

JESUIT *SCIENTIA* AND NATURAL STUDIES IN
LATE IMPERIAL CHINA, 1600-1800¹

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ABSTRACT

Arguably, by 1600 Europe was ahead of China in producing basic machines such as clocks, screws, levers, and pulleys that would be applied increasingly to the mechanization of agricultural and industrial production. In the seventeenth and eighteenth centuries, however, Europeans still sought the technological secrets for silk production, textile weaving, porcelain making, and large scale tea production from the Chinese. Chinese literati in turn, before 1800, borrowed new algebraic notations (of Hindu-Arabic origins), Tychonic cosmology, Euclidean geometry, spherical trigonometry, and arithmetic and trigonometric logarithms from Europe.

Until 1900, Chinese elites and their Manchu rulers interpreted the transition in early modern Europe—from new forms of scientific knowledge to new modes of industrial power—on their own terms. Each side made a virtue out of the mutually contested accommodation project, and each converted the other's forms of natural studies into acceptable local conventions of knowledge. The Ming and Qing imperial court induced Jesuit calendrical, military, and land mensuration experts to work as imperial minions in the government bureaucracy to augment each dynasty's own project of political and cultural control. Consequently, it would be a historiographical mistake to underestimate Chinese efforts to master on their own terms the Western learning of the Jesuits in the sixteenth, seventeenth, and eighteenth centuries.

Narrative accounts of the history of science worldwide from 1500-1800 have, until recently, been portrayed mainly through European frames of reference, even when comparative themes are stressed. Hence, the contested nature of the interaction since 1550 between late imperial Chinese and early modern Europeans over the meaning and significance of natural studies is a little known story. These Eurocentric portraits of the rise of modern science, while not monolithic, mainly represent variations of a single-minded historical teleology of Western European scientific "success," and non-western "failure." Usually the plots of such

¹ An earlier version of this article was presented at the panel on "Jesuits and the Frontiers of Science in China: New Perspectives in the History of Science and Medicine," at the American Historical Association Annual Meeting, San Francisco, January 4, 2002. My thanks to Norton Wise for his comments. For purposes of focus, the role of medical works in Ming-Qing natural studies will not be stressed here. How the medical classics became part of the recovery of antiquity will be discussed in a larger project entitled *A Short Cultural History of Modern Science in Late Imperial China* for the Themes in the History of Science, Medicine, and Technology Series at Harvard University Press.

accounts reproduce uncritically the story of the seventeenth-century Protestant-based scientific revolution, or return to the narrative of the medieval, Catholic roots of modern science.²

A common generalization scholars have made concerning natural studies in late imperial China is that, after about 1300, such fields, particularly astronomy and mathematics, were in steady decline until the arrival of Jesuit missionaries in the sixteenth century. When Matteo Ricci (1552-1610) described the prowess of the Chinese during the late Ming dynasty (1368-1644), he noted that they "have not only made considerable progress in moral philosophy but in astronomy and in many branches of mathematics as well. At one time they were quite proficient in arithmetic and geometry, but in the study and teaching of these branches of learning they labored with more or less confusion." Ricci concluded: "The study of mathematics and that of medicine are held in low esteem, because they are not fostered by honors as is the study of philosophy, to which students are attracted by the hope of the glory and the rewards attached to it."³

Chinese mathematics and astronomy, according to this view, had reached their pinnacle of success during the Song (960-1280) and Yuan dynasties (1280-1368) but had declined precipitously during the Ming.⁴ This longstanding perspective has been challenged by recent studies that indicate: 1) the Jesuits and their Chinese collaborators knew little of the history of Chinese natural studies; 2) mathematics and calendar reform were important concerns among Ming literati before the arrival of the Jesuits in China; and 3) Jesuit leadership in early modern European natural studies steadily declined.⁵

² See Toby E. Huff, *The Rise of Early Modern Science: Islam, China, and the West* (Cambridge, 1993). See also my review in *American Journal of Sociology* (1994): 817-19, and Steven Harris, "Transposing the Merton Thesis: Apostolic Spirituality and the Establishment of the Jesuit Scientific Tradition," *Science in Context* 3/1 (1989): 29-65.

³ For Ricci's comment, see *China in the Sixteenth Century: The Journals of Matteo Ricci: 1583-1610*, translated into Latin by Father Nichola Trigault and into English by Louis J. Gallagher, S.J. (New York, 1953), 31-33. See also Henri Bernard, "Notes on the Introduction of the Natural Sciences into the Chinese Empire," *Yenching Journal of Social Studies* 3/2 (1941): 220-41.

⁴ For the conventional perspective, see Joseph Needham, *Science and Civilization in China* several volumes (Cambridge, 1954-), vol. 3, 150-68, 173, 209, 437-461. The "decline narrative" is also enunciated in Ho Peng Yoke, *Li, Qi, and Shu: An Introduction to Science and Civilization in China* (Hong Kong, 1985), 169. Keizō Hashimoto, *Hsü Kuang-ch'i and Astronomical Reform* (Osaka, 1988), 17, though more sophisticated, continues this trend.

⁵ See Roger Hart, "Proof, Propaganda, and Patronage: A Cultural History of the Dissemination of Western Studies in Seventeenth-Century China" (Ph.D. dissertation, University of California at Los Angeles, 1996), passim. See also Thatcher E. Deane, "The Chinese Imperial Astronomical Bureau: Form and Function of the Ming Dynasty

Between 1600 and 1773, Jesuit authors worldwide wrote more than 4,000 works, 600 journal articles (almost all after 1700), and 1,000 manuscripts dealing with the early modern sciences, what was then called "*scientia*." The vast majority of these works were by Jesuit educators. Some 437 works were translated or compiled by the Jesuits and their converts in China between 1584 and 1790. Thirty per cent of that total (131) were in the sciences, while fifty-seven per cent (251) were on Christianity. Usually the Latin texts were orally translated by a Jesuit and dictated to a Chinese scribe in a style known as *kouyi* (oral translation) or *bishou* (received writing). The Chinese collaborator then prepared a polished written version for review. In this way, Chinese coworkers chose the classical terminology and concepts for Jesuit translations.

For example, Matteo Ricci translated Christopher Clavius' 1607 *Elementorum* in this manner, as did Sabbathin de Ursis (1575-1620) for his 1612 *Western Techniques of Hydraulics* (*Taixi shuifa*). Jean-Nicholas Smogolenski (1610-56) and his collaborators introduced the European method for calculating eclipses in an astronomical work of circa 1656, which was also the first to introduce spherical trigonometry and logarithms. Later, Ferdinand Verbiest's (1623-88) 1672 *Maps and Explanations of the Earth* (*Kunyu tushuo*), furnished further information on world geography beyond Ricci's earlier *mappa mundi*.⁶

Similarly, late Ming concerns about the inaccuracy of the official calendar forced Chinese literati to evaluate, translate, and apply specific Jesuit techniques to reform the official calendar. Derived from the Vatican's adoption (under Christopher Clavius' leadership) of the Gregorian calendar in 1582 to replace the Julian calendar, the technical prowess that some Jesuits such as Matteo Ricci had learned as a result of studying under Clavius at the *Collegio Romano* proved fortuitous in Ming China after 1600.⁷ Later, however, the Manchu throne sought to monopolize this potentially volatile area of translation expertise within the confines of the court. The contemporary calendrical debates between Jesuits,

'Qintianjian' from 1365 to 1627" (Ph.D. dissertation, University of Washington at Seattle, 1989), which documents the voluminous record of calendrical reform in China before the Jesuits. On the Jesuits in Europe, see Keith Baker, *Condorcet: From Natural Philosophy to Social Mathematics* (Chicago, 1975), 3-4.

⁶ See Tsuen-hsuei Tsien, "Western Impact on China Through Translation," *Far Eastern Quarterly* 13 (1954): 307-10, and S. Harris, "Transposing the Merton Thesis," 29-65. See also Elman, "Geographical Research in the Ming-Ch'ing Period," *Monumenta Serica* 35 (1981-83): 1-18.

⁷ Peter Dear, "Jesuit Mathematical Science and the Reconstitution of Experience in the Early Seventeenth Century," *Studies in History and Philosophy of Science* 18 (1987): 135-41.

Muslims, and literati-officials challenged the Yuan-Ming calendrical system during the seventeenth century.⁸

The example I will emphasize below is the mutual appropriation of the classical ideal of the "investigation of things" (*gewu*) by the Jesuits and their Chinese co-workers. I present this account of natural studies in pre-modern China in light of its ties to the classical epistemology of the "investigation of things and extension of knowledge" (*gewu zhizhi* or "*gezhi*" for short), a literati theme dominant since the Song dynasties. Moving the issue of science during the Ming and Qing (1644-1911) dynasties from the background to the foreground will allow me to present late imperial Chinese natural studies as an important, if not yet dominant, ingredient of literati thought. The Chinese terminology for Ming natural studies, and later for modern science, was organized in elite discourse around the "investigation of things and extension of knowledge" (*gezhi*) until 1900. This is a point that has remained muddled in contemporary accounts, which have tended to treat classical knowledge, "Western learning" (*Xixue*), and natural studies in China as mutually exclusive.⁹

Aspects of Ordering Knowledge and Antiquities in Ming China Before the Jesuits

The classical writings of the Southern Song (1127-1200) literatus Zhu Xi (1130-1200), and those of his followers, became the core commentaries for the late imperial classical canon tested in the civil examinations from 1400 to 1900. In particular, Zhu Xi had enunciated a classical vision that balanced moral inquiry with an impartial "investigation of things" in the world. During the late Yuan, "investigating things and

⁸ See Jonathan Spence, *Emperor of China: Self-portrait of Kangxi* (New York, 1974), xvii-xix, 15-16, 74-75. On the anti-Jesuit affair in Kangxi court life in the 1660s, see Chu Pingyi, "Scientific Dispute in the Imperial Court: The 1664 Calendar Case," *Chinese Science* (now *East Asian Science, Technology, and Medicine*) 14 (1997): 7-34.

⁹ See Wm. Theodore de Bary, "Reflections on the Chinese Rites Controversy," in *The Chinese Rites Controversy: Its History and Meaning*, ed. D. E. Mungello (Nettetal, 1994), 291-92, for the view that Christianity and science had only marginal influence on mainstream Chinese thought before the nineteenth century. De Bary is rightly reacting to John Fairbank and others who overstressed the "Western impact" in their earlier accounts of Ming and Qing history, but he has gone too far in the rebuttal. For new directions, see Michael Lackner et al., *Translating Western Knowledge into Late Imperial China* (Leiden, forthcoming), and *New Terms for New Ideas: Western Knowledge & Lexical Change in Late Imperial China*, ed. Michael Lackner, Iwo Amelung, and Joachim Kurtz (Leiden, 2001). See also Wang Hui, "The Fate of 'Mr. Science' in China: The Concept of Science and its Application in Modern Chinese Thought," *Positions* 3/1 (1995): 1-68.

extending knowledge," as a classical term, was already used by the medical writer Zhu Zhenheng (1282-1358), a disciple of Zhu Xi, to denote technical learning.

In Zhu Zhenheng's most famous work, entitled *Extra Treatises Based on Investigating Things and Expanding Knowledge* (*Gezhi yulun*), which was included in the Imperial Library in the late eighteenth century, he made a strong appeal to Yuan literati that they should include medical learning in their classical framework. In his view, medical learning was one of the key fields of study that not only complemented moral and theoretical teachings, but was also a key to the practical uses of the latter. The eighteenth-century Imperial Library editors cited Zhu's preface for the important claim that literati medicine was one of the concrete fields that informed the "investigation and extension of knowledge."¹⁰

In addition to its central epistemological place in literati classical learning since 1200, the "investigation of things" was also applied to the collection, study, and classification of antiquities, as in Cao Zhao's (fl. 1387-99) influential *Key Issues in the Investigation of Antiquities* (*Gegu yaolun*), which, when published in the early Ming and enlarged several times thereafter, became important in the formation of a Ming discourse about antiquities. The work originally appeared in 1387-88 with important accounts of ceramics and lacquer, as well as traditional subjects such as calligraphy, painting, zithers, stones, bronzes, and ink-slabs.

The 1462 edition prepared by Wang Zuo (palace degree-holder of 1427) was considerably enlarged and included findings from the official Ming dynasty naval expeditions led by Zheng He (1371-1433) to Southeast Asia and the Indian Ocean from 1405 to 1433. Wang also added the subjects of imperial seals, iron tallies, official costumes, and palace architecture. In his "Preface," Wang added: "Whenever you see an object, you must read all about it in the repertoires, study its provenance, classify its quality, and judge its authenticity." He was particularly interested in ancient bronzes, calligraphic specimens, and curiosities.¹¹

¹⁰ See the "Tiyao" (Abstract) prepared by the editors for Zhu Zhenheng's *Gezhi yulun*, in the *Siku quanshu* (Complete collection of the four treasures) (Taipei, 1983-86, reprint), vol. 746, 637.

¹¹ See the abridged version of the *Gegu yaolun*, in Hu Wenhuan (fl. ca. 1596) comp., *Gezhi congshu* (Collectanea of works inquiring into and extending knowledge) (Ming Wanli edition, 1573-1619; microfilm, Taipei, National Library of Taiwan, Rare Books Collection), vol. 25. See also Wang Zuo's "Xu" (Preface), 1a-b, and Sir David Percival, trans., *Chinese Connoisseurship, the Ko Ku Yao Lun: The Essential Criteria of Antiquity* (London, 1971).

The new information the Zheng He fleets brought back to Ming China from Southeast and South Asia did not challenge the existing frameworks of classical knowledge among literati. At first glance, this may seem difficult to accept because of the wide impact sixteenth-century oceanic discoveries allegedly had in early modern Europe. 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."¹²

More recently, however, Michael Ryan has argued that the newly discovered lands and new peoples registered relatively little impact on the values, beliefs, and traditions of sixteenth- and seventeenth-century Europe. Moreover, Ryan rejects Lach's view that new forms of cultural relativism emerged in Europe. Instead, by interrogating the conceptual strategies through which European contemporaries interpreted their world, Ryan has examined how these new worlds were incorporated into a European lexicon. Their use of organizing categories such as ancient paganism as a trans-historical category to classify the cultures of the new worlds enabled them to domesticate exotic peoples within the frame of Graeco-Roman pagan antiquity.¹³

In the same way, over a century prior to the Jesuit arrival, Ming China and its paradigm for knowledge based on investigating things and extending knowledge had enough epistemological power to allow the compilers of the *Key Issues in the Investigation of Antiquities*, for instance, to domesticate the new materials received from the Indian Ocean within a traditional focus on encyclopedic knowledge and its established range of classifications. We should add that any view that Ming literati (as compared to their early modern European contemporaries) were engaged in a merely subjectivist and idealist discourse about "investigating things" in the mind is far from the mark. Mark Elvin has contended that Wang Yangming (1472-1528) and his sixteenth-century followers led most literati away from the precocious intellectual promise of objectivist science and natural studies premised on the "investigation of things" in Song times; the pervasive influence of Wang Yangming in Ming times was thus one

¹² See Donald Lach, *Asia in the Making of Europe. Volume II, Book 3: A Century of Wonder* (Chicago, 1977), 446-89, 556-66.

¹³ Michael Ryan, "Assimilating New Worlds in the Sixteenth and Seventeenth Centuries," *Comparative Studies in Society and History* 23 (1981): 519-27.

of the key factors that had doomed Ming China to fall short in its global competition with early modern Europe. But this view of Ming intellectual history is ill-conceived.¹⁴

In fact, the proliferation of popular encyclopedias in the sixteenth century makes it clear that Ming encyclopedists never took literally Wang Yangming's efforts to find the principles of bamboo in the mind, through meditative techniques alone. The encyclopedic ordering of antiquity carried over to pharmacopoeia, for example. Li Shizhen's (1518-93) *Systematic Pharmacopoeia* (*Bencao gangmu*), published in 1596, reclassified the entire Chinese tradition of *materia medica* according to a new logic, which revealed Li's concern with the "investigation of things."

The future pharmacologist extraordinaire had early on passed the preliminary civil examinations but never advanced further. Unable to pursue an official career, Li Shizhen turned instead to medicine because he came from a family whose patriarchs had been medical practitioners who had also learned pharmacology for several generations. Hence, he was aware of the dubious quality of earlier compendia. If we place Li Shizhen's 1596 *Systematic Pharmacopoeia*, in its medical and pharmaceutical context, we find that Li worked tirelessly on producing a revised encyclopedia of pharmacopoeia that would correct the errors of identification, classification, and evaluation that had accrued since the standard Song dynasty series of pharmacopoeia. From 1556, Li traveled widely in major drug-producing provinces, which enabled him to include comprehensive information on mineralogy, metallurgy, botany, and zoology in the *Systematic Pharmacopoeia*, in addition to medicines.¹⁵

Li Shizhen's "Outline" for his work, for instance, stressed the problem of nomenclature (*zhengming*, literally, "rectification of names," a term from Confucius' *Analects*) as the main entry. All other sub-entries explained the names of things themselves. Accordingly, Li Shizhen's enterprise was also a scholarly project: "I have actually practiced what we literati scholars call the 'study of the investigation of things.' This can fill the hiatus in the commentaries on the *Approaching What is Elegant* [*Erya*, dictionary] and the *Classic of Poetry*." Li Shizhen's explicit work of medicine, which elaborated on the *materia medica* in the classical lexicography of the *Erya* and the rich annotations of flora and fauna in the classics, particularly

¹⁴ See Elvin, *The Structure of the Chinese Past* (Stanford, 1975), 203-34.

¹⁵ Nathan Sivin, "Li Shih-chen," in *Dictionary of Scientific Biography*, ed. Charles Gillispie (New York, 1973), vol. VIII, 390-98. See also Elman, *A Cultural History of Civil Examinations in Late Imperial China* (Berkeley, 2000), 125-42.

in the *Poetry*, thus also belonged to the long tradition of "investigating things and expanding knowledge."¹⁶

An unprecedented combination of an ample number of fully classically literate men (almost 1.4 million in 1590), whose chances for success in the civil service were declining, with a large audience of other potential male and female readers of practical manuals, compendia, and popular fiction, provided the publishing fuel for late Ming printers in south China to issue, profitably, a wide assortment of works by men such as Li Shizhen in the late sixteenth century. Chōson Korea, Tokugawa Japan, Le Vietnam, and the overseas Chinese communities in Southeast Asia were also important additional markets for Ming and Qing editions of such compendia. Other late Ming encyclopedias, known as "daily use compendia" (*riyong leishu*), represented manuals for everyday living that were widely printed in south China, where lower printing costs made cheaper editions accessible beyond the usual classically literate elite.¹⁷

The Ming scholar-merchant and Hangzhou bookseller Hu Wenhuan (fl. ca. 1596) prefigured the Sino-Jesuit dialogue concerning *scientia* in the 1630s when he compiled and published his widely circulated *Collectanea of Works Investigating Things and Extending Knowledge* (*Gezhi congshu*) in the 1590s as a late-Ming repository of classical, historical, institutional, and technical works from antiquity to the present in China. Its wide dissemination in Ming-Qing China and Japan, issued in many differing editions from Hu Wenhuan's Hangzhou and Nanjing print shops, marks it as a very influential and thus representative work. The late eighteenth-century compilers of the Imperial Library had received mention of 200 versions of Hu's *Collectanea*—a remarkably high figure—in the 1780s. Its wide circulation indicates that the *Collectanea* was representative of pre-Jesuit interest in natural knowledge.¹⁸

¹⁶ See Georges Métailé and Elisabeth Hsu, "The *Bencao gangmu* (Classified Materia Medica) of Li Shizhen—An Innovation for Natural History?" in *Innovation, Convention and Controversy in Chinese Medicine: Festschrift in Memory of Lu Gwei-Djen*, ed. Elisabeth Hsu (Cambridge, 2001), 221-261, and Nathan Sivin, "Li Shih-chen," 390-98.

¹⁷ Elman, *A Cultural History of Civil Examinations*, 140-41. See also Ōba Osamu, *Edo jūdai ni okeru Chūgoku bunka juyō no kenkyū* (Research on the acceptance of Chinese culture in the Edo period) (Tokyo, 1975), 6-48, and Sakade Yoshinobu, "Kaisetsu—Mindai nichiyō ruisho ni tsuite" (Explanations—Concerning Ming dynasty daily use compendia), in Sakade Yoshinobu et al., *Chūgoku nichiyō ruisho shūsei* (Collection of Chinese daily use compendia) 14 volumes (Tokyo, 1999-), vol. 1, 7-30.

¹⁸ See Wang Baoping, "Mindai no kakushoka Ko Bunkan ni kan suru kōsatsu" (An inquiry into the Ming dynasty printer Hu Wenhuan), *Kyūko* 36 (1999): 47-57, and Wang Baoping, "Zhongguo Hu Wenhuan congshu jingyan lu" (Record of viewing Hu Wenhuan's *Collectanea* in China), in *Zhong Ri wenhua luncong* (1991): 6-25.

Because Hu Wenhuan also had wide ranging interests in medicine, Buddhism and Daoism, some versions of his *Collectanea* contained a broad range of illumination texts, medical works, and esoteric writings. Overall, Hu Wenhuan's *Collectanea* encompassed natural and textual studies within a humanist and institutional agenda. Perhaps the most representative texts of early natural history included in the *Collectanea* were those that focused on "broad learning of things" (*bowu*). For example, famous medieval collections such as Zhang Hua's (232-300) *Treatise on Broad Learning of Things* (*Bowu zhi*), and Li Shi's ca. 1150 Song dynasty continuation, titled *Continuation to the Treatise on Broad Learning of Things* (*Xu bowu zhi*), were subsumed within Hu Wenhuan's collection. The *Collectanea* presented a cumulative account of all areas of textual knowledge important to a literati audience in the seventeenth century.

"Investigating Things" and Jesuit Translations

Thus, when the Jesuits arrived in China, there was already considerable discussion among Ming literati about an appropriate theory of knowledge. The early sixteenth-century debate between Wang Yangming and his opponents often took the form of claims that morality took precedence over formal knowledge. Earlier, we have seen that Zhu Xi had argued that "investigating things and extending knowledge" presupposed that all things had their principle. Zhu Xi therefore concluded: "one should in three or four cases out of ten seek principles in the outside realm." However, in most cases, six to seven out of ten, moral principles should be sought within. Wang Yangming gainsaid Zhu's views by stressing morality over external knowledge in all cases. Thereafter, the brouhaha over the investigation of things as an internalist versus externalist program became the key issue for literati versed in the Classics and Histories.¹⁹

The Jesuits in late Ming China saw the "investigation of things" and "exhaustively mastering principles" (*qiongli*) as a necessary way station to the doctrinal transmission of the experience of God to the Chinese they hoped to convert. Because of the physico-theology lurking in the

¹⁹ See *Zhuzi yulei* (Conversations with Master Zhu [Xi] Classified Topically) (1473 edition. Taipei: Zhengzhong Bookstore reprint, 1973), 18.14b-15a. See also Yamada Keiji, *Shushi no shizengogu* (Zhu Xi's natural studies) (Tokyo, 1978), 413-72, and Yü, Ying-shih, "Some Preliminary Observations on the Rise of Ch'ing Confucian Intellectualism," *Tsing Hua Journal of Chinese Studies*, new series 11/1 and 2 (1975): 105-46.

Jesuits' teleology of nature, however, the investigation of things was ultimately "to find God" for the Jesuits, just as many Chinese literati believed that the ultimate aim was "to fathom principles" of the "Way" (*Dao*). Despite this theological twist to the Jesuit interpretation, the Jesuit conception and practice of *scientia* was ingeniously presented by some of the Chinese who collaborated with the Jesuits, such as Xiong Mingyu (b. 1579), as roughly corresponding to the natural studies of the Chinese.²⁰

Both sides saw an order and purpose in the cosmos and on earth, which the Jesuits linked to theology and geography to delineate God and nature as one. Most Chinese literati also saw the earth and heavens as a harmonious whole, but their view of nature framed arguments for the design of the cosmos around an eternal and always changing "Way" rather than around the Christian chronology of a divine providence informing the cosmic order. In place of a cosmos composed of "four elements" (air-ether, fire, earth, water), the Chinese conceived of change in light of a "Supreme Ultimate" (*taiji*), which, through the medium of yang and yin forces, set in motion the five phases (*wuxing*, earth, fire, metal, water, and wood) of cosmic evolution and yielded the concomitant production and destruction cycles of all things in the world.²¹

Alphonso Vagnoni's 1633 *Investigating and Expanding Knowledge about the Atmosphere* (*Kongji gezhi*), was in part a refracted presentation of the theory of the four elements from the Conimbricenses edition of Aristotle's *Meteorologica*, which was used in the Jesuit University of Coimbra in Portugal where many missionaries were trained before leaving for Asia. In his translation, for example, Vagnoni vainly tried to convince the Chinese of the error of their ways for including wood and metal and excluding air-ether as the building blocks of things in the world.²² Rather

²⁰ See Xu Guangtai, "Mingmo Qingchu xifang gezhi xue de chungji yu fanying: yi Xiong Mingyu *Gezhi cao wei li*" (The impact of and reaction to Western natural studies in the late Ming and early Qing: Xiong Mingyu's *Gezhi cao* as an example), *Shibian chunti yu geren* (Taipei, 1996), 236-58.

²¹ On the five phases, see Nathan Sivin, "The Myth of the Naturalists," in Sivin, *Medicine, Philosophy, and Religion in Ancient China: Researches and Reflections* (Brookfield, 1995), 1-29, who notes that "by the first century B.C., a coherent theory of yin-yang and the Five Phases as aspects of *ch'i* [*qi*, energy] emerged." For comparison, see Clarence J. Glacken, *Traces on the Rhodian Shore: Nature and Culture in Western Thought from Ancient Times to the End of the Eighteenth Century* (Berkeley, 1967), and Keith Thomas, *Man and the Natural World: Changing Attitudes in England, 1500-1800* (London, 1983).

²² See the critique of Vagnoni by eighteenth century Chinese literati in the *Siku quanshu zongmu* (Catalog of the complete collection of the four treasuries), compiled by Ji Yun, et al. (Taipei, 1974, reprint), 125.34a-b. For the Jesuit critique of *qi*, see Qiong Zhang, "Demystifying Qi: The Politics of Cultural Translation and Interpretation in the Early Jesuit Mission to China," in *Tokens of Exchange: The Problem of Translation and Interpretation in the Early Jesuit Mission to China*, ed. Lydia Liu (Durham, 1999), 74-106.

than building blocks of the universe, Chinese literati perceived in the five phases evidence for the successive evolutive changes in all things. Chinese also perceived in *qi* (stuff, energy, etc.) a more fundamental material (*zhi*) and spiritual (*shen*) unity, which pervaded all things in the cosmos and undergirded the space-time evolution of yin and yang, rather than the lifeless air-ether element enunciated by Vagnoni, following Aristotle, as one of the substrates of matter. Ricci and Vagnoni, on the other hand, believed the Chinese to be guilty of atheism and materialism, since for them the "investigation of things" led away from God.²³

The Role of Early Modern Cartography

Because of their travels, one specific field of *scientia* about which the Jesuits could claim to be more knowledgeable than their Ming counterparts was world geography. Jesuit charts of the globe were based on the New World discoveries of the Portuguese and Spanish explorers whom they often accompanied. The *mappa mundi* that Ricci and others produced for literati in the late sixteenth century caused an immediate uproar because the Ming imperial system was based on a cosmological view of its geographical centrality in the world, which the Jesuit maps seemed at first to challenge. It was very difficult, for example, for literati to accept the Jesuit claim that the earth was round, because this suggested that the sky that enveloped the earth was circular as well. Most literati considered the earth flat and the sky a finite vault overhead.²⁴

By adding to the geographical knowledge of Ming literati in the late sixteenth century, the Jesuit impact on Chinese cartography was clearly evident. The first edition of Matteo Ricci's *mappa mundi*, for instance, was printed in 1584. A flattened sphere projection with parallel latitudes and curving longitudes, Ricci's world map went through eight editions in all between 1584 and 1608. The third edition was printed in 1602 with the help of Li Zhizao (1565-1630). Li devoted himself to the study of European mathematics and astronomy, in addition to geography, after meeting Ricci in Peking in 1601.²⁵

²³ See Vagnoni's *Kongji gezhi*, reproduction of the 1633 version in *Tianzhujiao dongchuan wenxian sanpian* (Taipei, 1979), A.1a-13b. See also Willard Peterson, "Western Natural Philosophy Published in Late Ming China," *Proceedings of the American Philosophical Society* 117/4 (1973): 295-322.

²⁴ For background, see *The History of Cartography. Volume 2, Book 2: Cartography in Traditional East and Southeast Asian Societies*, ed. J. B. Harley, and David Woodward (Chicago, 1994).

²⁵ Ricci's world map is reproduced in Needham, *Science and Civilisation in China*, vol. 3, 582-83 (Plates XC and XCI).

Ricci's description of the form and size of the earth forced many seventeenth-century literati to revise their views of the world. For the first time, the Chinese became aware of the exact location of Europe in relation to their own country. In addition, Ricci's maps contained technical geographical lessons for Chinese geographers: 1) Ricci taught Chinese cartographers to localize places by means of circles of latitude and longitude; 2) he invented many geographical terms and names, including Chinese terms for Europe, Asia, America, and Africa; 3) Ricci's maps transmitted to China the most recent discoveries made by European explorers; 4) Ricci described the existence of five terrestrial continents surrounded by large oceans; 5) the maps introduced the sphericity of the earth; 6) finally, Ricci spoke of five geographical zones and their location on the earth: i.e., the Arctic and Antarctic Circles, the zone between the Arctic Circle and the Tropic of Cancer, etc.²⁶

The subsequent history of "Western learning" reveals that Jesuit knowledge produced in seventeenth-century China was not easily domesticated in the eighteenth. Cordell Yee, for example, has compared Chinese and European maps in terms of traditional versus modern or scientific cartography; he concludes that works such as the Jesuit-inspired, official Kangxi Atlas of the Empire (*Huangyu quanlan tu*), compiled between 1708 and 1718 and based on European mensuration techniques, did not have much influence in China—in other words, mapping remained within traditional parameters. When viewed in light of the impact of evidential studies in eighteenth-century classical studies, however, literati views of geography and their turn from concern with foreign lands to internal military defense and historical and descriptive geography were not entirely traditional either.²⁷

Within the scholarly community that promoted evidential research, considerations of historical and physical geography took precedence over the application of the idealized geopolitical paradigms popular in Han and Song classical cosmography. The recognition of the physical difficulties involved in accepting ancient mensuration in the real world of existing mountains and rivers, indicated that Qing scholars were challenging the traditional approach to the ordering of space. Evidential scholars, for

²⁶ Helen Wallis, "The Influence of Father Ricci on Far Eastern Cartography," *Imago Mundi* 19 (1965): 35-45, and Kenneth Ch'en, "Matteo Ricci's Contribution To, and Influence On, Geographical Knowledge in China," *Journal of the American Oriental Society* 59/3 (1939): 325-59.

²⁷ Cordell Yee, "Traditional Chinese Cartography and the Myth of Westernization," in *Cartography in Traditional East and Southeast Asian Societies*, 170-202.

instance, no longer accepted uncritically the portent-astrology associated with the field allocation (*fenye*, literally, "allotted countryside") system. According to the latter, specific celestial fields, called the twenty-four lunar lodges, constituted the equatorial coordinate system. Based on medieval cosmology, the lodges were used to indicate the positions of celestial objects on the celestial sphere.²⁸

When Russians appeared in force along the northern frontier in the seventeenth century, Manchu officials and Chinese scholars quickly realized that they would require more accurate geopolitical information to deal with the latest threats to the empire. The Jesuits were commissioned to act as intermediaries and provide the necessary data that would enable Qing leaders to stem the tide of Russian infiltration into the Manchu and Mongolian homelands. The geographical knowledge that accrued during this time was an important addition to earlier information about foreign lands. In the process, the Kangxi court's awareness of the actual geographical divisions of the Sino-Russian frontier came apace of their long-standing knowledge of and interest in geographical realities in Korea, Japan, and Southeast Asia.

Laura Hostetler and Peter Perdue have described the comparable and dissimilar responses of the Central Asian empires of the Qing dynasty, Imperial Russia, and the Mongol Zunghars to international events, which led to a redrawing of frontier boundaries between Russia and the Qing in the region and the crushing of the autonomous state of Zungharia in 1760 by Qing armies. Perdue has noted how eighteenth-century Central Asian borders were constructed through military confrontation, negotiated treaties, and then culturally domesticated by inscription on Russian and Qing maps. The Qing dynasty, Zungharia, and Russia each produced important new maps of unprecedented scale and accuracy as political weapons in their struggle for control of Central Asia.²⁹

Russia and China defined their mutual borders in the treaties of Nerchinsk (1689) and Kiakhta (1727) by using new surveying techniques for cartography. In addition, new classification systems and ethnographic

²⁸ In popular culture, however, literati efforts to distance such correspondences and the mantic arts that were associated with them were unsuccessful. See Richard Smith, *Fortune-Tellers & Philosophers: Divination in Traditional Chinese Society* (Boulder, 1991), passim. See also Elman, "Geographical Research in the Ming-Ch'ing Period," 17-18.

²⁹ Peter C. Perdue, "Boundaries, Maps, and Movement: Chinese, Russian, and Mongolian Empires in Early Modern Central Eurasia," *The International History Review* 20/2 (1998): 263-86, and Laura Hostetler, "Qing Connections to the Early Modern World: Ethnography and Cartography in Eighteenth-Century China," *Modern Asian Studies* 34/3 (2000): 623-62.

atlases were compiled to control the movements of refugees, nomads, tribes, traders, soldiers, and other mobile groups across the borders. Both sides used tax and land registers, censuses, border patrols, passports, and visas to keep people from moving freely across the borders. Each also applied seventeenth-century European technical knowledge, that was transmitted through the Jesuits, to survey their new territories.³⁰

The goal of the "modern" map was predicated on delineating the modern political boundaries of the nation-state, but we can also view the Jesuit-mediated negotiations between the Russian and Manchu empires to determine their geographic boundaries in 1689 and 1727 as evidence of the successful impact of European cartography on the political construction of the international borders between China and Russia in Northeast and Central Asia, which carried over to the nineteenth century when Russo-Chinese borders were re-examined. Again, however, the Jesuit agents of such new cartographic techniques in China were subordinates of the Qing dynasty.³¹

Ming-Qing Reception of Jesuit Natural Studies

We have seen that the Chinese term for "investigating things and expanding knowledge" had been chosen by Ming literati in the early seventeenth century as one of the native categories of specialized learning, and that the latter was equated with early modern European *scientia* by those who worked with the Jesuits. Early Jesuit translations of Aristotle's theory of the four elements (*Kongji gezhi*, literally, "Investigating and Expanding Knowledge about the Atmosphere," 1633) and Agricola's *De Re Metallica* (*Kunyu gezhi*, literally, "Investigating and extending knowledge of the earth," 1640) into classical Chinese had used "investigating things and extending knowledge" in light of the Latin *scientia* in their titles.³² Such titles suggest that classical doctrine and natural studies, particularly medical and calendrical studies, were not mutually exclusive.³³

³⁰ Mark Mancall, *Russia and China: Their Diplomatic Relations to 1728* (Cambridge, 1971), 156-59, 249-55.

³¹ Laura Hostetter, *Qing Colonial Enterprise: Ethnography and Cartography in Early Modern China* (Chicago, 2001), 17-23, 51-80.

³² See Pan Jixing, "The Spread of Georgius Agricola's *De Re Metallica* in Late Ming China," *T'oung Pao*, 57 (1991): 108-18.

³³ See Roger Hart, "Local Knowledges, Local Contexts: Mathematics in Yuan and Ming China," paper presented at the Song-Yuan-Ming Transitions Conference (Lake Arrowhead, CA, June 5-11, 1997).

The collapse of the Ming dynasty and its Qing successor under non-Han rule created opportunities for Jesuit experts in mathematics and astronomy to break out of their subordinate positions and challenge a discredited Ming elite for political power under a new Manchu ruling elite. Because the new dynasty had to reformulate in expert terms its calendrical *raison d'être* as quickly as possible, the increased cultural importance of astronomical expertise probably outweighed, or at least challenged for a time, the cultural distinction accumulated by literati via mastery of classical studies.³⁴

By the 1680s, however, when the new Manchu dynasty had mastered its political and military enemies, the intellectual fluidity of the early decades of the Qing began to disappear, leaving Han literati and Manchu elites in a precarious balance at the top of the political and social hierarchies (and Jesuit, Muslim, and Chinese calendar specialists again in the middle). For example, circa 1711 the Kangxi emperor already knew of the Paris Académie Royale des Sciences, whose title the French Jesuit Jean-Francois Foucquet translated into Chinese as the "Academy for the Investigation of Things and Fathoming Principles" (*Gewu qiongli yuan*). The emperor modeled his "Academy of Mathematics" (*Suanxue guan*) for Manchu students after this French example. It remained, however, a temporary organization created by the emperor to solve his immediate needs. Neither the new academy nor the French Jesuits, who worked mainly on calendar reform and the empire-wide land survey, had a great impact outside the court. The emperor did not encourage a broader focus on natural studies.³⁵

By 1715, the Kangxi emperor banned any focus in the civil examinations on the study of astronomical portents and the calendar because they pertained to Qing dynastic legitimacy. For example, in 1713 he decreed that all examiners assigned to serve in provincial and metropolitan civil examinations were forbidden to prepare policy questions on astronomical portents, musical harmonics, or calculation methods. The latest works in Qing natural studies, court projects on which the Kangxi emperor had employed Jesuit experts, were also put off limits to examiners and candidates. The ban on natural studies occurred within

³⁴ *Eminent Chinese of the Qing Period*, ed. Arthur Hummel (Taipei, 1972, reprint), 473-75.

³⁵ Han Qi, "Gewu qiongli yuan yu Mengyangzhai: shiqi shiba shiji zhi Zhong-Fa kexue jiaoliu" (The Academy of Science and the Mengyangzhai: Sino-French scientific exchange in the seventeenth and eighteenth centuries) *Faguo hanxue* (Beijing) 4 (2000).

a general effort by the court to keep the mantic arts and discussion of auspicious or inauspicious portents out of public discussion.³⁶

Qing Literati and Natural Studies

Such bans in the civil examinations did not carry over to literati learning, where a decisive sea change was occurring in classical studies. The classical term for "investigating things and extending knowledge" subsequently reappeared in Chen Yuanlong's (1652-1736) encyclopedia entitled *Mirror Origins for Investigating Things and Extending Knowledge* (*Gezhi jingyuan*), which was published in 1735. Chen had received the Kangxi emperor's orders in 1704 to compile a comprehensive work on astrology, astronomy, geography, human affairs, plants and trees, and insects, but he held on to the manuscript for two decades before publishing it. A repository of detailed information divided into thirty categories culled from a wide variety of sources, the *Mirror Origins* represented a post-Jesuit collection of practical knowledge by a well-placed scholar in the Kangxi and Yongzheng courts.

In his collection, Chen Yuanlong narrowed the focus of Hu Wenhuan's late Ming *Collectanea of Works Investigating Things and Extending Knowledge*, some of which had already been lost, to cover almost exclusively the arts and natural studies. For instance, Chen left out all poetry, rhyme-prose, and fanciful "stories," which separated the *Mirror Origins* from Hu's *Collectanea* because the latter had included what some considered fictional material. Special attention was given to the origins and evolution of printing and stone rubbings, in addition to topics dealing with geography, anatomy, flora and fauna, tools, vehicles, weapons, tools for writing, as well as clothing and architecture. The Imperial Library editors included Chen's work in the Imperial Library in the 1780s because they contended that Chen's catalog of entries "all were [examples of] broad learning and thus the work was titled 'investigating things and extending knowledge.'" They had not copied Hu Wenhuan's *Collectanea* into the imperial collection.³⁷

³⁶ See *Huangchao zhengdian leizuan* (Classified materials on Qing dynasty government regulations), compiled by Xi Yufu (Taipei, 1969), 191.7b-8a. For discussion of these technical court compilations, see Elman, *From Philosophy To Philology: Social and Intellectual Aspects of Change in Late Imperial China* (Los Angeles, 2001, revised, second edition), 116-20.

³⁷ See Chen, "Fanli" (Outline), in *Gezhi jingyuan*, in *Siku quanshu* (Complete collection of the four treasures) (Taipei, 1983-86, reprint), vol. 1031, 1-3.

Because there were clear limits to the impact of imperial policies outside the government itself, the impact of Jesuit translations could also be felt in the attention evidential scholars gave to the European fields of mathematics and astronomy first introduced in the seventeenth century. Such interest had built upon the early and mid-Qing findings of Mei Wending (1633-1721), who was warmly sponsored by the Kangxi emperor and Han literati once his expertise in mathematical calculation and calendrical studies was recognized. Mei had contended that study of physical nature gave scholars access to the classical "principles" (*li*) enunciated by Zhu Xi, which undergirded reality. In essence, Mei saw Jesuit learning as a way to boost the numerical aspects of the principles that pertained in astronomy.³⁸ Under imperial patronage, mathematical studies were upgraded during the Kangxi reign from an insignificant skill to an important domain of knowledge for literati that complemented classical studies. In terms of rhetoric, this sea change was justified by an appeal to the "Chinese origins of Western learning" (*Xixue Zhongyuan*).³⁹

Although evidentiary concerns were significant for their Ming predecessors, scholars of late eighteenth-century "evidential research" (*kaozheng*) stressed exacting research, rigorous analysis, and the collection of impartial evidence drawn from ancient artifacts and historical documents and texts. Qing evidential scholars made verification a central concern for the emerging empirical theory of knowledge they advocated, namely "to search truth from facts" (*shishi qiushi*), a Han dynasty expression used as a slogan for impartial scholarship in the eighteenth century. The mid-Qing program involved placing proof and verification at the center of the organization and analysis of the classical tradition in its complete, multidimensional proportions, which now included aspects of natural studies and mathematics.⁴⁰

³⁸ See Wang Ping, "Qingchu lisuanjia Mei Wending" (Mei Wending—early Qing calendrical specialist), *Jindaishi yanjiusuo jikan* (Taipei, Academia Sinica) 2 (1971): 313-24, and John Henderson, "The Assimilation of the Exact Sciences into the Ch'ing Confucian Tradition," *Journal of Asian Affairs* 5/1 (1980): 15-31.

³⁹ See Limin Bai, "Mathematical Study and Intellectual Transition in the Early and Mid-Qing," *Late Imperial China* 16/2 (1995): 23-61, Catherine Jami, "Learning Mathematical Sciences During the Early and Mid-Qing," in *Education and Society in Late Imperial China, 1600-1900*, ed. Elman and Woodside (Berkeley, 1994), 223-56, and Minghui Hu, "Provenance in Contest: Searching for the Origins of Jesuit Astronomy in Early Qing China, 1664-1705," *The International History Review* 24/1 (2002): 28-35.

⁴⁰ See Elman, *From Philosophy to Philology*, 28-38, 93-115, and *A Cultural History of Civil Examinations*, 451-59.

Qing philologists, because they were trained as classicists, were faced with numerous passages in the official classics associated with Confucius and unofficial mathematical and medical classics from antiquity, which required technical training in mathematics, astronomy, medicine, geography, and calendrical studies to decipher. In the nineteenth century, when scholars softened their positions on the distinction between evidential studies and Song Learning, literati such as Ruan Yuan (1764-1849) and the Cantonese Chen Li (1810-82) linked empiricism once again to the "investigation of things." Ruan Yuan noted: "Many earlier literati discussed 'the investigation of things,' but they associated it [with so many] empty meanings that they apparently failed to grasp that this was not the basic intent of the sages. I don't dare to be different in my discussion of 'the investigation of things,' yet [I say] it is the search for truth from facts and that's all."⁴¹

A full-blown scientific revolution as in Enlightenment Europe did not ensue, but Qing textual scholars made astronomy, mathematics, and geography part of their research programs, another by-product of the changes in classical studies then underway. Animated by a concern to restore native traditions in the precise sciences to their proper place of eminence, which early in the eighteenth century was legitimated by the Jesuit accommodation policy toward Chinese learning, later evidential scholars such as Dai Zhen (1724-77), Qian Daxin (1728-1804), and Ruan Yuan successfully incorporated technical aspects of European astronomy and mathematics into the literati framework for classical learning.⁴²

Varieties of Native Responses

Literati scholars took a range of positions concerning European natural studies. A private scholar, Jiang Yong (1681-1762), for instance, combined traditional loyalty to Zhu Xi's Song classical teachings with knowledge of Jesuit studies obtained through evidential studies. Conservative

⁴¹ See Ruan Yuan, *Yanjingshi ji* (Collection from the Studio for the Investigation of Classics), 3 vols. (Taipei, 1964), "Yiji," 2.23b-24a, and Chen Li, *Dongshu dustu ji* (Ch'en Li's reading notes) (Taipei, 1970), 9.14.

⁴² Nathan Sivin, "Why the Scientific Revolution did not take place in China—or didn't it?" reprinted in Sivin, *Science in Ancient China: Researches and Reflections* (Brookfield, 1995), 45-66. See also Han Qi, "Bai Jin de Yijing yanjiu he Kangxi shidai de xixue zhongyuan shuo" (Joachim Bouvet's study of the Change Classic and the theory of the Chinese origins of Western learning in the Kangxi period), *Hanxue yanjiu* (Taiwan) 16/1 (1998): 185-200.

as a classical scholar, Jiang was radical in his critique of both the evidential scholarship associated with Han Learning and Mei Wending's use of Song Learning in natural studies. Both, Jiang thought, exalted nativist ancient studies in all cases. Jiang Yong recognized the advantages European astronomy had over native traditions, while at the same time he continued to uphold the cultural superiority of the Zhu Xi view of morality. Although Jiang preferred "Western learning" for understanding the "principles" of nature because it was more precise and consistent than native traditions, he maintained a clear distinction between astronomical methods and cultural values.⁴³

Overall, Ruan Yuan's *Biographies of Astronomers and Mathematicians* (*Chouren zhuan*), compiled while the author served as governor in Hangzhou from 1797 to 1799, reprinted in 1849 and later enlarged, marked the climax of the celebration of natural studies within the eighteenth-century literati world of classical learning. Containing biographies and summaries of the works of 280 astronomers and mathematicians, including thirty-seven Europeans, this work was followed by four supplements in the nineteenth century. The mathematical sciences had begun to grow in importance among literati beyond the reach of the imperial court in the late eighteenth century. They were now linked to classical studies via evidential research. Because Ruan Yuan was a well-placed literati patron of natural studies in the provincial and court bureaucracy, his influential *Biographies* integrated the mathematical sciences with evidential studies. Mathematical and natural studies remained dependent on classical studies.⁴⁴

Via evidential studies, philology became one of the key tools that later scholars cum mathematicians and scientists, such as Xu Shou (1818-82) and Li Shanlan (1810-82), employed to build conceptual bridges between "Western learning" and the traditional Chinese sciences. In the process, modern science and mathematics were initially introduced in the nineteenth century as compatible with native classical and technical learning.

Once recovered in the late eighteenth century, the mathematically sophisticated Song-Yuan "heavenly unknown notation" (*tianyuanshu*) and "four unknowns notation" (*siyuanshu*) for expressing and solving quadratic and higher algebraic equations of several unknowns in tabular

⁴³ Chu Pingyi, "Ch'eng-Chu Orthodoxy, Evidential Studies and Correlative Cosmology: Chiang Yung and Western Astronomy," *Philosophy and the History of Science: A Taiwanese Journal* 4/2 (1995): 71-108.

⁴⁴ *Eminent Chinese of the Qing Period*, ed. Arthur Hummel, 402. See also Limin Bai, "Mathematical Study and Intellectual Transition in the Early and Mid-Qing," 23-30.

form, were thought by Qing evidential scholars to be superior to the algebraic techniques introduced to China by the Jesuits. Not until the introduction of the differential and integral calculus in the mid-nineteenth century by Protestant missionaries, for which the Chinese could not find a precedent in China, did Chinese mathematicians finally admit that although the "four unknowns notation" was perhaps superior to Jesuit algebra, the Chinese had never developed anything resembling the calculus.⁴⁵

In the interaction with European *scientia*, then, Ming and Qing literati were drawn into a moderate transformation of their own traditions of natural studies. In the late Qing, between 1865 and 1900, reformist Chinese officials and scholars further reworked the notion of "investigating things and extending knowledge" to designate "modern science" (*gezhexue*). Subsequently "investigating things and extending knowledge" was replaced in the early twentieth century by the Japanese term of *kexue* (*kagaku* in Japanese, literally, "classified learning based on technical training," that is, *wissenschaft*) as the better equivalent for "modern science." This repeated use of "investigating things and extending knowledge"—from 1600 to 1900—indicates that native terms for European "science" were contested at different times and in different ways.⁴⁶

Arguably, by 1600 Europe was already ahead of Asia in producing basic machines such as clocks, screws, levers, and pulleys that would be applied increasingly to the mechanization of agricultural and industrial production. China in the period from 1600 to 1800 did not "possess optical lens makers, horological gear-wheel cutters, and men who could make accurate micrometer screws." Once harnessed to steam power, machines became the engines of the nineteenth-century industrial revolution. In the seventeenth and eighteenth centuries, however, Europeans still sought the technological secrets for silk production, textile weaving, porcelain making, and large-scale tea production from the Chinese.⁴⁷ Chinese literati in turn, before 1800, borrowed from Europe new algebraic notations (of Hindu-Arabic origins), Tychonic cosmology, Euclidean

⁴⁵ Hu, Mingjie, "Merging Chinese and Western Mathematics: The Introduction of Algebra and the Calculus in China, 1859-1903" (Ph.D. dissertation, Princeton University, 1998), 180-231.

⁴⁶ For discussion, see Lydia Liu, *Translingual Practice: Literature, National Culture, and Translated Modernity—China 1900-1937* (Stanford, 1995), 20-42.

⁴⁷ D. Lach, *Asia in the Making of Europe*, 397-400. See also Han Qi, *Zhongguo kexue jishu de xichuan ji qi yingxiang* (The transmission of Chinese science and technology to the West and its influence) (Beijing, 1999), 135-69, on printing, porcelain, metallurgy, and textiles, and Lydia Liu's fascinating "Robinson Crusoe's Earthenware Pot," *Critical Inquiry* 25 (1999): 728-57.

geometry, spherical trigonometry, and arithmetic and trigonometric logarithms.⁴⁸

Indeed, the epistemological premises of modern science were not triumphant in China until the early twentieth century. Until the nineteenth century, Chinese elites and their Manchu rulers interpreted the transition in early modern Europe—from new forms of scientific knowledge to new modes of industrial power—on their own terms. Each side made a virtue out of the mutually contested accommodation project, and each converted the other's forms of natural studies into acceptable local conventions of knowledge. The Ming and Qing imperial court induced Jesuit calendrical, military, cartographic, and land mensuration experts to work as imperial minions in the government bureaucracy to augment each dynasty's own project of political and cultural control. Consequently, it would be a historiographical mistake to underestimate Chinese efforts to master on their own terms what they called "Western learning" in the sixteenth, seventeenth, and eighteenth centuries.

If Europeans increasingly thought themselves scientifically and technologically superior to others after 1500, as Michael Adas has shown, neither Ming nor Qing Chinese literati agreed with this perspective until the military effects of the nineteenth century industrial revolution were plainly visible on the naval battlefields in the East China Sea.⁴⁹ Unlike the colonial environment in India, where British imperial power after 1700 could dictate the terms of social, cultural, and political interaction, natural studies in late imperial China, as in Japan, were until 1900 part of a nativist imperial project to master and control European views on what constituted legitimate natural knowledge.⁵⁰

Late imperial Chinese literati and their government, whether under a Ming Chinese or Qing Manchu ruler, effectively contested all European claims to scientific and religious superiority at every stage of interaction after 1580. One of the reasons we have accounts of the conditions in Chinese prisons in the sixteenth and seventeenth centuries, for instance, is that those accounts were prepared by overly aggressive religious proselytizers from the Augustinian, Dominican, and Franciscan orders who

⁴⁸ Allan Chapman, "Tycho Brahe in China: the Jesuit Mission to Peking and the Iconography of European Instrument-Making Processes," *Annals of Science* 41 (1984): 441.

⁴⁹ See Michael Adas, *Machines as the Measure of Men: Science, Technology, and Ideologies of Western Dominance* (Ithaca, 1989), *passim*.

⁵⁰ On India, see Bernard Cohn, *Colonialism and Its Form of Knowledge: The British in India* (Chicago, 1996), 5-56, and Gyan Prakash, *Another Reason: Science and the Imagination of Modern India* (Princeton, 1999), 3-14, 17-85. On Japan, see Numata Jirō, *Western Learning: A Short History of the Study of Western Science in Early Modern Japan* (Tokyo, 1992), 3-4, 97, 147-69.

were locked up by the Ming imperial state as rabble-rousers. Similarly, the terms for Adam Schall von Bell's (1591-1666) incarceration under the Qing are instructive.⁵¹ Native vicissitudes in the emergence of modern science in China, as in Japan and India, deserve a more nuanced account, one that is not automatically subsumed under the neat, historical cadences of the rise of modern science in early modern Europe circa 1500-1800.⁵²

Appendix 1: Glossary of Chinese and Japanese Terms and Titles in Main Text

- Bencao gangmu* 本草綱目
bishou 筆受
bowu 博物
Bowu zhi 博物志
 Cao Zhao 曹昭
 Chen Li 陳澧
 Chen Yuanlong 陳元龍
Chouren zhuan 疇人傳
 Dai Zhen 戴震
 Dao 道
Dongshu dushu ji 東塾讀書記
Erya 爾雅
 Fanli 凡例
fenye 分野
Gegu yaolun 格古要論
gewu 格物
 Gewu qiongli yuan 格物窮理院
gewu zhizhi 格物致知
gezhi 格致
Gezhi congshu 格致叢書
Gezhi jingyuan 格致鏡原
gezhixue 格致學
Gezhi yulun 格致餘論
 Hu Wenhuan 胡文煥

⁵¹ See Chu, "Scientific Dispute in the Imperial Court," 16-17. Derk Bodde, "Prison Life in Eighteenth Century Beijing," *Journal of the American Oriental Society* 89 (1969): 311-33, gives references to earlier accounts of prisons.

⁵² Roger Hart, "Beyond Science and Civilization: A Post-Needham Critique," *East Asian Science, Technology, and Medicine* (formerly *Chinese Science*) 16 (1999): 88-114.

- Huangyu quanlan tu* 皇輿全覽圖
 Jiang Yong 江永
kaozheng 考證
kexue 科學
Kongji gezhi 空際格致
kouyi 口譯
Kunyu gezhi 崑崙格致
Kunyu tushuo 坤輿圖說
li 理
 Li Shanlan 李善蘭
 Li Shi 李石
 Li Shizhen 李時珍
 Li Zhizao 李之藻
 Mei Wending 梅文鼎
qi 氣
 Qian Daxin 錢大昕
qiongli 窮理
riyong leishu 日用類書
 Ruan Yuan 阮元
shen 神
shishi qishi 實事求是
Siku quanshu 四庫全書
siyuanshu 四元術
Suanxue guan 算學館
taiji 太極
Taixi shuifa 泰西水法
tianyuananshu 天元術
 "Tiyao" 提要
 Wang Yangming 王陽明
 Wang Zuo 王佐
 Xiong Mingyu 熊明遇
Xixue 西學
 "Xu" 序
Xu bowu zhi 續博物志
 Xu Shou 徐壽
 Zhang Hua 張華
 Zheng He 鄭和
zhengming 正名
zhi 質
 Zhu Xi 朱熹
 Zhu Zhenheng 朱震亨

Appendix 2: Characters for Chinese and Japanese Language Works Cited
in Footnotes

- Han Qi 韓琪, "Gewu qiongli yuan yu Mengyangzhai: shiqi shiba shiji zhi Zhong-Fa kexue jiaoliu" 格物窮理院與蒙養齋:十七十八世紀之中法科學交流, *Faguo hanxue* 法國漢學 4C.
- , "Bai Jin de Yijing yanjiu he Kangxi shidai de xixue zhongyuan shuo" 白晉的易經研究和康熙時代的西學中源說, *Hanxue yanjiu* 漢學研究.
- , *Zhongguo kexue jishu de xichuan ji qi yingxiang* 中國科學技術的西傳及其影響.
- Huangchao zhengdian leizuan* 皇朝政典類纂, compiled by Xi Yufu 席裕福.
- Ōba Osamu 大庭脩, *Edo jidai ni okeru Chūgoku bunka juyō no kenkyū* 江戸時代における中國文化受容の研究.
- Ruan Yuan, *Yanjingshi ji* 擘經室集 "Yiji" 一集.
- Sakade Yoshinobu 土反出祥伸, "Kaisetsu—Mindai nichiyō ruisho ni tsuite" 解說—明代日用類書について.
- Sakade Yoshinobu et al., *Chūgoku nichiyō ruisho shūsei* 中國日用類書集成. *Siku quanshu zongmu* 四庫全書總目.
- Tianzhujiao dongchuan wenxian sanpian* 天主教東傳文獻三篇.
- Wang Baoping 王寶平, "Mindai no kakushoka Ko Bunkan ni kan suru kōsatsu" 明代の刻書家胡文煥に関する考察, *Kyūko* 汲古.
- , "Zhongguo Hu Wenhuan congshu jingyan lu" 胡文煥叢書經眼錄, in *Zhong Ri wenhua luncong* 中日文化論叢 (1991).
- Wang Ping 王萍, "Qingchu lisuanjia Mei Wending" 清初曆算家梅文鼎, *Jindaishi yanjiusuo jikan* 近代史研究所集刊.
- Xu Guangtai 徐光台, "Mingmo Qingchu xifang gezhi xue de chungji yu fanying: yi Xiong Mingyu Gezhi cao wei li" 明末清初西方格致學的衝擊與反應:以熊明遇格致草爲例, in *Shibien chunti yu geren* 世變, 群體與個人.
- Yamada Keiji 山田慶兒, *Shushi no shizengagu* 朱子の自然學. *Zhuzi yulei* 朱子語類.