]

The astronomical instruments that Jamal al-Din described to the Mongol court in Beijing strongly suggests that the astronomers at the Marâgha Observatory, which was founded about 1260 near Tabriz in Persia for the Mongol Ilkhan Hūlâgû (r. 1256–1265), Kublai's (r. 1260–1294) brother, were in touch with their Beijing counterparts. The plans for the astronomical instruments that Jamal al-Din described at the Yuan capital were the most advanced instruments of the time for both Islamic and Chinese mathematical astronomy, as were the Ilkhani computational tables completed in 1271.[16]

Yuan-Ilkhanid relations were also important factors in the physical and decorative similarities of ceramic types in both regions. These shared forms in the crafting of ceramics combined the geometric characteristics of the Near East with the floral designs of China. The Islamic experts who filled Kublai's Astro-calendric Bureau in 1280 in Beijing were paralleled by similar developments in 1259 in the Marâgha Observatory during the Mongol era of conquests in Asia.[17]

The Yuan establishment of a separate Muslim Astro-calendric bureau in 1271, which in principle used the Ptolemaic geocentric world system, segregated Mongol experts from their Chinese counterparts in the bureau, however. The claim that the Islamic Bureau held an Arabic or Persian version of Euclid's *Elements* and Ptolemy's *Almagest* remains speculative, however.[18] Nevertheless, the Islamic influence in the design of Guo Shoujing's (1231–1316) "Simplified Instrument" (*jianyi*), a simplified armillary sphere or astrolabe, and large masonry gnomon towers was clear. The reforms associated with the Yuan calendar introduced many innovations and represented a new astronomical synthesis in the long history of the Astro-calendric Bureau.[19]

In particular, the Season Granting astronomy system promulgated in 1281 applied new computational techniques of a prototrigonometric nature to convert the equatorial coordinates observed on the celestial spheres into numerical equations solvable using counting rods (*chousuan*). The compilers of the new calendar also recognized the computational differences in the procedures for positioning lunar and solar movements. This led to a gradual understanding of the lunar nodes (where the moon's path intersects the ecliptic) and thus of the conditions in which eclipses take place.[20]

By 1478, however, a memorial from the Astro-calendric Bureau acknowledged that its observational instruments were in disrepair. A 1612 memorial from the Ministry of Rites painted a darker picture of instrument dilapidation in the bureau, which has suggested to many scholars that before the Jesuits arrived the bureau was unable to use the astronomical instruments bequeathed from the Yuan dynasty. Although they were excellent by thirteenth-century standards, because the instruments were never very precise, reports on their deficiencies may have been inflated later by the Jesuits and their supporters. The mandated responsibilities of the bureau did not require precise observation until Jesuits challenged the competence of official astronomers.

Even then, Jesuit instruments quickly became obsolete as European standards rose.

For instance, the Ming bureau could not predict the location of an eclipse, only its time, duration, and magnitude. As the accuracy of calendrical computations improved, the standards for rationalizing errors in the calendar also heightened. Accuracy in predicting eclipses had gradually improved since antiquity, and what constituted error also changed. In the Han period, eclipses were predicted to the nearest day. During the Tang such predictions pointed to the nearest hour and gradually improved. By the Yuan, precision was possible to the nearest quarter of an hour. The Jesuits went further by predicting a solar eclipse to the nearest minute. Hence, by 1630 the Ming bureau was considered deficient because it was unable to achieve this new level of accuracy.[21]

Because such determinations occurred within the Observatory of the Imperial Palace, imperial complicity with bureau staff was unavoidable, particularly when the political stakes of an astrological interpretation were high, as when the Jesuits threatened to take over the Astro-calendrical Bureau. Such collusion usually took place, however, after an astronomical observation had been made by the staff, and they had turned it over to the personnel for astrological interpretations.[22]

Accordingly, the need for accurate observations inside the bureau usually outweighed the potential for the fabrication of celestial events based on politically biased motives. In addition, the Islamic calendric system was treated as a second opinion. Thatcher Deane has studied official Ming notices of the planet Mercury (known as the "Water Star") as a case example. He has found that the record of observations of Mercury in the Ming *Veritable Records* were in close accord with the planet's known position based on modern calculations. In one case, however, after the third Ming emperor came to the throne following a civil war, the mistaken record of a celestial anomaly in 1404, whereby Mercury intruded on a star, may have been fabricated to legitimize the new emperor.[23]

Even though routine observations were separate from astrologic interpretations, the manipulation of recorded anomalies by those charged with astrological interpretation was not uncommon. Because of discrepancies in the prediction of lunar and solar eclipses, astrological interpretation could impact the observation of celestial events. A formal "Relief Ceremony," for example, was enacted for solar or lunar eclipses when the predicted eclipse was visible or not. This curious ritual was more frequently performed for solar eclipses, which were the most serious anomaly. When an unpredicted solar eclipse occurred, an imperial apology on the part of the ruler and his government was obligatory. In a parallel way, when a predicted eclipse was not observed, then officials were expected to express their congratulations to the ruler for his governing achievements.[24]

Procedures for Computing Eclipses

In the Chinese lunisolar calendar, each month began on the day of a sun-moon conjunction, when no moon was visible. Total solar eclipses happened only on the day of a new moon. The coincidence of New Year's day and a solar eclipse, for instance, was improbable. A solar eclipse on any day other than the first of the month indicated an error of prediction, giving the event astrological significance. After three hundred years of use, however, the Yuan-Ming calendar in 1580 was off by one full day. This calendrical error mattered because a solar eclipse could now occur on the last or second day of the month. In addition, numerous ceremonies and events were tied to the first day of the new month. Because of the superiority of the Islamic Ptolemaic system in computing lunar-solar conjunctions, the court authorized its use in 1584.[25]

Half of the Ming bureau's solar eclipse predictions were spurious. This tendency toward overprediction was a way to protect the bureau from unpredicted anomalies and minimize the chances of missing a solar eclipse. Unverified but predicted eclipses were interpreted as Heaven's approval of imperial virtue. Failure to predict an actual solar eclipse, however, was a serious offense for the Bureau. A consistently correct prediction of local solar eclipses was not possible using the tables of periodicities in the Ming calendar until more accurate European geometric techniques arrived. Accordingly, the astronomical constraints within the bureau combined with ideological issues in the court to promote a tolerable level of overprediction.

An unpredicted lunar eclipse that occurred, however, was not treated as a culpable error. There were also fewer spurious overpredictions of lunar eclipses. Those that were predicted but spurious were regarded as failures, again the reverse of spurious solar eclipses. Because lunar eclipses were easier to predict than solar eclipses, higher standards were applied in such cases. A predicted but spurious lunar eclipse, however, stood out as a major error because of the higher expectation of accuracy. In other words, the Ming government treated solar and lunar eclipses differently because of the varying difficulties in computation. The court cushioned itself with ritual responses to unexpected solar eclipses because they were truly uncharacteristic, while lunar eclipses were not.[26]

Timekeeping, the Calendar, and the Selection of Auspicious Dates

To overcome the limits of sundials to mark time during darkness, the Chinese created water clocks. In 1090, a Northern Song government official, Su Song

(1020–1101), constructed a forty-foot-high hydro-mechanical clock that he called the "Cosmic Engine." Its interior mechanism of hooks, pins, interlocking rods, coupling devices, and locks served as a mechanical escapement that alternately engaged and disengaged to control the movement of a revolving wheel. Su's demonstrational water clock included a star globe and an armillary sphere. Each was connected by chains and turned by gears. What remained of Su Song's clock mechanism after the Song dynasty was conquered, however, finally vanished in the fourteenth century, when Ming forces drove the Mongols from Beijing, and was forgotten. Hence, when Jesuit missionaries brought European clocks to China in the late Ming, such mechanical devices were welcomed by the Chinese as an ingenious invention and an improvement over their simple water clocks.[27]

Nevertheless, regular operation of Ming water clocks continued in large cities with drum and watchtowers. There the daily changing of placards for the twelve double hours of every day were routine tasks, which urban dwellers could see in addition to hearing the drum rolls. Also routine was the compilation of the annual calendar for empirewide distribution. The dating was based on the governmental assumption that calendricizing the world of time would bring order and predictability to the sequence of celestial phenomena, which would in turn order social, political, and cultural events within the empire.

The bureau was responsible for selecting auspicious days and hours for various court and public activities such as imperial funerals. The Ming government distributed approximately 2.7 million printed calendars, or one for every seven households, for officials and commoners to follow these determinations. Although these calendars were not doled out casually, they were available beyond most administrative units and profusely reprinted by private publishers.

Neighborhood specialists trained in local yin-yang schools complemented the Astro-calendric Bureau. The government established prefectural and county schools of yin-yang divination to train functionaries to divine auspicious days and related matters of geomancy based on topography and directional orientations. Such efforts were symbolic and ineffective. A pool of hereditary families provided such personnel, but often, as in 1458, the Ming bureau received authorization from the Ministry of Rites to initiate an empirewide call for officials who were expert in astrological interpretation, mathematical astronomy, geomancy, and fortune-telling.

The politically sensitive selection of auspicious times and days by the bureau was tied to geomantic considerations in naming and siting venues for imperial ceremonies, selecting appropriate tombs for the dead, and bestowing honorific titles on the deceased. Geomantic service was a bureau duty in siting tombs, for instance. We will see in the next chapter that this became a serious bone of contention in 1658 when the Jesuits in charge of the bureau allegedly chose an inauspicious date for the funeral of an emperor's favorite son.[28]

Career Patterns in the Ming Astronomical Bureau

The first Ming emperor's 1373 regulations for the Astro-calendric bureau specifically excluded the descendants of bureau personnel from other positions in the government. Although this interdiction was lifted in 1458, the long-term effects of this policy lingered on. A career there was therefore likely a dead end. Given the politically sensitive nature of the bureau's work, moreover, it was in the interests of the imperial court and the top levels of the bureaucracy to confine astronomical and astrological expertise to the bureau.

To make such positions more attractive, the bureau granted its personnel special privileges, in addition to allowing the descendants of calendrical officials to serve in other bureaucratic appointments. Like regular officials they were exempted from corvée duties, and likewise they faced a reduced scale of punishments when involved in civil litigation. These privileges, however, were granted to all civil examination licentiates—some 500,000 by 1600—and were not comparable to the benefits and prestige accorded the highest degree holders who passed the triennial metropolitan and palace examinations in the capital.

With less career mobility, fewer degree-holders among their midst, and less governmental prestige when compared even to physicians in the Imperial Academy of Medicine, the staff of the bureau, like doctors, were at best middle-level personnel in a system that guaranteed the dominance of those proficient in classical learning. Directors of the Five Offices in the bureau typically served ten to fifteen years. They usually spent ten years first as students or yin-yang specialists.[29]

Outsiders were sometimes brought in to supervise the bureau, particularly in periods of badly needed reform. In such times, the Astro-calendric bureau became a venue for struggles over the mathematical astronomy that that spilled over into the court. Below we will see that the Astro-calendric bureau was penetrated by Jesuits beginning in the late Ming. Like Indians under the Tang and Muslims under the Yuan, the Catholic Jesuits correctly perceived mathematical astronomy as a convenient means to influence the imperial court and the emperor. The Jesuits, unlike their Indian and Muslim precursors, eventually gained control of the bureau during the Qing and were not easily relegated to an auxiliary role.

Evolution of the Late Ming Calendar Crisis

As early as 1525 officials recognized that the Ming calendar and the Astro-calendric Bureau were failing, but the prescribed remedy, as in the past, was a call for new personnel and for better management of the bureau's offices. The reform of the calendrical system itself was not yet considered necessary. Moreover, the bureau, because of the low prestige of its middle level personnel, was not in a strategic position to impact calendrical debate in the court. Additionally, Ming mathematics, in general, was linked more to commerce, such as wide use of the abacus, than to further development of its rich crafts of algebra based on calculation techniques such as counting rods, which had peaked during the Song-Yuan period and which the abacus did not support.[30]

Calendar reform, that is, the replacement of the computational system, remained an imperial prerogative only insofar as it received criticisms and recommendations from outside the bureau. Until officials associated with the Jesuits appealed to the emperor and his court for a substantial reform of the Grand Concordance astronomy system in the 1630s, the government was content to rely on special supervising officials or to recruit new talent for the bureau. This policy, however, opened the door for the Ming and Qing dynasties to accept Jesuits as calendrical experts, just as Tang and Yuan rulers had accepted Indians and Muslim specialists.[31]

The usual pattern was for an official to send a proposal for calendar reform in a memorial to the emperor, which the Ministry of Rites would adjudicate as the chief supervising agency of the Astro-calendric bureau. In theory, if the proposal had merit, then an official trial to compare the new proposal with the old methods would be scheduled. Often, however, the results of a debate over a new proposal were never clear-cut enough to justify a trial run. In other words, bureaucratic inertia prevailed because the Yuan-Ming calendar had achieved unprecedented success, unlike in earlier dynasties where numerous reforms had been required.

In 1481 the Ming court received a peculiar recommendation by Yu Zhengji, an instructor in a dynastic school, to scrap all the calendrical systems since the Han dynasty and return to the ancient nineteen-year Rule Cycle. Han dynasty astronomers had thought that at the beginning of the world cycle there had been a general conjunction of planets and that at the end of that cycle this would recur. From this fixed point in a cyclical cosmos, future reckoning of seasonal solstices or lunar-solar conjunctions and eclipses could begin. Han astronomers also thought that every 138,240 years all the planets would repeat their motions. This cycle was combined with another cycle to yield a Great Polarity Superior Epoch of 23,639,040 years.[32]

Nathan Sivin has described the Rule Cycle of 6939¾ days, adopted at the end of 105 B.C., which had been used for intercalation before the Grand Inception reform. This cycle was based on 235 lunations of 29.53085 days, which roughly equaled 19 solar years of 365¼ days. Because this Rule applied ancient values for the year and lunations, its lack of rigor perpetuated obsolete solar year and lunation values, and thus necessitated continual calendar reform.

Since nineteen lunar years of twelve months comprised only 228 lunations, the Rule Cycle required adding seven intercalary months every nineteen years to equal the 235 months in nineteen solar years. Nineteen years was the smallest interval in which the winter solstice and new moon (or any other combination of solar and lunar events) would recur on the same day (although not at the same hour). A cycle of intercalations that repeated after as few years as possible would minimize cumulative errors. After nineteen years, the errors of adding an intercalary month seven times at an interval of approximately once every 2.71 years would cancel out because the number of months and years that had passed were both integral.[33]

Yu Zhengji's claim that the placement of the intercalary months in the Ming calendar was incorrect was taken seriously, even though his views would have ended eclipse predictions. The proposal was debated but not accepted. This bit of arcane literati fundamentalism concerning the calendar may have been a caricature of Ming efforts to return to antiquity, but the nineteen-year cycle, which China had abandoned, was still important in early modern Europe as a calendrical tradition before the 1582 Gregorian reform.[34]

The Metonic Cycle

The Metonic cycle of nineteen years had been used in ancient Greece and Babylon to correlate the periods of the sun and moon for calendrical purposes. Meton had discovered circa 432 B.C. that nineteen solar years contained 235 lunations. On that basis he also computed the length of solar year as 365¼ days. The Metonic cycle accepted 6,940 days or 235 synodic months between observed new moons over nineteen solar years. Because nineteen years of 12 lunar months equaled a total of only 228 months, the Metonic cycle also required an intercalation of 7 months in the cycle, the same as the Rule cycle in the Han calendar that Yu Zhengji wished the Ming to reauthorize.[35]

The problems that both ancient Chinese and European calendrical scholars faced were the incommensurable periodicities of the sun and moon. One mean tropical year equaled 365.2422 mean solar days, which matched the average period of changing seasons in the solar year. On the other hand, one mean synodic month equaled 29.53059 mean solar days.[36] Neither the mean tropical year nor one synodic month was an integral number of days, however, and thus neither could provide exactitude in the calendar. The incommensurability of the two figures meant that the tropical year did not contain an integral number of months but, rather, an average of 365.2422 days that when divided by 29.53059 days in a month equaled 12.368266 lunar months in a solar year. This discrepancy was the raison d'être for intercalary months in both China and the ancient world.[37]

Discrepancies in Easter computations continued in Eastern and Western Christendom until Victorius discovered the first true Easter cycle, known as the 532-year Paschal cycle of twenty-eight Metonic cycles (28 × 19). In A.D. 457, Victorius used Alexandrian computations based on the nineteen-year cycle to improve on past calculations and accepted March 21 as the date for the vernal equinox. In the process, he discovered that Easter dates began to repeat themselves every 532 years. Armed with this Paschal cycle, Victorius successfully dated all 430 Easters (based on Jesus' death and resurrection) up to 457 and then for 102 years into the future, although opposition kept the solution from being immediately implemented in the Latin world.[38]

The Paschal cycle remained important in early modern Europe before and after the 1582 Gregorian reform. The French Jesuits Joseph de Prémare (1666–1736) and Joachim Bouvet (1656–1730), who arrived in China in the late seventeenth century, believed for example that the Paschal eclipse, which occurred upon the death of Christ, had been a supernatural event that was allegedly recorded in Chinese records. This claim was quickly challenged by other Jesuits, such as Antoine Gaubil (1689–1759), who accepted the independent integrity of Chinese records. Similarly, the systematic identification of Biblical and Chinese personages was common among the Jesuits and their converts. Some maintained that Chinese observational records came from Jewish patriarchs before the great deluge.[39]

Such calendrical claims reveal the European chronographic mind-set then in place when the Jesuits competed with Han Chinese and Muslims for control of the Astro-calendric Bureau in the early seventeenth century. Moreover, the nineteen-year Metonic cycle slipped by one day in roughly 308 years because its 235 calendar months were slightly longer than nineteen solar years. The pre-Gregorian calendar in Europe had not surmounted this limitation and was now ten days ahead, while the Chinese had stopped depending on the Rule Cycle shortly after the fall of the Han in A.D. 220.

The Ming calendar employed a more sophisticated approach since the Han and was significantly more accurate. The astronomical systems established by the Han, Tang, and Song dynasties all followed the precedent of the Triple Concordance system of 104 B.C. The Triple Concordance system adopted a day divisor of 81, which amounted to setting the length of a lunar month as 29.53086 days, and counted accumulated days from an epoch 143,727 years in the past. It was inevitable that the small discrepancy in the constant of

29.53086 minus the modern value of 29.53059 days, which equaled an error of only one day per 310 years, would accumulate over such a great span of time so as to become appreciable.

The Yuan dynasty calendar treatise completed in 1280 by Guo Shoujing (1231–1316) improved upon the Triple Concordance system and its successors to give more precise measurements of the length of a solar year. The Mongol system adopted precise decimal constants and counted from a recent solstice rather than an ancient epoch.

Ming Recognition of a Calendar Crisis

Criticisms of the Ming calendar occurred within a climate of rising expectations of accuracy. In 1483, discrepancies in the calendar were attributed to the difference in location between the bureau's observations in Nanjing, where the instrumentation to measure celestial phenomena had originally been designed, and Beijing. In a pre-Jesuit environment, such discrepancies were usually within the margins of permissible error. Hence, errors in computation were rationalized because the bureau's predictions were still sufficiently accurate.

No consensus was yet possible about the urgency of the problem. For instance, in 1498 a secretary in the auxiliary Astro-calendric bureau in Nanjing called for selection of a high-level minister to study why failures in lunar eclipse prediction had increased. The appointment of a plenipotentiary to recruit talented scholars to produce a new calendric system would have been a major undertaking, however. The emperor followed instead the advice of the Ministry of Rites that the request was impractical.

After a series of inaccurate eclipse predictions in 1517–1518, Zhu Yu, a timekeeping official in the Beijing bureau, contended that the secular difference in the annual difference introduced by the Yuan calendar to deal with the drift forward of the calendar was the root of the problem with eclipse predictions. Because of this discrepancy, the bureau had been over-predicting solar eclipses less often but under-predicting them more often, an ominous sign for the dynasty. The debate over this proposal was argued in terms of the distinction between new methods (*xinfa*) and old methods (*gufa*).[40]

When Zhu Yu's own prediction of a lunar eclipse turned out no better, however, Zhou Lian, another official in the bureau, convinced the court that continued readjustments in computations would suffice. Despite the problems in the Grand Concordance astronomy system, no consensus emerged that new and more accurate observations were needed to compose a new system. The focus was still on trial and error adjustments of the old and new regimes for calculation. The introduction of a Western calendar by the Jesuits in the 1620s was perceived in light of these Ming categories of old and new methods.[41]

When a new emperor took the throne in 1521, Zhu Yu, still a timekeeping official, called for new instrumentation because accurate measurements were no longer possible using the observational instruments in Beijing. Zhu called on the emperor to construct a new bronze gnomon, which was needed in Beijing to adjust for its latitude. Later in 1523 an outside overseer of the bureau, Hua Xiang, proposed that officials be dispatched to Henan province to study the giant masonry gnomon erected there for the Yuan calendar. This proposal prioritized improving instrumentation for constructing a new computational system. Hua was stalemated at once, however, by another supervisory official, who contended that the Grand Concordance astronomy system should not be changed. Both the court and Ministry of Rites waffled.[42]

The prestigious legacy of the Yuan calendar promulgated in 1281 was part of the problem. Its very success for three centuries, coming after some twenty deficient calendars launched during the Song dynasties, was a policy obstacle that reformers would have to hurdle. Ming adoption of a reformed Yuan calendar created an institutional constituency in the bureau bound to oppose any major reform on the grounds that the system in place was reliable. In effect, the institutional status of the Ming calendar limited debates over its future reform.

Although no major changes in the calendar occurred, the issue was serious enough to be taken up in civil service policy questions of the time. For example, civil examiners raised the reform of the calendar for approximately three thousand candidates taking the 1525 provincial examination in Jiangxi. In one of the policy questions, the examiners asked the candidates to think over the history of the official Ming calendar and discuss its accuracy. In this way, the examiners ingeniously solicited literati opinion about the official calendar.[43]

To answer these specific questions, the candidates needed to comprehend both mathematical astronomy and its history, which was available to candidates in the Jin and Yuan Dynastic Histories and statecraft-oriented encyclopedias. The Yuan calendar developed between 1274 and 1280 gave more precise measurements of the length of a tropical year as 365.2425 days (compared to the modern value of 365.2422 mean solar days). Without the earlier sources of error, a major revision of the Ming system was unnecessary until the sixteenth century.[44]

The 1525 policy question dealt with proposals to alter the Yuan-Ming system because, like its predecessors, it was bound eventually to show accreted errors. The examiners raised the perennial issue of calendrical calculations in the Astro-calendric Bureau, namely the tension between prediction based on continual observation and extrapolation to adjust computational procedures on one hand, and, on the other, forecasts derived from rigorous determinate mathematical techniques that did not require continual infusions of new data. The examiners had opened the door to calendar reform through an official avenue for submitting opinions to the throne. It was also a time when an embattled emperor and his entourage of powerful eunuchs in the imperial household were increasingly faced with aroused literati factions inside and outside the court.[45]

The published answer to the question by one of the highest-ranked examinees focused on the chief theoretical question: "Creating an astronomical system is a matter of conforming celestial phenomena [lit., "the sky"] to find what [techniques] accord with them, and not forcing accord, so that predictions can be validated [by phenomena]." This led him naturally to his answer. "The orbits in the sky are not uniform, but astronomy [between Han and Song] was restricted to set methods, because they were not aware of 'conforming to the heavens to find what accords with it.'"[46]

Although the Yuan system was the first to master it, a succession of astronomers had worked out simple empirical corrections that minimized precessional error. The candidate listed them and accurately summarized the techniques used by each. It took considerable understanding to see that these earlier adjustments had anticipated the annual difference. The candidate had obviously digested the account in the *Yuan History* of the Season Granting system's predecessors.[47]

Writing fifty years before the arrival of the Jesuits, the candidate recommended reviving the instruments used in the Yuan reforms of 1280. His appeal to Yuan instrumentation as a corrective measure suggests that the 1525 policy question was meant to draw responses about what to do with the Ming calendar. Accordingly, the candidate argued that the dynasty should rely on instruments to reform the calendar. Rather than technical manuals, which were unavailable, the candidate cited dynastic histories as his sources of information.[48]

In addition to this official airing of the 1521–1523 debate about the problems with the Ming calendar, private scholars—many also involved in the partisan politics that became routine in late Ming governance—also voiced their opinions about the discrepancies between the calendar and celestial events. The scholar-official Tang Shunzhi, for instance, had come to prominence when he finished first on the 1529 metropolitan examination. After a turbulent political career in which he was banished twice, Tang explored his literary and statecraft interests during his forced absences from politics. Generally regarded as one of the leading scholars of mathematics in his time, his studies also encompassed Islamic traditions in astronomy.[49]

Seeking a resolution between a fixed versus a flexible system to resolve calendrical problems, Tang assessed the Yuan-Ming calendrical system in light of what he called "concrete studies" (*shixue*). Such critical assessments of the calendar, according to Tang, had lost their vitality during the Ming. Hoping to broaden literati education to include technical learning, Tang Shunzhi also sought to reintegrate mathematics and mathematical astronomy. According to Tang, calculations based on the relational features for the sides of a right triangle (*gougu*), had been separated during the Ming from the underlying principles of mathematical astronomy. Tang wrote:

> One must know both mathematical and astronomical principles. This is where I differ from literati students [today]. One must know both fixed calculations and variable calculations. This is where I differ from officials in charge of the calendar. Principles and computations are not separate things. Computations represent the concrete applications and extensions of principles. Variable and fixed calculations are not separate things [either]. Fixed computations represent the basis for variable calculations.[50]

Tang Shunzhi stressed the "six arts" (*liuyi*) of antiquity as the model for reintegrating calendrical theory with concrete computations. He then blamed the Ming lack of integration on its literati, who had denigrated the study of numbers as a "lesser technique" not worthy of their attention, thus leaving the calendar for the mediocre staff of the Astro-calendric Bureau to compute. Tang's call for a return to the more comprehensive vision of antiquity, in which the mathematical arts held a prominent place, represented a precocious effort to recapture classical antiquity in its full technical complexity.

Usually we attribute this positive perspective of mathematics to Qing dynasty literati and their response to the introduction of Western learning in the early eighteenth century, when they called for rediscovering the Chinese origins of Western learning (*Xixue Zhongyuan*). Efforts to recover antiquity during the late Ming, however, had already carried over from astronomy to mathematics before the Jesuits arrived in south China. Tang Shunzhi used traditional crafts of early trigonometry to solve simultaneous algebraic equations in mathematical astronomy.[51]

The straw that broke the camel's back came in 1592 when the Ministry of Rites charged that the Astro-calendric Bureau had erred by a full day when predicting a lunar eclipse, which meant that the Relief Ceremony had to be rescheduled. An error of a full day also affected ceremonies tied to the first day of the month, season, and the new year. In 1595, a Ming prince with exceptional mathematical talent, Zhu Zaiyu (1536–1611), proposed a new calendar, which he called the "Ten Thousand Year System for Sagely Longevity."

Zhu tried to combine the Yuan and Ming calendar systems, but because his synthesis was not based on new observations, it failed to make the prediction of eclipses any more precise at a time when accuracy was expected within one mark (= 14 minutes).[52]

The Ministry of Rites, however, never tested Zhu's proposal. Zhu was later listed in the official *Ming History* as a meritorious proponent of reform who was unjustly ignored. His biographers were Qing scholars who had the advantage of hindsight. In 1596, Wang Honghui (1542–1601?) broached with Matteo Ricci the possibility that Ricci might contribute to the reform discussions. In 1597 the scholar-official Xing Yunlu (1573–1620), who had written a work comparing ancient and recent calendars, claimed that the procedures employed in the Ming calendar to determine the winter solstice were in error by one day, thus extending the error to encompass a full season. The director of the bureau dismissed its critics, however, and defended the calendar as a stable institution that should not be recklessly changed.[53]

Gregorian Reform

The European calendar aimed at simplicity and convenience for dating civil and religious events. This was essential if hundreds of sovereign states were to accept it. To this end the Gregorian calendar reform followed the Julian, which had come roughly 1,500 years earlier, in reducing the amount of observation and computation and provided an artificial system independent of astronomical tables or observations of celestial phenomena. But, as in the time of Julius Caesar, localities continued to use incompatible lunisolar calendars, some long after the Gregorian reform. Because of its focus on physical anomalies, the Ming calendar was always linked to observable celestial phenomena such as solar eclipses. The Astro-calendric Bureau recorded celestial phenomena so that the government could deal with the ominous ones and take credit for the propitious ones.[54]

Pre-Gregorian Efforts at Calendrical Reform

For both Catholics and Protestants after the Reformation, the death and resurrection of Jesus were the most important events in a linear history. Even so, there was no agreement when the year began. Some reckoned it from Christmas Day. In the civil calendar it was January 1. Another system had it in March, the time of the vernal equinox, as in pre-Julian and some old Germanic calendars. England used March 25 for the feast of the Annunciation and the old Roman vernal equinox as New Year's Day, until it accepted the Gregorian calendar in 1752.[55]

Victorius' 532-year Paschal cycle was successful because it was a self-repeating Easter cycle since God's creation of the world, but its computational procedures required technical improvements. When compared to the Julian calendar of 365¼ days (19 inaccurate Julian years = 6,939 days, 18 hours), the Metonic ratio of 19-year cycles of 235 calendar months (= 6,939 days, 16 hours, 31 minutes, 14 seconds) was too short by 1 hour and 29 minutes. Consequently, the lunar cycle allowed calendrical slips back of one full day in roughly 308 years, which necessitated a lunar correction.[56]

The length of the tropical year was computed as 365.2423154 days at the beginning of the Christian era, compared to the Chinese value of 365.2425 and the modern value of 365.2422. The date assigned to the vernal equinox was problematical. By the year 1000, the Julian calendar (one year = 365.25 days) had drifted ahead of the tropical year, which meant that the calendar was drifting forward one extra day in a little over 130.1 years. This discrepancy required a solar correction. In 1500, the drift was one day in 128.6 years.[57]

Between the time of Julius Caesar and Pope Gregory, the precession of the equinoxes had shifted by roughly fifteen days—a figure that made the Ming Chinese problems negligible by comparison. Paul of Middleburg had asked Copernicus to advise the Fifth Lateran Council in 1512 on proposed calendar reforms. Although Clavius had reservations about Copernicus's heliocentric cosmology, he recognized him as an authority on astronomical measurements and used his data in the Gregorian reforms. The Gregorian commission heeded the Prutenic tables of Erasmus Reinhold (1511–1553), which were a revised and expanded version of the tables from Copernicus's *On the Revolution of the Heavenly Spheres,* published in 1543. Copernicus's astronomical reforms were intended to provide an accurate prediction of the correct dates for Easter and Christmas, not just a delineation of space but also a demarcation of time.[58]

The Council of Trent met in 1562–1563 and authorized the pope to deal with calendar reform at a time when the calendar date for the vernal equinox had receded to March 11. Petrus Pitatus (Verona, 1564, written 1539) advocated that at least fourteen days should be dropped from the solar calendar to bring it back to that of Julius Caesar when the vernal equinox was March 25. Curiously, Martin Luther preferred Easter as a fixed day rather than a movable feast and thought that calendars were irrelevant to faith and only reflected worldly authority. The Gregorian reform of 1582 managed to overcome these divergent views because of its elegant simplicity, which contrasted with the contemporary paralysis in the Ming court concerning elaborate calendar proposals.[59]

The Gregorian Calendar and Its Reception

After serving at the Council of Trent, Gregory XIII quickly nominated a commission when he became pope in 1572, which met for ten years until 1582 and reviewed various proposals for calendar reform. Alosius Lilius, a lecturer in medicine at the University of Perugia, presented an ingenious plan to restore the date of March 21st for the vernal equinox through a ten-day displacement. Once Lilius's proposal was accepted by the commission in 1577, Gregory authorized preparation of a *Compendium* based on Lilius' original, which was circulated for review. When these outside views were received and evaluated, Clavius attended to a residual error of one more day in 308 years. Gregory then introduced the new calendar via an apostolic letter in February 1582. It was written in the form of a papal bull and represented ecclesiastical law.[60]

The final rules for intercalation in the Gregorian calendar were as follows:

1. A common year contained 365 days, a leap year 366, the extra day being added to the end of February.
2. Every year of the Christian Era after 1582 that is evenly divisible by 4 is a leap year,
3. Except for centennial years, which are leap years only if evenly divisible by 400 (to repair the solar cycle).[61]

In this manner, 1600 and 2000 were designated as leap years, but 1700, 1800, and 1900 were not. The Gregorian result was ninety-seven additional days in four hundred years, or three days less than the Julian calendar, which intercalated every four years without exception, i.e., one hundred days in four hundred years. One day in the lunar cycle was omitted every 312.5 years.

Calendar reform was easily accomplished in Catholic Italy, Spain, and Portugal, but it became a bone of contention in the Protestant world because the papacy presented the reform as an act of the Catholic renewal to challenge the Reformation. The Eastern Patriarch in Orthodox lands was cautious, but Rome's unilateral declaration made it impossible for him to accept. In the sixteenth century, church and state in Europe were so interwoven that civil acceptance of the new calendar was determined by the religious affiliation of respective rulers. Criticism of the Gregorian calendar was colored by different religious and intellectual positions.[62]

In this light, Protestant Germany saw the pope as an Antichrist for instituting the calendar. Others contended that Gregory had stolen ten days from a farmer's life. Protestant sovereigns did not relent until Protestant astronomers increasingly supported it. In 1724 and 1744, the celebrations for

Easter in Protestant countries were one week earlier than for Catholic celebrations. In 1775, Germany finally adopted the Gregorian calendar by the decree of the German Emperor and King of Prussia, Frederick II.[63]

In England, secular authorities were sympathetic with the Gregorian reform, but the Anglican clergy was not. The latter insisted on consultations regarding the pope's unilateral promulgation of the new calendar, and this procedural obstacle doomed the reform in England. Scotland accepted the new calendar from 1600. When England finally passed an Act of Parliament in 1752 to enact the calendar by omitting eleven days, the Anglican clergy's hatred of Rome was no longer an obstacle.[64]

The mathematical scheme used in the Gregorian reform was prudent because it was independent of physical hypotheses and emphasized instead computational mechanisms to produce the calendar. The new calendar served mainly as a puzzle solver, that is, a set of computational practices that were increasingly rule-like regardless of the nature of the cosmos. In this sense, the Gregorian reforms marked a climax of the Medieval Computus, which survived the Copernican revolution as a calendrical tool kit.[65]

The Impact of Clavius on Jesuits in China

When the Gregorian calendar reform began in 1572, Clavius was still an isolated mathematical scholar in his Roman college. By its end he was a leading mathematical astronomer. Clavius prepared a series of mathematical textbooks at the Collegio Romano, beginning with his edition of Euclid's *Elements of Geometry,* which included a voluminous collection of notes and commentaries. Matteo Ricci would later use this edition for the classical Chinese translation of Euclid that he helped to prepare in Ming China. Knowledge of geometry, especially the first four or six books of Euclid, became particularly important in sixteenth-century Europe for engineers, cartographers, architects, land surveyors, and painters, while in the late fifteenth century expertise in geometry was increasingly valued for fortifications and ballistics.[66]

Clavius also planned to prepare a work on theoretical astronomy that would revise the planetary system and provide an alternative to Copernicus's heliocentrism. He never completed that work. In his own work, Clavius still accommodated observational tables from Copernicus's work within a geocentric cosmology. Clavius's personal opposition to astrology was strengthened by the Collegio Romano's placement of mathematical astronomy separately in the faculty of arts and medicine, where astrology was also important. The tension between astronomy and astrology among Jesuits would later affect their role in the Qing Astro-calendric Bureau, where astrological interpretation based on portents remained important.[67]

We return below to the calendrical crisis in late Ming China, where the puzzle-solving mechanisms for maintaining an accurate calendar had unraveled. The Chinese calendar had since the Han dynasties been reformed through computational means, as in Europe, and, like European calendrical specialists, the staff of the Astro-calendric Bureau did not require allegiance to any particular view of the cosmos to employ their tool kit of computational puzzle solvers.[68]

Ricci and his immediate successors in China drew on the Ptolemaic geocentric framework, which had been questioned but reaffirmed by Clavius and the Gregorian reform commission. Later, after Ricci's death in 1610 and Clavius's death in 1612, Johann Adam Schall von Bell (1592–1666) and Ferdinand Verbiest (1623–1688) were increasingly influenced by Tycho Brahe's new findings, which helped them gainsay in Europe, and elide in China, the heliocentric cosmology of the Copernicans in favor of geoheliocentricity.[69] Jesuits in China quickly adapted their religious goals to the late Ming local context and accommodated their order, with some dissent, to the inescapable priorities of the Chinese imperial system, its cultural elites, and the astrological applications of the calendar to portents and hemerology (the art of determining auspicious days).[70]

Jesuits and Late Ming Calendar Reform

The Jesuits entered China during a time of heated debate and discussion about the calendar in the late Ming. Literati inside and outside the government had noted the drift forward of the Chinese date for the lunar new year by one day since the Yuan dynasty, but the Astro-calendric Bureau had not yet provided a solution. Despite some superficial similarities, the situation in which the Jesuits would find themselves in seventeenth-century China was not really comparable to Clavius's role in Rome in the 1570s. The Gregorian calendar was formulated by a Papal commission and not a sovereign state. Although there were parallels between the Papal Curia and the Ming imperial court, the former was in scope and magnitude a minor political authority, while the latter was not a religious organization. Nor was the Astro-calendric Bureau the haven for religious debates.

Moreover, the Christian concern was to date Easter accurately in light of God's creation and Jesus' resurrection as linear events. For the Ming, however, the concern was not with linear time, which since antiquity had not been stressed. Rather, the Chinese calendricists were concerned with recurring events within a cosmology that had no beginning or end. To domesticate time meant to predict the periodicity of repeating celestial events and not to date them accurately from creation.

The key issue for the Astro-calendric Bureau was to predict anomalous events, such as solar and lunar eclipses, whose periodicity affirmed an orderly political reign by a legitimate ruler. The auspiciousness or inauspiciousness of the present depended on its interpretive place in a cyclical calendar. Different versions of time were at stake in the interaction between the Jesuits in China, who had experienced the Gregorian reforms in Europe, and Chinese literati and dynastic rulers, who believed in cosmically recurring events in time.

The Calendar and Time

Jesuits such as Clavius were insiders in the Gregorian reforms, whereas Jesuit missionaries were always outsiders in Ming China, opposed by native Han Chinese in the Ming bureaucracy and additionally contested by the Muslim calendrical staff in the Astro-calendric Bureau. The social positions of the Jesuits, who first dressed as Buddhists, had to be clarified and heightened before their calendrical proposals would be taken seriously by the Chinese literati, who served the imperial court as government officials and elite partners in local governance.

The Jesuits had to deliver their message to intelligent and cultured elites who could appreciate their spiritual sincerity and technical prowess or would gainsay both as dangerous. Likewise, the Jesuits would have to master via language, dress, and experience the different discourses of political and cultural supremacy that informed the Ming calendar and made even a one-day error in the onset of the seasons, the first day of the month, and New Year's Day a potential calamity. Getting the calendar right in China meant applying a cyclical blueprint to grasp recurring events.[71]

Nevertheless, the Ming bureau and the Christian Computus still shared, functionally and historically, a nexus of social, political, cultural, and religious elements that informed the calendar. Although such elements were divided up differently and integrated uniquely in Europe and China, Clavius's followers and the later students of Brahe and Kepler could understand why an accurate and up-to-date calendar mattered to the Ming and Qing state. More importantly, Ricci, Schall, and Verbiest understood the important role the new Christian calendar played in unifying the faith in early modern Europe.[72]

The calendar crisis was not merely an opportunity for the Jesuits in China to influence literati and an emperor enshrouded by a sophisticated bureaucracy. The crisis also allowed them access to the technical fundaments of the Chinese chronological construction of cyclical time, its conceptual limits, historical interpretation, and technical determination, which were woven into the ideological fabric of the imperial dynasty. Lurking in Jesuit efforts to promulgate a new calendar for China, constructed "in accordance with new Western methods," for example, was an effort to Christianize creationless imperial time.

For instance, Jesuits claimed, based on the biblical chronicles after the Great Deluge, that the Chinese were descendants of Noah. Chinese critics saw this as an assault on the integrity of their classical antiquity. Chinese and Manchu political power stood in the way of and transmuted the Christian agenda, triumphant in the New World and for a short time in parts of Japan, into more muted forms of technical improvement in the Chinese calendar based on Chinese time. The Jesuits had to preserve the Chinese time-measurement system and the basic structure of the cyclical imperial calendar. From the Ming point of view, what needed improvement were the technical aspects of the calendar, such as the tables used in calculation. Which world system was used for cosmological prolegomena mattered neither to the non-Christian Chinese nor the anti-Copernican Jesuits, many of whom were open to change in cosmology but all of whom were prevented from teaching it.[73]

The Jesuit Novitiate and Mathematics

The Jesuit era in China coincided with the Thirty Years War that overwhelmed Catholics and Protestants in bloody conflicts from northern to central Europe. European wars took precedence over concern with non-European matters. Similarly, England was beset with social and religious battles and civil wars that led to the execution of the king in 1649. Until the Glorious Revolution four decades later, England was not a factor in Asian affairs.

The Portuguese support of the Jesuits in China, Japan, and India, and the Spanish sponsorship of the Dominican, Franciscan, and Augustinian orders in the New World and the Philippines meant that Catholics still monopolized interactions between China and western Europe from the sixteenth to the eighteenth century. Because of growing influence of Jewish converts after the Inquisition, however, the General of the Order in 1593 commanded that the applications of all new Christians should be rejected. Luis de Almeida, for example, was the first Jesuit to introduce European medicine to Japan circa 1583, but because he descended from an old Portuguese Jewish family, his reputation for this was effaced in the seventeenth century.[74]

By 1600 the Jesuit order included 8,272 members and operated 236 colleges in southern Europe and Germany, in addition to those in Spanish and Portuguese colonies. The order's growth coincided with the unification of the Spanish and Portuguese thrones from 1580 until 1640. Over fifteen thousand members in 1626 had been trained in 444 Jesuit colleges and 100 seminaries. Within a century of its founding in 1540, the Society of Jesus controlled more than 700 educational institutions and held a virtual monopoly over chairs of the arts faculties at almost every Catholic university.

While preparing to become upholders of the Church, Jesuits such as Matteo Ricci became novices for two years, which was twice as long as any other religious order. Novices were introduced to the society's rules and discipline, and they were tested for their fitness for the Jesuit way of life. For those who entered the priesthood, many but not all had several more years of academic training in grammar, dialectics, and rhetoric, typically at one of the society's several colleges, such as the Collegio Romano. Upon completion of their philosophical and theological studies, the candidates were ordained as priests but had to finish a third year of the novitiate before they were admitted into the society.

Initially the Collegio Romano was the center of the Jesuit educational system, and its evolution influenced the development of a uniform educational curriculum, the *Ratio Studiorum,* throughout other Jesuit colleges in Europe. For the study of mathematics, it was extremely important that the formation of a Jesuit mathematical program had been organized by Clavius at the Collegio Romano, which increasingly took shape during and after the Gregorian reforms in Rome. The focus on Euclid's *Elements of Geometry*, for instance, represented Clavius's imprint on Jesuit mathematical training. Clavius had a following in the 1570s, and Matteo Ricci studied mathematics at the Collegio Romano from 1573 to 1577.[75]

Clavius's role in the promulgation of the Collegio Romano's *Ratio Studiorum* in 1586 was pivotal in the important role of mathematics in Jesuit pedagogy. Among the Jesuits sent to China at this time, besides Ricci, Giulio Aleni (1582–1649) studied under Clavius, as did the physician Johann Schreck (Terrenz, 1576–1630) and Giacomo Rho (1592–1638). Terrenz also befriended Galileo when both studied at Padua. Schall came to Rome in 1608, when Clavius was probably too old to teach, but he also belonged to the Collegio Romano's Academy of Mathematics. Verbiest's formal Jesuit studies at the Jesuit college in Leuven, Belgium, included training in medicine, mathematics, and astronomy. Later, Verbiest also studied at the Collegio Romano and the Jesuit college in Seville.[76]

The largest number of Jesuits sent to China were trained in the first tier of Portuguese colleges at Coimbra and Évora. Moreover, the majority of Jesuits who went to China were Portuguese, although they have not received the attention they have deserved until the recent study by Liam Brockey. Most were in their late twenties or early thirties when they reached China, and who had by then spent some fifteen years in Jesuit schools as students or teachers prior to their departure. The majority were involved in the religious conversion of commoners after their arrival, and they benefited from the local toleration they gained when Italians such as Ricci and Germans such as Schall worked among Han Chinese elites and for the imperial court.

Emphasizing grammar and rhetoric, philosophy, and theology, the education promulgated at Coimbra and Évora was based on the *Ratio Studiorum*. The curriculum, although not always strictly followed, included Greek and Hebrew and was intended to provide intellectual training and teaching experience for those assigned at home or sent abroad. Philosophy courses were spread over three years and included logic, ethics, physics, and mathematics (which included astronomy).

Much of the latter was drawn from Greek natural philosophy, particularly the writings of Aristotle (384–322 B.C.) and Euclid (ca. 325–265 B.C.). Scholastic theology courses usually took four years. Often, however, earlier students completed or abridged training after receiving permission to sail to China. Ricci received only two years of training in theology before departing Portugal, for example. Giulio Aleni, on the other hand, taught mathematics for two years before arriving in China in 1610.[77]

The ideology of the Jesuits drew from Ignatius's vision of an elite corps dedicated to reforming the Church and protecting Catholic lands from the Reformation. It required a long and exacting internalization of the values and ideals of the society. Full members completed the probationary period and were accepted into the society. They were divided into three groups: temporal coadjutors who were lay brothers and served as cooks, secretaries, and apothecaries, etc.; spiritual co-adjutors; and those who professed the fourth vow, that is, in addition to the three traditional vows of poverty, obedience, and chastity, they also professed obedience to the pope. The last two groups were ordained priests and received advanced training in theology. Only the professed could attend the society's General Congregation or be sent on a mission.

Ruled from Rome by its superior general, the Jesuit order penetrated the Old and New Worlds through a residence system, which was the basic unit of organization and daily life for its members. In the Beijing and Hangzhou residences, for example, novices received their training from the Jesuits who lived there. Language learning took place in the residences. In Beijing, the residence also served as the venue for a sophisticated translation project that included the fathers and their converts. The "multi-functional, military-like organization" of the Jesuit residences was flexible enough to take on secular tasks, such as the translation of European mathematical astronomy into classical Chinese.[78]

Outside of Europe, a provincial head led the order. Jesuit unity of purpose was generally achieved through a detailed protocol of written communication between the residences in each province and between provinces. Disagreements among the Jesuits over their engagement in mathematical studies, however, affected this unity. In 1615, for example, the order's provincial head for Japan and China, Valentim Carvalho, sent a mandate to Macao reversing Ricci's policy in China and prohibited the teaching of mathematics and *scientia* by the Jesuits. The mandate was later withdrawn, but it shows how Jesuit unity could be complicated by differences of opinion.

When the Augustinian, Dominican, and Franciscan orders openly opposed the Jesuits in China and elsewhere, the venue for adjudicating such disagreements shifted to the pope in Rome. Similarly, to get around papal control, which was tied to the Portuguese monopoly of Jesuit missions in Asia since 1493, Louis XIV (1643–1715) sent five French Jesuits to China in 1685 as the "King's Mathematicians." The Missions Étrangères de Paris, a congregation of secular priests, who missionized as part of the Rome-based Congregation Propaganda Fide, had since the late seventeenth century challenged Portugal and the Jesuits by establishing a clerical hierarchy in China independent of Portugal. Louis XIV's representatives also refused to take oaths that would have subjugated them to the bishops in Southeast Asia and China.[79]

As a religious order, Jesuits lived and worked as missionaries for the salvation of their neighbors. Ignatius had not intended them to live a cloistered life. Thus, they were experienced and tested before being admitted to the society. Their elevated status in the Church was also based on a dedication to learning, which was combined with worldly involvement. Jesuits participated in the intellectual changes that informed the Society's textbooks and commentaries. They also defined the religious boundaries of orthodox Catholic natural philosophy, which climaxed during the debates over the heliocentric world system developed by Copernicus and championed by Galileo.[80]

Like other Jesuits sent to China, Matteo Ricci, once he had completed his training at Coimbra in 1577–1578, embodied the intellectual affinity between Jesuit religious values and Aristotelian natural studies and philosophy. His expertise in mathematics and *scientia,* drawn in part from study under Clavius, served him well in China. After Ricci, a succession of Jesuits with mathematical and astronomical abilities were sent because Valignano honored requests from Ricci in 1605 and other Jesuits in Beijing after Ricci died in 1610 that their mission required clerics with technical expertise in mathematical astronomy. They were needed to aid in the calendar reform projects then underway in the 1620s under Chinese government supervision. In effect, the Jesuits in China now served two masters, the Church and the Ming government.[81]

Translations from Europe and the Beginning of Ming Calendar Reform

In December 1610, the Astro-calendric Bureau predicted a solar eclipse that was challenged in and outside the Bureau. The prediction was two marks late (between fifteen and twenty-nine minutes) according to the observatory chief in the Bureau, or three marks (twenty-nine to forty-three minutes) late according to a high official in the Ministry of War, who had also sent in a report on the eclipse. Diego de Pantoja (1571–1618), in China since 1599, had a made a more accurate prediction, which Chinese associates of the missionaries knew about. The supervising Ministry of Rites called for imperial approval to study calendar reform, but, as before, the Wanli emperor's court did not act on the request. In mid-1611, however, the Ministry of Rites again urged the court to initiate calendrical reforms.[82]

In its report, the ministry this time noted that for the ten eclipses reported during the Wanli reign the error in prediction usually ranged from one to two marks (fourteen to twenty-nine minutes) and rarely exceeded four marks (forty-four to fifty-eight minutes). To keep such errors from getting worse, however, reforms were needed, according to the ministry. Officials should be appointed to compare alternative systems with the Ming calendar, they urged. Moreover, the ministry reported that the Astro-calendric Bureau director, Zhou Ziyu, had recommended translation of some relevant overseas works in the possession of two foreigners from the "Great Western Ocean" (*Da xiyang*): Pantoja and Sabatino de Ursis (1575–1620). The report justified this recommendation by citing a 1382 precedent for translating Muslim works.[83]

Xing Yunlu, who had called for calendar reform in 1597, and Fan Shouji, who had noted that the 1610 eclipse prediction was off by three marks, were recommended for appointments to supervise the reform. In addition, the ministry put forward the names of two officials who also wished to work on the translation of foreign works on astronomy. They were Xu Guangqi (1562–1633), by then serving in the Hanlin Academy after taking his palace degree in 1604, and Li Zhizao, a 1598 palace graduate and the former vice-director in the Nanjing Ministry of Rites, then in mourning for the death of his father.

Both Xu and Li were confidants of the Jesuits and admirers of Matteo Ricci. Xu had been baptized in 1603. Along with Li Zhizao, whom Ricci baptized in 1610, Xu had studied under Ricci continuously from 1604 to 1607. They were first impressed in 1600 with Ricci's revised map of the world and its five continents, completed after his 1582 arrival. It was published in Chinese as the *Complete Map of the Myriad Countries on the Earth* (*Kunyu wanguo quantu*) in 1602 with the help of Li Zhizao.

The group had already completed a number of translations, such as Xu's contributions to the 1607 Chinese version of the first six chapters of Euclid's

Elements of Geometry. Ricci's writings on mathematics and astronomy generally relied on his teacher Clavius's Latin editions. Ricci's translation of cosmology, printed posthumously in 1614, called the *Structure of Heaven and Earth* (*Qiankun tiyi*), was based on Clavius's commentary on the *Tractatus de sphaera* of Sacrobosco (fl. ca. 1232), an elementary textbook that defended the Ptolemaic system. Along with the *Elements,* Sacrobosco's cosmography was taught at the Jesuit colleges in Portugal and elsewhere as an aid to navigation using applied mathematics.[84]

Until the eclipse controversy of 1610, Xu Guangqi had been more interested in the new mathematics, which he linked to traditional "measurements based on the relational features for the sides of a right triangle" (*gougu celiang,* i.e., geometry), for reform of Ming agricultural practices and for water control measures. His translation and publication of the *Western Techniques of Hydraulics* (*Taixi shuifa*) was a case in point. Xu Guangqi and Xiong Mingyu (1579–1649) together worked with Sabatino de Ursis to translate the *Western Techniques* and had it published in 1612 to introduce European principles of water management (*shuili*).

The preface to the translation equated "studies of numerical correspondences between the heavens and earth" (*xiangshu zhi xue*) with studies of the investigation of things and exhaustively mastering principles, an indication of the accommodation between European and Chinese learning that the Jesuits and their converts were seeking in their translations. The *Western Techniques* was later included in Xu's magnum opus, published posthumously as the *Complete Works on Agrarian Management* (*Nongzheng quanshu*), and reveals how early modern European learning was also applied to statecraft issues and traditional agrarian crafts, pharmacopoeia, and horticulture.[85]

Although Xu Guangqi and Li Zhizao were interested in working on the translations for the calendrical reforms, the Wanli court again took no action. Up to 1619, the emperor tolerated calendrical reform proposals but did nothing about them. Rather than entrenched conservatism, it was his inaction that made such proposals moot. The Ministry of Rites, however, had clearly recognized the serious dimensions of the calendar problem. In 1613, Li Zhizao was summoned to Beijing from mourning in Hangzhou to begin work on the reforms, while Zhou Ziyu as director of the bureau ordered revision of Chinese methods used to calculate the calendar and predict eclipses.[86]

Zhou intended to use Western methods to correct the errors in the Grand Concordance astronomy system, but this was not yet done because the Jesuits only had Clavius's original works on astronomy and some minor instruments such as an astrolabe. They needed more technical treatises on mathematical astronomy before they could proceed. Ricci had written a letter on May 12, 1605, requesting that a mathematician, an astronomer, and calendrical treatises be sent to China. Ricci's successor as head of the China mission, Nicolas Longobardo, called on Rome several times to send specialized books and instruments, as well as Jesuits with mathematical training, to further the cause of Christianity in China. In 1612, the Belgian Jesuit Nicholas Trigault (1577–1628) was sent to Rome to report the order's progress in China and to collect as many mathematical and astronomical works for the mission in Beijing as possible.

To gain support from the Ming court and literati for the larger missionary enterprise, Ricci decided to present the Jesuits in China as specialists in mathematical astronomy. After Trigault's return, they mastered how these technical fields had changed and advanced since the Gregorian calendar reform in 1582. Until 1616, no papal fiat prevented them from transmitting more dangerous parts of the new learning, such as Copernicanism, although Copernicus's cosmology was generally neglected. For instance, Longobardo wrote to Rome, "If this plan is successful, two or three missionaries will professedly occupy themselves with these scientific studies, while the rest of the missionaries will calmly and safely attend the Christians in other parts of the kingdom." This plan was worked out in advance with Xu Guangqi and Li Zhizao, then high officials in the Ming government. What Longobardo did not say was that this would mean a significant portion of the Jesuit contingent in China would become subordinates of the Ming and Qing dynasties.[87]

In 1613, Li Zhizao memorialized the throne, itemizing fourteen new features of Western learning when compared to Chinese calendrical procedures. Among these, Li included the mathematical device of deferents and epicycles from Ptolemaic astronomy; the graduation of 360 degrees in a circle rather than the 365 degrees based on the tropical year of the Chinese; and the geometrical representation of celestial phenomena that provided a spatial theory of eclipses. Li also regarded the Western notion of the precession of the equinoxes as novel without seeing its parallel to the annual difference used since the Yuan to adjust for the displacement of the winter solstice. At the same time, Li recommended that the proposed translation project should move forward with the assistance of Pantoja, de Ursis, Longobardo, and Manuel Diaz the younger (1574–1659). Xu Guangqi planned to use European astronomical tables as supplements to the existing ones, just as Arabic tables were used in the past.[88]

After these early translations were authorized, however, the vice-minister of the Ministry of Rites in Nanjing, Shen Que (d. 1624), proscribed the Jesuits in 1616 for establishing illegal residences in China and "staining the minds of the people." Shen urged that the Jesuits and converts be executed for clandestine meetings similar to the subversive White Lotus sect's religious groups. He was influenced by local literati who feared the Jesuit presence in

Nanjing. Shen also opposed any Jesuit role in calendrical reform. In Nanjing, Shen jailed Alfonso Vagnoni (1566–1640) as the leader of the mission, along with other Jesuits and several of their converts. The Jesuit house in Nanjing was dismantled, and its building materials were used to restore a shrine honoring an early Ming martyr. Vagnoni and Alvaro Semedo (1585–1658) were beaten and then transferred in cages to Guangzhou for expulsion. A sympathetic prefect there freed them, fortunately, and provided for their care before they were sent on to Macao.[89]

In contrast, Yang Tingyun (1562–1627), a convert, and Li Zhizao, who again retired temporarily, provided the Jesuits from Beijing with a haven in Hangzhou. Some Jesuits had already arrived in Hangzhou in 1611 at the invitation of Li Zhizao while Li observed a period of mourning for his father. Yang Tingyun met the Jesuits at that time following his retirement to Hangzhou in 1609. Yang then collaborated in Hangzhou with Pantoja to produce the *Seven Overcomings* (*Qike*), a tract on the seven deadly sins. In 1615, the *Explicatio Sphaerae Coelestis* (*Tianwen lue*) was translated by Diaz the younger. It included an updated geocentric model of the Ptolemaic cosmos and also presented a description of the telescope and Galileo's discoveries using it. After 1616, most of the fourteen Jesuits remaining in China studied Chinese texts and language in seclusion in Hangzhou.[90]

Shen renewed the persecution of the Jesuits from 1621 to 1627 when he became a grand secretary in Beijing during the final factional debacles of the Ming. After brief returns to office, Xu Guangqi and Li Zhizao again resigned. This time of palace infighting between asymmetrical factions of eunuchs and officials, many sympathetic with the Donglin Academy partisans, coincided with wars against the Manchus in the northeast. Shen was able to take advantage of a calamity in Beijing in 1621 to continue his attacks on the Jesuits. By this time, however, they were presented in Beijing as military experts, which gained them permission to reside there. Xu ordered a shipment of European cannon, procured through the Jesuits, to be used in the anti-Manchu campaigns, but two of them exploded, causing loss of life when they were fired in Beijing.[91]

Several years later, when the Chongzhen emperor (r. 1628–1644) came to power, he recalled Xu as a court diarist. In 1629, Xu became a senior vice-minister in the Ministry of Rites. In his new position, Xu Guangqi reported on the competition for predicting the solar eclipse of June 21, 1629. Chinese and Muslim predictions were not as accurate as the Jesuit determination of the time and length of the eclipse. When calls for calendar reform continued and drew government support, Xu then announced the need for immediate calendar reform. The Astro-calendric Bureau continued in its normal duties, but in 1629 Xu Guangqi proposed establishing an independent agency in

Beijing. When approved, the agency resided at a separate venue in a former academy conveniently located next to the Catholic church established by Ricci.

Once in charge of calendrical reform, Xu presented a plan to manufacture ten new astronomical instruments. He also prioritized the key astronomical problems that required technical attention. The reforms for a Sino-Jesuit calendrical system were presented in stages between 1631 and 1635, but the final steps of implementation failed, in part due to Xu's death in 1633, and definitively at the fall of the Ming dynasty due to internal revolts and external invasion in 1644.[92]

Xu could proceed with an ambitious translation project to solve these problems because Trigault had returned in 1621 from his 1613–1614 assignment to Rome with some 7,000 new works, many scientific, published in Europe in the 1610s. Most were still Ptolemaic, i.e., geocentric, in orientation. By 1628, Li Zhizao, for instance, had used several of these works to compile the *First Collection of Celestial Studies* (*Tianxue chuhan*), which included nineteen of the books Trigault brought back. The *First Collection* included the *Translations of Guidelines for Practical Arithmetic,* which had been translated by Ricci and Li jointly, as well as Xu's and Ricci's *Elements of Geometry* (*Jihe yuanben*). Li's collection represented the last stage of Ptolemaic astronomy in China. It would be replaced there in the 1630s by the geoheliocentric system devised by Tycho Brahe at the end of the sixteenth century.[93]

Many works of Aristotelian natural philosophy were also translated into classical Chinese by the Jesuits and their collaborators. *A Summary of Western Learning* (*Xixue fan*), for example, was compiled by Aleni to introduce the Scholastic educational system to China. It was first published in Hangzhou in 1622 and later was given eminence of place in Li Zhizao's *First Collection of Celestial Studies.* It discussed the system of schools, curricula, examinations, and degrees in a Thomistic manner and was based on both the Jesuit *Ratio Studiorum* for pedagogy at the Collegio Romano and the Coimbra texts known as the *Commentarii Collegii Conimbricensis,* which represented a new synthesis of the works of Aristotle. Aleni presented the six divisions of Scholasticism and *scientia*, i.e., specialized learning.[94]

The Coimbra textbooks used to train Jesuit missionaries were famous in Catholic and Protestant countries, where they were also widely used. Li's *First Collection* marked the initial group of European teaching materials made available in Chinese. To encompass Western learning, it was divided into two parts: (1) "principles or patterns" (*li*) and (2) applications, literally, "implements or utensils" (*qi*). The first part included Aleni's summary of Western European fields of knowledge and world geography; the second included geometry, astronomy, and hydraulics.

Similarly, the *Inquiry into the Universe* (*Huanyou chuan,* 1628) by Li Zhizao and Francisco Furtado (1587–1653) represented a translation of

Aristotle's' *De coelo et mundo*. Other Aristotelian materials that were translated included *De Logica* (*Mingli tan,* 1631), again by Furtado and Li Zhizao; the *Treatise on the Composition of the Universe* (*Kongji gezhi*) by Alphonso Vagnoni (1566–1640), from the Coimbra edition of Aristotle's *Meteoriologica* in 1633; and Vagnoni's *Creation of Heaven and Earth* (*Huanyu shimo*) in 1637. Other works on medicine, mining, and mechanics were also translated, such as Agricola's (Georg Bauer, 1490–1555) *De Re Metallica* (*Kunyu gezhi,* lit., "investigation of the earth") by Schall in 1640.[95]

For the future calendrical reform, however, the most significant Jesuits who arrived in China with Trigault in 1621 were the German Johann Adam Schall von Bell and the Italian Giacomo Rho (1593–1638). Both brought with them a new orientation to the cosmos drawn from the work of Tycho Brahe, which replaced the Ptolemaic system with a geoheliocentric one in which the sun and its planets revolved around the earth. In the face of the Copernican challenge, this development represented a compromise position beyond Ptolemy's increasingly discredited geocentrism, but one not yet acknowledging Copernican heliocentrism.[96]

The Compilation of the Mathematical Astronomy of the Chongzhen Reign

The inauguration of a formal astronomical reform system in 1629 by Xu Guangqi, Li Zhizao, and their coterie of Jesuit translators led to the official production of an essential series of translations from the latest Western works, which was titled the *Mathematical Astronomy of the Chongzhen Reign* (*Chongzhen lishu,* 1635). Although the work was never published as a collectanea, i.e., a collection of books published as a set, many works from it were. Some works included had been translated before 1629, such as Li's and Schall's *On the Farseeing Optic Glasses* (*Yuanjing shuo,* i.e., the telescope) completed in 1626 with help of Li Zubo, later martyred in 1665. In the early 1630s, a telescope, the first of many, was sent from Rome.

Published in 1630, *On the Farseeing Optic Glasses* introduced some findings but no cosmology by Galileo. It also presented information on the manufacture and practical use of telescopes. It was arguably the earliest book that introduced the Tychonic system to China. The earth was immobile, i.e., nonorbiting and nonrotating; the planets rotated around the sun, and all en masse rotated around the earth. The choice of this system by Xu Guangqi as a replacement for the "spherical heavens" (*huntian*) cosmology preceded the inauguration of calendrical reform in 1629 and meant that a decision had already been made by the Jesuits not to adhere to the Ptolemaic system and by the Chinese not to adhere to "spherical heavens" cosmology.[97]

Two ancient Chinese models of the cosmos were initially influential, since the account in *The Gnomon of the Zhou Dynasty and Classic of Computations*

(*Zhoubi suanjing*) appeared in the early Han period. The "vaulted heavens" (*gaitian*) cosmology was usually interpreted as a hemispherical dome, an umbrella-like canopy, over a flat earth. Its classical alternative, beginning in the transition from the early to later Han, was called the "spherical heavens" (*huntian*) cosmology, which became influential in the period between A.D. 100 to 180, but was not further elaborated, and was seldom discussed afterward. The Chinese computus was essentially numerical, like modern computer programs. Therefore, mathematicians in the Astro-calendric Bureau after the Han did not correlate their methods with an actual mapping of the cosmos.[98]

As director in charge of the reform effort until his death in 1633, Xu Guangqi organized a calendrical team to systematically adopt European astronomical knowledge. Moreover, as the official supervisor of Jesuit translators, he allowed them to implement the Tychonic system as the theoretical and observational foundation of the calendar reform. In early 1631, Xu presented the throne with the first group of eight works in twenty-three volumes translated by his team.

To avoid the charge that European learning took precedence over Chinese learning, Xu's memorial to the emperor stressed that the translations of Western methods were the first step in preparing a comprehensive system of correspondences between European and Chinese measurements: "Melting the material and substance of Western knowledge, we will cast them into the mold of the Grand Concordance system." Such accommodative language diverted attention from what the translations actually signified, that is, a new cosmological system. Unlike Li Zhizao, who earlier in 1610 had stressed the newness of Jesuit calendrical methods, Xu in 1631 minimized novelty and stressed accuracy instead. This emphasis on unifying European and Chinese knowledge was a tactic that would continue during the Qing dynasty.[99]

Xu noted that, for the 1,350 years between the Han and Yuan dynasties, calendrical methods had developed continuously. Because no major improvements in the Yuan-Ming calendar had been achieved in the 350 years since the Mongol system, it was now time for reform. Xu added that the usual rule of thumb was that any calendrical system had to be reformed every 300 years, which was close to the slip of one day every 308 years that so concerned the Gregorian reformers.

Stressing accuracy based on improved observation, Xu contended that every calendar must be reformed to maintain accuracy. Islamic materials had been used for Yuan and early Ming reforms, and now Xu would use Western methods to provide newer and more up-to-date source materials for contemporary reform. Measurement and mathematics were the key for Xu. He regarded mathematics as the root of European expertise, which followed Ricci's view, derived from Clavius. To find a precedent, Xu appealed to the ancient

Rites of Zhou (*Zhouli*) for technical corroboration of the importance of mathematics for early Chinese scholar-officials.[100]

In 1632 Xu Guangqi presented a second set of seven translated works to the emperor dealing mainly with fixed stars (which brought the total to 72 volumes), and a star atlas. Falling ill in September 1633, Xu recommended Li Tianjing (1579–1659) to succeed him as head of calendrical reform. Rho and Schall continued their work on the project, and they later made a third presentation of seven more translations. In 1634, Li Tianjing presented the fourth group of translated calendrical works, which comprised twenty-nine volumes and one star atlas. A last installment was presented in 1635. The five sets of works were then combined into the *Mathematical Astronomy of the Chongzhen Reign*, totaling 137 volumes and two star atlases. The traditional goals of reform, to determine seasonal divisions and verify eclipses by observation, were satisfied by 1642.[101]

Unfortunately for the Jesuits, Li Tianjing allowed Muslim calendricists in the Astro-calendric Bureau to establish a fourth branch in 1634, which was known as the Eastern Office. The reform center was renamed the Western Office. In effect, the Ming bureau now had competing Chinese, Islamic, and European branches. After 1634, Li negotiated a compromise to compare the results of all the systems, even though the European remained the most accurate. After various predictions for the 1642 solar eclipse were evaluated, the old calendrical system was replaced with the new system, but this decision came too late for the Ming dynasty.[102]

The works included in the *Mathematical Astronomy of the Chongzhen Reign* were quickly taken by Adam Schall to the conquering Manchu court in 1644. When the Shunzhi emperor (r. 1644–1661) appointed Schall as the first European head of the Qing Astro-calendric Bureau, Schall strategically changed the title to *Mathematical Astronomy According to New Western Methods* (*Xiyang xinfa lishu*) and had it recopied in 1645 for the Manchu court in 103 volumes with minor rearrangements. The Qing dynasty's computus for the Temporal Model astronomy system (*Shixian li*) accordingly was based on the European system adapted for the Ming dynasty.

The Jesuits' change of loyalty to the conquering Qing did not please literati loyal to the fallen Ming, however. This episode confirmed their view of Schall and the Jesuits as opportunists, particularly since Schall was also eager to work with the anti-Ming rebel leader Li Zicheng (1605?–1645) when he briefly captured Beijing in 1644. Some later argued to the Shunzhi court in 1660 that Schall subordinated the Chinese empire to Europe. They accused Schall and the Jesuits of touting the superiority of Christianity through their calendar. After Schall became director of the bureau, except for a successful attack on the Jesuits from 1664 to 1669, a Jesuit was in charge of the bureau from 1645 until 1775, although the society was suppressed by the pope in 1773. The Jesuits were unable to substitute a linear calendar based on Christian notions of time for the cyclical Ming and Qing calendars.[103]

Schall also added a few new works to the *New Western Methods,* such as Aleni's *Essential Methods for Determining Quantities* (*Jihe yaofa*), and the *Methods for Using Counting Rods* (*Chousuan*), which included Napier's device (without mentioning John Napier, 1550–1617) for quickly multiplying, dividing, and taking square and cubic roots of numbers by using multiplication tables on rods. Schall also included a translation introducing Galileo's proportional compass (again without cosmology) and a work by Xu Guangqi answering his Chinese critics (often attributed to Schall).[104]

Aleni's *Essential Methods* was read more widely in the late Ming and early Qing than the now-more-famous Ricci/Xu translation of Euclid's *Elements of Geometry.* Measuring a quantity, literally, "measuring magnitudes" (*jihe*) had initially referred in Aleni's *A Summary of Western Learning* to the Aristotelian category of continuous quantity, that is, a theory of magnitudes. In the early Qing, Mei Wending (1633–1721), separating geometry from arithmetic, followed Ricci's translation of the term rather than Aleni's. Aleni's book collected applications of mathematical astronomy and was not a geometry for beginners. Just as in medieval and early modern Europe, Euclid's geometry was introduced to the Chinese in different forms, which were aimed at different audiences for different purposes.[105]

From the "Spherical Heavens" to the Tychonic World System

When Tycho Brahe obtained a higher degree of precision for his celestial observations by using new astronomical instruments, his observations opened a new era of precision in astronomy. Clavius had checked Copernican data to correct earlier positions because Brahe's findings had challenged the astronomical tradition. Clavius apparently also had his doubts about the Ptolemaic system, based on Galileo's observations. Building on such developments, Rho and Schall as the chief astronomers in Jesuit circles introduced the Tychonic system to Ming China.

Because the Copernican system replaced the Tychonic system in Protestant European astronomy, the continued use of the Tychonic system in Ming and Qing China bequeathed disadvantages to the further development of astronomy in China. These limits were set by the Jesuits, whose intellectual stratagems in this regard have been described by Nathan Sivin. The development of Chinese mathematical astronomy would have been different if the Copernican system had been introduced in a timely fashion by the Jesuits in the Astro-calendric Bureau. A few of Galileo's discoveries, for example, were noted in Ming Jesuit translations, but not his support of heliocentricity.[106]

Nevertheless, the Tychonic age in the Ming and Qing Astro-calendric Bureau meant that Chinese specialists by the 1630s had available to them a rich tool kit of new computational techniques, more accurate observations, a new view of the cosmos that modified the "spherical heavens" system, and the latest precision instruments that went beyond those available to the Gregorian reformers in Europe a generation earlier. Johannes Kepler and Christian Longomontanus (1562–1647), Brahe's assistant, became the European authorities on geoheliocentricity named in Chinese accounts. Longomontanus's *Astronomia Danica,* published in 1622, was crucial for the adoption of the Tychonic system in China.

Furtado, an Aristotelian, refused to accept the corruptibility of the heavens, a finding which had resulted after the discovery of sunspots by using the telescope. Schreck's *Brief Description of the Measurement of the Heavens* (*Cetian yueshuo*), presented to throne in 1630, had already included a description of sun spots. Opposition by older Jesuits in China suggests that the newer Jesuits were able to introduce more recent astronomy so long as they observed the proscription against Copernicus. Furtado and others, for instance, also published objections to Longomontanus's claims about the rotation of the earth in the modified version of geoheliocentricity.[107]

Rho's translation titled the *Treatise on the Motion of the Five Planets* (*Wuwei lizhi*) was subsequently revised by Schall with help of Chinese scholars and presented to the throne in 1635. It presented Longomontanus's semi-Tychonic system and included illustrations of the old Ptolemaic and new Tychonic world systems, which were integrated into the *Mathematical Astronomy of the Chongzhen Reign*. The planets, it was contended, moved freely by themselves through the clear ether of the atmosphere. Longomontanus had also denied the Aristotelian boundary between a changing sublunar world and an unchanging celestial world.

Rho gave no clear indication of what Copernicanism was when he presented its peripheral features by perhaps intentionally mixing it up with Brahe's general method. The motions of the sun, moon, and five planets all relied on the Tycho-Longomontanus interpretation. For the general model of lunar motion, however, the works in the *Mathematical Astronomy of the Chongzhen Reign* presented both the Copernican and Tychonic mapping of that motion. Both remained, of course, geocentric. Rho's mathematical explanations of the motions of the planets were presented in three categories: Ptolemaic, Copernican, and Tychonic. It marked the first transcription of epicycles in Chinese. Similarly, Rho worked out a sort of hybrid Tycho-Copernican system.[108]

The geometric understanding of eclipses also came from Rho's and Schall's reliance on Longomontanus. The influence of Kepler's optical astronomy on the geometrical theory of solar and lunar eclipses was also essential. For instance, Schall's treatise and table on eclipses, prepared under Xu Guangqi's supervision from 1632, included Kepler's chart of optical refraction. Kepler's optics had noted the important effect of atmospheric refraction. The aim of the translators was clear: to present a precise theory of eclipses, the prediction of which was so important to the Chinese. Interestingly, the materials included in the *Mathematical Astronomy of the Chongzhen Reign* portrayed Kepler as a student of Brahe. He was also seen as contributor to the development of an unexplained theory of the motion of Mars, but Kepler's elliptical laws were not introduced for another century, although he was the first to correctly explain planetary motion around the sun in 1605.

Numerical Tables, Star Maps, and Instrumentation

To enhance the accuracy of the Chinese computus, Xu Guangqi recognized how important European astronomical tables, maps of the heavens, and instruments were for the reform. All of these accompanied the treatises presented to the throne from 1631 to 1635. For his astronomical tables, Rho had used early seventeenth-century calendars. Others used the 1551 Copernican Prutenic tables by Reinhold, which the Gregorian reformers had also employed. Kepler's Rudolphine Tables of 1627 were not available in China until a full set was sent to Beijing in 1646. The Chinese created correspondence tables between European calculation tables and Chinese measurements through a synthesis (*huitong*, lit., "combining and interpenetrating").[109]

In addition, the Jesuits introduced trigonometric tables in the *Mathematical Astronomy of the Chongzhen Reign* and translated the Englishman Henry Briggs's (1556–1630) *Arithmetica Logarithmica*, which was published in Chinese in 1624. Briggs was a professor of Gresham College, the original site of the British Royal Society until 1710, and later professor of geometry at Oxford. Nikolaus Smogulecki (Jean Nicholas, 1611–1656) and his collaborator Xue Fengzuo (1600–1680) introduced trigonometric logarithms in the early Qing. In an astronomical work, circa 1656, which pioneered spherical trigonometry and logarithms in China, Smogulecki introduced the latest European method for calculating eclipses. The use of both arithmetical and trigonometric logarithms enhanced the ease of astronomical calculations. For example, when Verbiest was asked by the Kangxi emperor to prepare the groundwork for the Eternal Calendar (*Yongnian li*), which was completed in 1678, he had to calculate its accuracy for two thousand years in the future. To accomplish this task, the Astro-calendric Bureau had to go through an enormous number of calculations that were made easier using trigonometric logarithms.[110]

In addition, the Jesuits provided the Ming court with up-to-date star maps, which culminated a classical tradition in China dating back to the *Clas-*

sic of Stars (*Xingjing*) around 70 B.C. The "Catalog and Atlas of Fixed Stars" in the late Ming improved on the mapping of fixed stars earlier in China, but in this astronomical field the Jesuits had to follow the Chinese system of constellations because they were unable to correlate all the stars known to them with the Chinese star maps. Hence Chinese constellations survived, and the Jesuits could only contribute further to the Chinese tradition of star catalogs.

Xu Guangqi and Adam Schall completed a remarkable star atlas in 1631 while also presenting the throne with a treatise on fixed stars. The latter followed Brahe's methods and other works on positional astronomy. Schall had to transform the two coordinate systems, equatorial in China and ecliptic in Europe, even though Brahe, like late Europeans, chose equatorially mounted instruments and recorded in equatorial coordinates rather than ecliptic. Because trigonometric logarithms were not introduced until the early Qing by Smogulecki and Xue Fengzuo, the system of equatorial coordinates used in the Jesuit star atlas was classically Chinese and became universal in Europe only after Brahe's time.[111]

The 1631 atlas, although a sort of hybrid between Chinese and European star maps, gave the positions for 1,366 stars in the epoch 1628. The planisphere assimilated European knowledge into Chinese constellations. The 1634 "General Atlas of Fixed Stars in the Southern and Northern Hemispheres Divided by the Equator" increased the number of stars mapped to 1,812. The outside was graduated into 360 Western degrees, while the inside used 365.25 Chinese degrees. Beside these, it employed the twelve houses of the zodiac and the twenty-eight Chinese equatorial mansions in the graduated circumferential circle belt along the border.[112]

Finally, Xu was very enthusiastic about instrument making for the calendar reform. Ricci had noted the old instruments preserved since the early Ming in Nanjing and Beijing, but many new instruments were acquired by the Bureau after reforms began in earnest in 1629. These included the quadrant for measuring the altitude of celestial bodies; the parallactic ruler for measuring time; the celestial globe; the sextant; an equatorial astrolabe to observe the movement of the stars; an ecliptic-equatorial armillary sphere to measure planetary motions; and gnomons to find the declination of the sun through the year.[113]

For example, until the Jesuits introduced the ecliptic armillary sphere, which worked from coordinates based on the sun's path through the fixed stars, the Chinese had employed equatorial coordinates, i.e., the equator of the earth extrapolated to the celestial sphere. These instruments were all illustrated and explained by Brahe in his 1598 work titled *Astronomiae Instauratae Mechanica,* which Ferdinand Verbiest (1622–1688) duplicated in 105 woodcut illustrations prepared in Beijing circa 1674. They were discussed and printed in the *Astronomia Europaea* and later included in the *Syn-*

thesis of Books and Illustrations Past and Present encyclopedia. The illustrations were based on instruments produced in 1669 and the early 1670s, when Verbiest succeeded Adam Schall in 1670 as the Jesuit codirector of the Astro-calendric Bureau and reequipped the imperial observatory (see Figure 2.1).[114]

The telescope gave a special boost because it allowed study of the phases of Venus and the motions of the four Jovian moons around Jupiter in terms of the Tychonic world system. In addition, Kepler's optical astronomy and Galileo's telescopic works were very important in China and became part of

[To view this image, refer to
the print version of this title.]

Figure 2.1. Verbiest's instruments in the Beijing Observatory.
Source: F. Verbiest, *Xinzhi yixiang tu* (Beijing, 1674).

the new astronomy. A telescope was used to observe a solar eclipse in China on October 25, 1631. Kepler also made a wooden pinhole device to measure the apparent diameters of the sun and moon and to observe solar eclipses in 1600, which was introduced into China circa 1632.[115]

Sighting devices were graduated (as they had been in China for centuries), but now used Brahe's degree subdivisions. Later, when Adam Schall was appointed to the Qing bureau in 1644, he replaced Chinese *du* with European degrees (i.e., a circle = 360 degrees rather than the Chinese 365.25) and time (one day divided in ninety-six units rather than the Chinese one hundred). Yang Guangxian (1597–1669) and other literati attacked this change in units in 1667 when Yang objected to instruments for astronomical prediction calibrated according to European methods. In the end, however, the Astro-calendric Bureau adopted European measurements.[116]

Just as timekeeping in Europe had provided a ritual regularity within society, so too furnishing standard time to the dual capitals of Beijing and Nanjing was the most routine function of the Astro-calendric Bureau. Official timekeeping in China's largest cities had depended on a water clock for quantitative astronomical observation. Timekeeping officials in the belltower and drumtower in large cities marked public time. The Chinese reception of European mechanical clocks, which Ricci and the early Jesuits first introduced in part to amaze the Chinese, should also be seen in light of the Ming and Qing dynasties' imperial horological needs, although the mechanical clock never replaced the three-chamber inflow type clepsydra then in use.[117]

The principles of mechanical clock making was part of the second-year curriculum at the Collegio Romano, for example, when Ricci studied under Clavius, along with studies of the astrolabe, planetary theory, perspective, and ecclesiastical computation. The Jesuits also became the Qing dynasty court's clock makers, and a Jesuit, usually Swiss, was placed in charge of the emperor's clock collection. Later under the Kangxi emperor, Chinese who worked under the Jesuits were expected to make native mechanical clocks. Imperial clock-making workshops were also established in Suzhou and Hangzhou. By the eighteenth century, both telescopes and mechanical clocks became common playthings in the imperial palace.[118]

The Ming calendrical crisis created an institution in the palace, where Chinese literati and Jesuit scholars interacted in translating European mathematical astronomy and instruments into Chinese texts and artifacts. Despite their Tychonic features, the instruments that Xu Guangqi and Verbiest produced for the imperial observatory represented a cultural hybrid. Allan Chapman has noted that "the European circles and technical parts were mounted upon stands contrived in the form of lions, dragons, flaming pearls, and other oriental motifs. The technology is wholly European, while the decorative features are characteristically Chinese."[119]

On the other hand, Louis Le Comte (1655–1728), one of the French Jesuits who arrived in China in 1687, noted in his 1696 memoirs that while the Beijing instruments that Verbiest produced were the finest in the world in terms of design and execution, the quality of the scale graduations was very poor by European standards. In other words, the accuracy of Chinese instruments remained deficient even after the late Ming calendar reforms. Yet, the late Ming and early Qing calendrical reforms had been successful in correcting the calendar and predicting eclipses to the minute. The implications of this paradox requires further elucidation before we turn in Chapter 3 to the further consequences of the Jesuit presence in seventeenth-century China.[120]

Chapman has described how Verbiest in his 1687 *Astronomia Europaea* illustrated a wide variety of Tychonic instruments in the fields of astronomy, ballistics, mechanics, meteorology, navigation, and optics as they were understood up to the 1650s. For instance, there were several illustrations of telescopes in the treatise, but Verbiest failed to discuss the telescope as a measuring device as well as a viewing instrument. Nor was there any awareness of astronomical instruments incorporating the telescopic sight or micrometer. In other words, Verbiest had not gone beyond Brahe's 1598 astronomical instruments.

European positional astronomy, according to Chapman, still functioned in a Tychonic context for over half a century after Brahe died in 1601. Consequently, when Verbiest left Europe for China in 1656, he sailed on the eve of a string of key advances in European instrument technology. In 1658, Huygens produced the first efficient pendulum escapement, which transformed the clock into a precise measuring instrument. Horological developments were paralleled by the invention of the micrometer in the 1660s, which enabled astronomers to read celestial angles more precisely than by using Tychonic scale graduations. Simultaneously, the telescopic sight significantly improved the accuracy of the sextant and quadrant by overcoming the physiological limits, for even Tycho Brahe, of the naked eye.[121]

These new inventions dramatically transformed the manner in which astronomical instruments in the observatories at Greenwich and Paris, for instance, were designed. Smaller, more delicate, and much more accurate than the large and unwieldy instruments in the Beijing observatory, the new astronomical instrumentation and timepieces in Europe after 1658 left the late Ming and early Qing far behind. When Verbiest arrayed his huge Tychonic instruments at the Beijing observatory in 1669–1670, he had outfitted them with obsolete equipment. Moreover, the production of more accurate timepieces in western Europe was increasingly tied to efforts to determine the thorny problem of the longitude of ships in open seas. This level of immediate accuracy went well beyond the needs of a Gregorian or Qing calendar that calculated a solar year within several minutes of accuracy. At sea, an error of just a few minutes in plotting longitude could be fatal and lead to a shipwreck.[122]

On the one hand, the Jesuits in China were certainly cut off from the latest developments in European science and technology, Schall in particular after 1656. On the other hand, just as the Jesuits made no effort to introduce the Chinese to the Copernican cosmology that eventually superseded Brahe's geoheliocentric system, so too they—especially Verbiest and his Jesuit successors in the Astro-calendric Bureau—failed to keep up with subsequent developments in astronomical instrumentation, precision timepieces, or, as we will see in Chapter 5, the revolutionary implications of analytical geometry and the differential and integral calculus for European engineers in the eighteenth century. Because Jesuit mathematicians stressed that mathematics could not explain motion, they never went beyond the focus on Euclidian geometry that Clavius had imprinted as a curriculum in the Jesuit colleges.[123]

By 1660, the Jesuits were no longer on the cutting edge of the emerging scientific community in Europe. A century earlier, under the leadership of Clavius and others in Rome, the papacy had forged a Gregorian calendar that was revolutionary in impact if not in conception. After the Church's proscription of Copernicanism in 1616 and the condemnation of Galileo in 1633, however, the Catholic Church and its leading intellectual lights, the Jesuits, rarely forged ahead in *scientia* and its new instrumentation. Even when they had just arrived in China in the late sixteenth and early seventeenth centuries, Ricci and his colleagues—because they were not specialists—were at first unable to provide the Ming court with the technical expertise needed to resolve the problems in the Ming calendar. After Ricci, the other Jesuits required a crash course based on the new materials Trigault brought back in 1621 dealing with the post-Gregorian changes in astronomy.[124]

The Jesuits were not in China to further the boundaries of *scientia* or to improve European-style astronomical instruments. They sought to make China a Catholic country. Nevertheless, a few of the French Jesuits were sent by Louis XIV to the Kangxi court as royal mathematicians and as members of the Paris Academy of Sciences founded in 1666. In addition, Clavius and his contemporaries redefined Jesuit education at the Collegio Romano to include astronomy, mathematics, and clock making. Finally, Schall and Rho in the late Ming, and Verbiest in the early Qing, could not have accomplished what they did in astronomy without the accruing astronomical literature in Latin that had made the Gregorian reforms possible.

Chapman is right, however, when he concludes, "The Jesuit observatory [in Beijing] never produced any discoveries that were of significance to Western science." The technical work the Jesuits performed for Xu Guangqi in the late Ming and for the Shunzhi and Kangxi emperors in the early Qing gave them access. They were willing minions of the state because, as their letters back to Europe indicated, this approach sanctioned their religious success in China. The Ming and Qing emperors required an accurate calendar and precise eclipse predictions. To give the Chinese what they wanted, the Jesuits provided the imperial government with a new cosmological system, mathematical tables, and instrumental techniques needed to satisfy the carefully itemized list of demands that Xu Guangqi outlined in 1629.[125]

More importantly, perhaps, a model translation laboratory was created in China from 1600 to 1635 that enabled Europeans, Chinese, and later after 1669, Manchus to work together for a common technical goal, even though many on each side had ulterior religious (the Jesuits) or political (the Ming and Qing governments) motives. This translation project far outweighed what the Jesuits achieved as individuals or the Church achieved in aggregate. The translations bequeathed an archive of books, manuscripts, maps, and instruments that would become part of the imperial library and the literati intellectual world. The intellectual impact of Jesuit works in natural studies and their assimilation by the literati, for example, belied how few Jesuits lived in China. Even the Japanese sought these works.

Despite Xu Guangqi's political and administrative success in reforming the Astro-calendric Bureau, Adam Schall's imprisonment in 1665 indicates that the Jesuit reform of the imperial calendar and Chinese time was not yet complete when the Ming dynasty buckled in 1644. Moreover, it was clear to Ricci that Ming literati were usually more interested in his knowledge of *scientia* than the teachings of Christianity he conveyed. With the help of Li Zhizao, he tried to encompass both in his use of the term "studies of Heaven" (*Tianxue*), which designated both astronomy and theology in the *First Collection of Celestial Studies*. Qing literati, with some exceptions, would also welcome the former and elide the latter. Rather than the linear date since creation for Easter, they remained focused on the prediction of cyclical celestial events in a creationless cosmos.[126]