Some Comparative Issues in the World History of Science and Technology: Jesuit Learning in Late Imperial China

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Abstract

For over a century, Europeans have heralded the success of Western science and assumed the failure of science elsewhere. Since 1954, Joseph Needham had stressed the unique rise of modern science in Europe, but at the same time he acknowledged the achievements in traditional Chinese science and technology until 1600. In the decades since Needham answered his provocative question, "why didn't the pre-modern Chinese develop modern science?" we have increasingly acknowledged that our focus on the "failure" of Chinese science to develop into modern science is heuristically interesting but historiographically misguided. We are now forced to reassess how the history of science globally should be rewritten. This article will focus on why the Chinese never learned about the "Newtonian Century" in Europe and its analytic style of mathematical reasoning until after the Opium War (1839–1842). Some still contend that the Qing state during the Macartney mission in 1793, for example, was too closed-minded to learn about the emerging early modern world. With hindsight, such views appear incontrovertible, but there were many external factors to China, such as the collapse of the Jesuit mission in China and Europe in the middle of the eighteenth century, which help explain why the Newtonian revolution came so late in Asia, and not in the eighteenth century.

Key words: history of science, technology, Jesuits in China, Macartney mission

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. Narrative accounts of the history of science worldwide from 1500–1800 have, until recently, been portrayed mainly through European frames of refer-

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ence, even when comparative themes are stressed. These Eurocentric portraits of the rise of modern science, which are 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 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.[1]

The basic argument presented in Toby E. Huff, *The Rise of Early Modern Science: Islam, China, and the West*, one of the most ecumenical of works in the genre of the comparative historiography of science, is that the fortuitous concatenation of Greek natural philosophy, Roman civil law, and rationalist Christian theology during the twelfth century Renaissance created an intellectual climate conducive for the emergence of the European scientific revolution in the seventeenth century. By comparison, the promising development of Arabic science before the fourteenth century was subsequently aborted by the power of the Islamic clergy to Islamicize foreign knowledge and exclude natural science from the education curriculum in universities. Similarly in China, where the Song dynasty (960–1280) was well advanced in technology before the thirteenth century Mongol conquest, the retarding influence of the imperial state and its civil service examination curriculum based on the Confucian Classics prevented autonomous institutions conducive to the social legitimation of men of science to emerge. Only in late medieval Europe did legal, social, and institutional revolutions occur that permitted rise of autonomous universities in which study of natural science was affirmed by both state and society. Only in Europe did the requisite "neutral spaces for public discourse" appear that "created structures of action and agency" conducive for growth of the impartial and skeptical "ethos of science."

Adopting what Huff calls "civilization frames of reference," his book describes "cultural climates" in medieval Europe, the Islamic world, and imperial China that abetted or hindered emergence of "modern science" in each cultural region. The cultural trajectories of Christian Europe, Islamic Asia, and Confucian China are examined according to affinities with the roles of scientists in society, development of social norms of impartiality and legitimate skepticism, and elaboration of an autonomous reward system under control of professional members of scientific communities. Islamic breakthroughs in study of the natural world were initially advanced because of input from Greek and Indian natural philosophy and mathematics. In the fields of optics, astronomy, and medicine, Islamic scholars were important pioneers, but the

1. See Toby Huff, *The Rise of Early Modern Science: Islam, China, and the West* (Cambridge, UK: Cambridge University Press, 1993/2003, second edition). See also my review of the first edition in *American Journal of Sociology*, 100.3(1994), pp. 817–819.

fate of the Marâgha Observatory, which flourished in Tabiz between 1259 and 1305, is emblematic according to Huff of the short-lived success of Islamic science. Clerical power based on Islamic mysticism, fundamentalist appeals to sacred law (*shari'a*), and the inherent elitism and secrecy of Islamic elites over the long-term created obstacles that effectively prevented emergence of modern science.

In China, according to Huff, social and political elites had access to the fruits of Islamic science in the Mongol era, and they had access to European science through the Jesuits in the seventeenth century. Despite their technological head start in the Song dynasty, Chinese were unable to break through roadblocks erected by the imperial state (required secrecy imposed on state astronomers and mathematicians) and the alternative and more appealing reward system (based on competitive examinations) to become a Mandarin official that diverted incentives toward study of the Confucian Classics and away from precise study of natural phenomena. In Europe, according to Huff, the late medieval "legal, social, and institutional revolution" singularly provided fertile ground for planting seeds for modern science in the twelfth century that grew to maturity in the seventeenth.

Huff's history of European, Islamic, and Chinese science focuses on the intellectual history of natural philosophy in cultural and social context. By rejecting Joseph Needham's claim that there is no meaningful distinction between science and technology, Huff too conveniently concludes that experimentalism after Galileo was not the driving force in the birth of modern science and that in China technological superiority had little to do with Chinese natural knowledge. By sowing the seeds of scientific revolution in Catholic culture before the Protestant Reformation, Huff presents the "symbolic technology" of late medieval Europe as the key to that revolution without fully coming to grips with the problem of why it took over five centuries for European natural philosophy to begin to produce the industrial revolution.

In the final analysis, therefore, Huff's otherwise thoughtful comparative history of science essentializes science as a universal mental exercise practiced only in neutral institutions within an open society. The intellectual revolution—its philosophical roots and cultural context in Catholic Europe—is not properly contextualized historically in light of the later political and industrial significance of the scientific revolution in Protestant Northwestern Europe. By surgically eliding technology and industry from the problem of the scientific revolution, Huff thus avoids coming to grips with the more convincing "Protestant" history of science and industry as elaborated by Margaret C. Jacob,[2] or the actual practice of modern science as described by Bruno Latour.[3]

2. See Margaret Jacob, *Scientific Culture and the Making of the Industrial West* (New York: Oxford University Press, 1997).

Moreover, without any discussion of technology, Huffs history of science in Catholic Europe, the Islamic world, and in imperial China is limited to the domains of Catholic, Islamic and Confucian educational institutions. Huff's comparison of Catholic Europe, Islamic Asia, and Confucian China in terms of natural philosophy and educational institutions is timely and rewarding, but his conclusions are insufficient to understand why elites and commoners in Europe, the Islamic world, and China were interested in the natural world and how they actually created and applied their natural knowledge before the scientific revolution.

1. China, India, and Japan

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 production. Once harnessed to steam power, machines became the engines of the nineteenth century industrial revolution. But in the seventeenth century, Europeans still sought the technological secrets for silk, textile weaving, porcelain, and tea production from the Chinese.[4] Chinese literati in turn borrowed from Europe new algebraic notations (of Hindu-Arabic origins), geometry, trigonometry, and logarithms from the West.

Indeed, the epistemological premises of modern Western science were not triumphant in China until the early twentieth century. Until 1900, then, Chinese elites 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. Moreover, the accommodation project should be viewed as something more than an imaginary shared rationalism between the Jesuits and Chinese literati. As we will see below, comparison between late imperial China and early modern Europe, as with India and Japan, should also take into account natural anomalies, monsters, supernatural events,

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3. Bruno Latour, *Science in Action: How to follow scientists and engineers through society* (Cambridge, MA: Harvard University Press, 1987).
4. Donald F. Lach, *Asia in the Making of Europe. Volume II. A Century of Wonder, Book 3: The Scholarly Disciplines* (Chicago: University of Chicago Press, 1977), pp. 397–400. See also Han Qi, *Zhongguo Kexue Jishu de Xichuan ji qi Yingxiang(The Westward Transmission of Chinese Science and Technology and Its Influence)* (Shijiazhuang: Hebei Renmin Chubanshe, 1999), pp. 135–169, on printing, porcelain, metallurgy, and textiles, and Lydia Liu, "Robinson Crusoe's Earthenware Pot," *Critical Inquiry*, 25 (1999), pp. 728–757.

and religious faith.[5]

If Europeans increasingly thought themselves scientifically and technologically superior after 1500, as Michael Adas has shown, neither the Chinese nor Japanese agreed with this perspective until the effects of the nineteenth century industrial revolution were visible. In Japan, for instance, aristocratic and merchant elites domesticated Western learning using classical Chinese and Japanese frames of reference—despite the impact of "Dutch Learning" in the seventeenth and eighteenth centuries—until the Meiji period (1868–1911).[6] Unlike the colonial environment in India, where British imperial power after 1700 could dictate the terms of social, cultural, and political interaction between natives and Westerners, natural studies in late imperial China were until 1900 part of a nativist imperial project to master and control Western views on what constituted legitimate natural knowledge.[7]

In South Asia, on the other hand, the British colonial regime successfully set the epistemological agenda for natural studies in "India" by defining the body of Western knowledge that would be augmented in that colony through local collecting procedures. Such knowledge would in turn be ordered and classified according to the standards of authoritative British scientific practice. Colonial forms of knowledge, according to Bernard Cohn, translated into reports, statistical records, histories, gazetteers, legal codes, and encyclopedias that induced elites in "India" to become part of Britain's project of political and cultural control. Through such knowledge formation within the Western structures of science, colonized natives acquired enough practical experience to understand how natural knowledge was acquired, studied, and interpreted.[8]

5. See Donald Mungello, *Curious Land: Jesuit Accommodation and the Origins of Sinology* (Honolulu: University of Hawaii Press, 1985), pp. 23–43, and Lionel Jensen, *Manufacturing Confucianism: Chinese Traditions and Universal Civilization* (Durham, NC: Duke University Press, 1997), pp. 34–75. See Qiong Zhang, "About God, Demons, and Miracles: The Jesuit Discourse on the Supernatural in Late Ming China," *Early Science and Medicine*, 4.1(1999), pp. 1–36.
6. See Michael Adas, *Machines as the Measure of Men: Science, Technology, and Ideologies of Western Dominance* (Ithaca: Cornell University Press, 1989), passim. See also Wai-ming Ng, "The *I Ching* in the Adaptation of Western Science in Tokugawa Japan," *Chinese Science*, 15 (1999), pp. 94–115, Grant Goodman, *Japan: the Dutch Experience* (London and Dover(N.H.): Athlone Press, 1985), p. 228, and Masao Watanabe, *The Japanese and Western Science* (Philadelphia: University of Pennsylvania Press, 1990).
7. On India, see Bernard Cohn, *Colonialism and Its Form of Knowledge: The British in India* (Chicago: University of Chicago Press, 1996), pp. 5–56. See also Gyan Prakash, *Another Reason: Science and the Imagination of Modern India* (Princeton: Princeton University Press, 1999), pp. 3–14, which notes that the British "civilizing mission" in India initiated the cultural authority of modern science in South Asia. Prakash adds that nativists also identified a body of indigenous South Asian traditions consistent with Western science, but he focuses on colonialist discourses rather than pre-colonial traditions in natural studies in India.
8. Bernard Cohn, *Colonialism and Its Form of Knowledge,* pp. 5–76.

Gyan Prakash adds to Cohn's perspective an account of how the British regime actually "staged" science in India via museums, exhibitions, and governmental projects throughout the colony. Such stagings thereby presented science as a universalist sign of modernity, which augmented colonial rule by educating native elites in the acceptable forms of scientific knowledge and natural history. Western educated elites then portrayed modern science and technology as a preferred value system and useful technology, which could enrich indigenous traditions. Prakash also describes how native elites renegotiated the terms of their acceptance of the British regime of science and technology and created a hybrid discourse of science and nation that included the Vedas and inscribed Hindu philosophy with modernist claims of nationalism. The colonized thus were not passive agents in their participation in the production of modern science. Colonial power provided the intellectual space within which Indian intellectuals appropriated science and refashioned their own traditions in light of the ideals of universal science and not simply British colonial power. Prakash describes this process as the indigenization of the authority of science and the formation of a Hindu modernity out of the colonial experience. One ironic result was the eventual gainsaying of the British colonialist regime by the very Indian nationalists cum modernists the British Raj produced.[9]

2. The Jesuits in Late Imperial China

Fascinating as the colonial case is in the rise of modern science in India, late imperial Chinese literati and the imperial government, whether under a Chinese or Manchu ruler, openly and effectively contested all European claims to scientific and religious superiority at every stage of interaction since 1550. One of the reasons why we have detailed 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 Domincan and Franciscan orders who were locked up by the imperial state as rabble-rousers.[10]

Because they were not and did not perceive themselves as subordinated to the West, until the late nineteenth century perhaps, Chinese and Manchus did not have to engage in the covert colonialist renegotiations that Hindu nativists in India carried out. At the same time, the imperial court induced Jesuit calendrical, military, and land men-

9. Gyan Prakash, *Another Reason: Science and the Imagination of Modern India,* pp. 17–85. See also Paula Findlin, *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy* (Berkeley: University of California Press, 1994), pp. 1–11.
10. Derk Bodde, "Prison Life in Eighteenth Century Peking," *Journal of the American Oriental Society*, 89 (1969), pp. 311–333, gives references to earlier accounts of prisons.

suration experts to work as imperial minions in the state bureaucracy to augment first the Ming (1368–1644) and then the Qing (1644–1911) 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 (known as *Xixue* 西學 or *Gezhixue* 格致學) of the Jesuits in the sixteenth, seventeenth, and eighteenth centuries.[11]

Literati scholars and Chinese and Muslim specialists in the government's imperial calendrical bureau interpreted early modern Western achievements in calendrical reform and natural studies in light of nativist traditions of scholarship. Derived from Christopher Clavius' success in moving the Papacy and Western Christendom from the Julian to the Gregorian calendar in 1582, the technical prowess that some Jesuits such as Matteo Ricci (1552–1610) had learned as a result of studying under Clavius proved fortuitous in Ming China. Ming concerns about the accuracy of the official calendar forced Chinese literati to evaluate and apply specific Jesuit techniques to reform of the Ming calendar.[12]

This "local" research agenda among the court's calendrical specialists represented neither an indigenous modernization process nor the beginnings of a modest scientific revolution, at least by Western standards.[13] And in not searching for a Western form of modernity until the late nineteenth century, late imperial Chinese and Manchus were not acting out a purely anti-Western ideological agenda either, although at times court politics in Beijing interceded and the Jesuits as bearers of Western tidings were faced with the political animosities such "new" learning produced among those in power who were satisfied with the "old" learning.

Unfortunately, one of the most common generalizations scholars make today concerning the role of "science" (= "natural studies") in late imperial China is that after about 1300 studies of astronomy and mathematics were in steady decline there until the arrival of Jesuit missionaries in the sixteenth century.[14] When Matteo Ricci

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11. See Xu Guangtai, "Ruxue yu Kexue: Yi ge Kexueshi Guandian de Tantao (Confucianism and Science: From a Viewpoint of History of Science)," *Qinghua Xuebao (Tsing Hua Journal of Chinese Studies)*, 26. 4 (1996), pp. 369–392.
12. Peter Dear, "Jesuit Mathematical Science and the Reconstitution of Experience in the Early Seventeenth Century," *Studies in History and Philosophy of Science*, 18 (1987), pp. 135–141, and Willard Peterson, "Calendar Reform Prior to the Arrival of Missionaries at the Ming Court," *Ming Studies*, 21 (1986), pp. 45–61.
13. But see 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,* VII (Brookfield: Variorium, 1995), pp. 45–66.
14. Keizō Hashimoto, *Hsu Kuang-ch'i and Astronomical Reform* (Osaka: Kansai University Press, 1988), p. 17.

described the scientific prowess of 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."[15]

Chinese mathematics and astronomy, according to this view, had reached their pinnacle of success during the Song and Yuan (1280–1368) dynasties but had declined precipitously during the Ming.[16] This longstanding perspective has been challenged by recent studies that indicate: 1) the Jesuits and their Chinese collaborators knew little of Chinese natural studies; 2) mathematics and calendar reform were important concerns among Ming literati before the arrival of the Jesuits in China.[17] Others have demonstrated that the Jesuits misrepresented their knowledge of contemporary European astronomy to suit their religious objectives during the late Ming and early Qing dynasty. Such self-serving tactics, which produced contradictory information about new, Copernican trends in European astronomy, lessened their success in transmitting the European sciences to late Ming dynasty (1368–1644) literati.[18] From this new perspective, late Ming scholars were not lifted out of their scientific "decline" by contact via the Jesuits with European astronomy. Rather, they themselves reevaluated their astronomical legacy and its current inadequacies, successfully taking into account per-

15. Matteo Ricci, *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: Random House, 1953), pp. 31–33.
16. For the conventional perspective, see Joseph Needham, *Science and Civilization in China,* vol. 3 (Cambridge, UK: Cambridge University Press, 1959), p. 173, 209, and Ho Peng Yoke, *Li, Qi, and Shu: An Introduction to Science and Civilization in China* (Hong Kong: Hong Kong University Press, 1985), p. 169.
17. See Roger Hart, "Proof, Propaganda, and Patronage: A Cultural History of the Dissemination of Western Studies in Seventeenth-Century China," Ph.D. Dissertation (Los Angeles: University of California, 1996), passim. See also Thatcher E. Deane, "The Chinese Imperial Astronomical Bureau: Form and Function of the Ming Dynasty 'Qintianjian' From 1365 to 1627," Ph.D. Dissertation (Seattle: University of Washington, 1989), which documents in detail the voluminous record of calendrical reform efforts in China from the early empire to the late Ming before the Jesuits.
18. Nathan Sivin, "Copernicus in China," in Marian Biskup ed., *Colloquia Copernica II: Études sur l'audience de la théorie héliocentrique* (Warsaw: Union Internationale d'Historie et Philosophie des Sciences, 1973), pp. 63–114.

tinent features of the European sciences introduced by the Jesuits.[19]

To paraphrase the views of Peter Winch, we must first acknowledge that as yet we do not have appropriate categories of learning that resemble the pre-modern Chinese frames for what we call "natural studies" or "natural history," and according to which Chinese evaluated Western learning.[20] Moreover, as Donald F. Lach has pointed out, an analytical ordering of early modern European scholarship within the framework of modern learning is equally problematic.[21] To understand the pre-modern Chinese frames for their knowledge systems of the natural world, as for early modern Europe, we should first try to extend our own understanding and make room for them. Placing natural studies in China within its own internal and external contexts enables us to reconstruct its communities of interpretation.[22]

Simply understanding Chinese views of the natural world in light of our own modern Western distinctions between science and non-science has not gotten us very far beyond the usual narratives of Western "success" in science and the concomitant Chinese "failure." The issue of "superiority" or "inferiority" of natural studies in late imperial China vis-à-vis early modern Europe should be "bracketed" as an unnecessary value judgment, because by today's standards both the pre-Newtonian, Aristotelian framework for natural studies (dominant in Europe to 1600) and the organicistic system of classical explanations (used in imperial China) have each been discredited. Choosing between the "four elements" of the Greeks and Romans, which the Jesuits transmitted to Ming China, and the "five phases" of the Chinese, which the Jesuits discredited, is now a historical— not a cutting-edge scientific— problem.[23] Indeed, the exact premises for the European monopoly of modern science since 1700 (some would mistakenly say since 1500) must be unraveled before we can compare and contextualize the bicultural historical dialogue from 1550 to 1800 between late imperial Chinese

19. Jacques Gernet, *China and the Christian Impact* (Cambridge, UK: Cambridge University Press, 1982), pp. 15–24. See also Sivin's biography of "Wang Hsi-shan (1628–1682)," in Charles Coulston Gillispie ed., *Dictionary of Scientific Biography*, vol. 14 (New York: Scribner's Sons, 1976), pp. 159–168, and Thatcher E. Deane, "The Chinese Imperial Astronomical Bureau," pp. 401–441.

20. Peter Winch, "Understanding a Primitive Society," in Bryon Wilson ed., *Rationality* (Oxford: Basil Blackwell, 1970), pp. 93–102.

21. Donald F. Lach, *Asia in the Making of Europe. Volume II. A Century of Wonder, Book 3: The Scholarly Disciplines*, p. 395.

22. Cf. Stanley J. Tambiah, *Magic, Science, Religion, and the Scope of Rationality* (Cambridge, UK: Cambridge University Press, 1990), p. 154.

23. See Qiong Zhang, "Demystifying *Qi*: The Politics of Cultural Translation and Interpretation in the Early Jesuit Mission to China," in Lydia Liu, ed., *Tokens of Exchange: The Problem of Translation and Interpretation in the Early Jesuit Mission to China* (Durham: Duke University Press, 1999).

elites (who in no way felt inferior) and early modern Europeans (many of whom recognized in learned Chinese literati a powerful intellectual tradition) concerning fathoming and measuring the natural world.[24]

3. Natural Studies in China and the West, 1550–1700

For example, when Europeans reached China during the "age of exploration," the scientia of their men of learning did not mean or connote "natural science" per se among humanists, Jesuits, or more secular scholars in early modern Europe. A medieval French term, science, which was synonymous with "accurate and systematized knowledge," became, when Latinized, "scientia." The word represented among scholastics and early modern elites the specialized branches of Aristotelian moral and natural philosophy.[25] Included were the seven sciences of medieval learning: grammar, logic, rhetoric, arithmetic, music, geometry, and astronomy.[26] These seven liberal arts in Roman times had served educationally as preparation for more specialized training in philosophy, medicine, or law. In medieval times, Boethius' (c. 475–524) pioneering translations of Aristotle into Latin, for example, named the four mathematical disciplines (arithmetic, geometry, music, and astronomy) as the *quadrivium* (four roads to wisdom), which balanced the three disciplines of logic (grammar, dialectics, rhetoric) known later as the *trivium* (three roads). By the time of Thomas Acquinas in Paris, the logical order of Aristotelian learning had been set for the Renaissance scholars and bookmen: 1) logic; 2) mathematics; 3) natural science; 4) moral philosophy; and 5) metaphysics.[27]

Similarly in Ming China, when terms such as *scientia* were translated by the Jesuits and their Chinese colleagues from Latin into classical Chinese, the elite written language of Chinese literati, the translations reflected the views and frames for the natural studies of the sixteenth century in China and Europe—not the "science" of more modern times. "*Xuewen* 學問" was the classical Chinese equivalent to correlate native

24. Gyan Prakash, *Another Reason: Science and the Imagination of Modern India*, pp. 17–120, describes how modern science in colonial India initially was a British monopoly that was translated intellectually and transmitted materially downward to India's social and political elites and later was indigenized in nationalist ideology.
25. See James Weisheipl, "Classification of the Sciences in Medieval Thought," *Medieval Studies*, 27 (1965), pp. 54–55.
26. See Sydney Ross, "*Scientist*: The Story of a Word," *Annals of Science*, 18.2 (1962), pp. 65–71, who notes that the term "scientist" was not commonly used in English until the nineteenth century.
27. James Weisheipl, "Classification of the Sciences in Medieval Thought," pp. 58–68, 81–90.

categories of specialized learning with the *scientia* of the Jesuits.[28] Moreover, in the Jesuit-Chinese interaction, the "investigation of things," "exhaustively mastering principles," and "knowing heaven" (窮理知天) were at core of the intellectual encounter between China and the West. These classical Chinese terms were used by Chinese literati and Jesuits to accommodate both western and Chinese views of practical studies, which included natural studies. In this cultural endeavor, we see an overlap between religious and scientific work on the part of the Jesuits and their Chinese converts and sympathizers.[29]

The Jesuits saw the "investigation of things" (格物) and "exhaustively mastering principles" (窮理) as a necessary way-station to the doctrinal transmission of the experience of God to the Chinese. For late Ming Chinese, their recovery of the "concrete studies" (實學) of antiquity predisposed some literati to accept the Western learning brought by Jesuits because it was an alternate form of the "investigation of things" and was presented by the Jesuits as a confirmation of Chinese ancient learning. Because of the physico-theology lurking in the Jesuits teleology of nature, however, the investigation of things was ultimately "to find God" for the Jesuits and "to fathom principles" for the Chinese. Despite this twist to the Jesuit interpretation, the Jesuit conception and practice of *scientia* roughly corresponded to the natural studies of the Chinese, or so it was presented.[30]

Both sides saw an order and purpose in the cosmos and on earth, which the Jesuits linked into a physico-theology that used 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 teleological view of nature framed arguments for the design of the cosmos around an eternal and always changing Dao rather than around the chronology of a divine providence informing the cosmic order in Christianity. In place of a cosmos made up of "four elements" (air-ether, fire, earth, water), the Chinese conceived

28. On the issue of *scientia* = *xuewen* in Chinese glosses of Latin terms, I have benefited from discussion concerning Latin-Chinese glossaries with Han Qi 韓琦 of the Chinese Academy of Sciences, Beijing. Latin-Chinese word glossaries compiled by the Jesuits and their Chinese collaborators were of course forerunners of modern dictionaries of the Chinese language. For a conceptual mapping project of Latin materials on China in Rome currently underway, see Federico Masini, "Using the works of the Jesuit missionaries in China to study the Chinese language: a research project," paper presented at the International Conference "Translating Western Knowledge into Late Imperial China," Göttingen: Göttingen University, December 6–9, 1999.

29. Nicolas Standaert, S. J., "The Investigation of Things and the Fathoming of Principles (*Gewu Qiongli*) in the Seventeenth-Century Contact Between Jesuits and Chinese Scholars," in John W. Witek, S. J. ed., *Ferdinand Verbiest (1622–1688): Jesuit Missionary, Scientist, Engineer and Diplomat* (Nettetal: Steyler Verlag, 1994), pp. 395–420.

30. Ibid.

of change in light of a "Supreme Ultimate" (*Taiji* 太極), which through the medium of yang and yin forces set in motion the five phases (*Wuxing* 五行, earth, fire, metal, water, and wood) of cosmic evolution and yielded the concomitant production of the "myriad things" (*Wanwu* 萬物) in the world.[31]

In an analogous way, the term "*Gezhi*" 格致 (lit., "inquiring into and extending knowledge," *Gewu Zhizhi* 格物致知) was also chosen by Ming literati in the seventeenth century as roughly equivalent to early modern European natural studies, which were the preserve of Renaissance humanists and Counter-Reformation Jesuits, who still championed Aristotelian frames for "scientific knowledge."[32] "Natural studies" in China had at times since the Yuan dynasty been classified under the phrase *gezhi*. At other times, particularly in the medieval period, and often simultaneously after the Yuan, such interests were expressed in terms of *Bowu* 博物 (lit., "broad learning concerning the nature of things"). The full mapping out of the asymmetrical conceptual categories associated with these two potential candidates in late imperial times for "natural studies" and "natural history" respectively remains incomplete. Moreover we are still unsure how the two terms usually were deployed vis-à-vis each other. In addition, in ancient and medieval bibliographic classifications other terms such as *Shuji* 術技 (skills and techniques) were used to demarcate what we today refer to as science and technology. Nonetheless, it appears to me, tentatively, that among late imperial literati elites *Gezhi* 格致 was the most common epistemological frame for the accumulation of knowledge *per se*. *Bowu* 博物 on the other hand carried with it a more common and popular notion of "curiosities."[33]

The influential philosopher Zhu Xi 朱熹 (1130–1200), who—similar to Thomas Acquinas's role vis-à-vis the Scholastic Canon—became the core interpreter of the late imperial classical canon, argued that "inquiring into and extending knowledge" presupposed that all things had their principle (*Wanwu zhi Li* 萬物之理). Thereafter, the "investigation of things" became the key to opening the door of knowledge for Chinese

31. For discussion, 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: University of California Press, 1967), and Keith Thomas, *Man and the Natural World: Changing Attitudes in England, 1500–1800* (London: Penguin Books, 1983).
32. James Weisheipl, "Aristotle's Concept of Nature: Avicenna and Acquinas," in Lawrence Roberts ed., *Approaches to Nature in the Middle Ages,* vol. 16 (Binghamton: Center for Medieval and Early Renaissance Studies Series, 1982), pp. 137–160.
33. See Robert F. Campany, *Strange Writing: Anomaly Accounts in Early Medieval China* (Albany: SUNY Press, 1996), pp. 49–52. See also, Qiong Zhang, "Nature, Supernature, and Natural Studies in Sixteenth- and Seventeenth-Century China," paper presented at the Colloquium sponsored by the Center for the Cultural Studies of Science, Medicine, and Technology, Los Angeles: UCLA History Department, November 16, 1998.

literati versed in the Classics and Histories, and hence why in the Jesuit-Chinese dialogue the term occupied such an important place.[34] Due to Zhu Xi's scholarly eminence after the Southern Song dynasty, *Gezhi* 格致 became a popular classical (lit., *Daoxue* 道學 [Dao Learning], often called "Neo-Confucianism") term borrowed from the Great Learning (*Daxue* 大學; one of the Four Books) in the *Record of Rites* (*Liji* 禮記 one of the Five Classics) by literati to discuss the form and content of all knowledge, i.e., *scientia*, in scholastic terminology.[35]

Gezhi studies were the preferred genre for Jesuit presentation of astronomical and philosophical works, which would complement religious works to prove the truth of Christianity. Early Jesuit translations of Aristotle's theory of the four elements (*Kongji Gezhi* 空際格致, lit., "investigation of space," 1633) and Agricola's *De Re Metallica* (*Kunyu Gezhi* 坤與格致, lit., "investigation of the earth," 1640) into classical Chinese, for example, had used the term *Gezhi* 格致 in light of the Latin *scientia* (= "organized or specialized knowledge") in their titles.[36] Alphonso Vagnoni's (Gao Yizhi 高一志) 1633 *Kongji Gezhi*, was in part a refracted presentation of the theory of the four elements from the Conimbricenses edition of Aristotle's *Meteriologica* entitled *In Libros meteorum*, which was then used in the Jesuit University of Coimbra in Portugal where many missionaries were trained before leaving for Asia. Adam Schall's *Kunyu Gezhi* (1640) was presented as a manuscript to the Ming emperor. In addition, there were Ferdinand Verbiest's *Kunyu Gezhi Lueshuo* 坤與格致略說 (Precis of studies of the earth) (1674), a work on geography, and his *Qiongli Xue* 窮理學 (Studies for exhaustively mastering principles), which collected the Chinese translations of the commentaries on Aristotle used at Coimbra known as the *Commentarii Collegii Conimbricensis.* Verbiest saw the *Qiongli Xue* (1683) as the beginning point for astronomy and mathematical studies, although the Kangxi emperor declined to have it published and returned the work to Verbiest because he saw it as perverse.[37] Such titles suggest our earlier image of literati intellectual life before the arrival of the Jesuits has been one-

34. See Zhu Xi, *Zhuzi Yulei (Topically Arranged Conversations of Master Zhu)* (Taipei: Zhongzheng Bookstore reprint, 1473 edition), 18, pp. 14b–15a. See also Yamada Keiji, *Shushi no Shizengaku (Zhu Xi's Studies of Nature)* (Tokyo: Iwanami, 1978), pp. 413–472.
35. Daniel Gardner, *Chu Hsi and the Ta-hsueh: Neo-Confucian Reflection on the Confucian Canon* (Cambridge, MA: Harvard University Council on East Asian Studies, 1986), pp. 27–59.
36. See Pan Jixing, "The Spread of Georgius Agricola's *De Re Metallica* in Late Ming China," *T'oung Pao*, 57 (1991), pp. 108–118, and James Reardon-Anderson, *The Study of Change: Chemistry in China, 1840–1949* (Cambridge, UK: Cambridge University Press, 1991), pp. 30–36, 82–88.
37. Nicolas, S. J. Standaert, "The Investigation of Things and the Fathoming of Principles (*Gewu Qiongli*) in the Seventeenth-Century Contact Between Jesuits and Chinese Scholars," in John W. Witek, S. J. ed., *Ferdinand Verbiest (1622–1688): Jesuit Missionary, Scientist, Engineer and Diplomat*, pp. 406–417.

sided, and that classical doctrine and natural studies, particularly medical and calendrical learning, were not mutually exclusive.[38]

For example, Xiong Mingyu's 熊明遇 (b. 1579) Jesuit inspired work entitled *Gezhi Cao* 格致草 (Draft for investigating things and extending knowledge) revealed how far the classical ideal of *Gewu* could be extended using European criteria for determining the fundamental ground of all things in the world. Published in 1648, after the fall of the Ming and in the midst of the Manchu takeover of south China, the *Gezhi Cao* represented a remarkable accommodation between Jesuit natural philosophy cum theology and the classical repertoire of literati natural studies based on *Gewu*.[39]

By way of contrast, the Ming scholar and Hangzhou bookseller Hu Wenhuan 胡文煥 (fl. ca. 1596) ignored the Sino-Jesuit dialogue concerning *scientia* when he compiled and published the *Gezhi Congshu* 格致叢書 (Collectanea of works inquiring into and extending knowledge) as a late-Ming repository of classical, historical, institutional, lexical, and technical works from antiquity to the present in China. It presented a cumulative account of all areas of textual knowledge, including natural studies, important to a literati audience in the seventeenth century. The three hundred and forty-six works allegedly collected by Hu (only 181 were apparently extant by the late eighteenth century, according to the compilers of the *Siku Quanshu* 四庫全書), many of which he himself had written or compiled, were divided into thirty-seven categories (*lei* 類), such as classical instruction, philology, phonology, historical studies, rituals and regulations, legal precedents, geography, mountains and streams, medicine, Daoism, Buddhism, agriculture, stars, physiognomy, preserving life, poetry and literature, painting, and epigraphy, among others.[40]

Overall, the *Gezhi Congshu* collectanea emphasized a broad learning of phenomena (*Bowu* 博物), one of the thirty-seven categories, that encompassed natural and textual studies within a humanist and institutional agenda framed by Chinese classical learning—not Jesuit studies as in the works by Verbiest et al. Within the collection, Zhang Hua's 張華 (232–300) *Bowu Zhi* 博物志 (A treatise on curiosities), and Li Shi's 李石 Song dynasty continuation, titled *Xu Bowu Zhi* 續博物志 (Continuation to a treatise on curiosities) were subsumed under the general category of *Gezhi* here. Other works included in the *Gezhi Congshu* were the *Shiwu Jiyuan* 事物紀原 Record of the

38. See Roger Hart, "Local Knowledges, Local Contexts: Mathematics in Yuan and Ming Dynasties," paper presented at "Song-Yuan Ming Transitions: A Turning Point in Chinese History," Lake Arrowhead: June 5–11, 1997.
39. See Xiong Mingyu, "Zixu" 自序, *Gezhi Cao* (1648 edition in the Library of Congress Asian Library).
40. See Hu Wenhuan, "Xu" 序, *Gezhi Congshu* (edition of the *Gewu Lunyao)*, Vol. 25, pp. 1a–2a.

origins of things and affairs) compiled by Gao Cheng 高承 circa 1078–85, and the *Gujin Shiwu Kao* 古今事物考 (Examination of ancient and contemporary things and affairs) prepared by Wang Sanpin 王三聘 in the Ming dynasty.[41]

In addition to Hu Wenhuan's Ming "*Gezhi* studies," Dong Sizhang 董斯張 (1586–1628) completed the *Guang Bowu Zhi* 廣博物志 (Expansion of a treatise on curiosities), which paid more attention to "natural history." Such works on *Bowu* 博物 as "natural history" suggests that as a term *Bowu* needs to be conceptually mapped asymmetrically with *Gezhi*. Sometimes the former was included under the latter, sometimes not. In both *Gezhi* oriented and *Bowu* framed late-Ming works, the naturalization of objects into artifacts, antiquities, and art objects was attempted. From heaven and earth to birds, animals, insects, fish, grasses, foodstuffs, architecture, and tools, the inventory of "organized knowledge" about nature within a Chinese frame of reference represented a systematic collection of data from a wide variety of native sources about China's natural resources, the arts, and manufactures (see further below). In the interaction with Western *scientia*, Chinese literati were drawn into a moderate transformation of their own traditions of natural studies.[42]

4. Civil Examinations, Natural Studies, and Anomalies

Views that late imperial literati, unlike their Song and Yuan predecessors, were participants in a strictly humanist civilization, whose elite participants were trapped in a literary ideal that eschewed interest in the natural world, have been common since the Jesuits.[43] Historians have typically appealed for corroboration to the infamous Chinese civil examination system. Matteo Ricci, for example, wrote: "The judges and the proctors of all examinations, whether they be in military science, in mathematics, or in medicine, and particularly so with examinations in philosophy, are always chosen from the senate of philosophy, nor is ever a military expert, a mathematician, or a medical doctor added to their number."[44] Catholic scholars were aware of the role played by political and social institutions in Chinese cultural matters, and the Jesuits realized that the civil recruitment system achieved for Chinese education a degree of standardiza-

41. See Hu Wenhuan, *Gezhi Congshu* (NCL edition), which contains 46 works, and Campany, *Strange Writing: Anomaly Accounts in Early Medieval China*, pp. 51–52.
42. *Gezhi Congshu*, passim. See also Ssu-yü Teng and Knight Biggerstaff, *An Annotated Bibliography of Selected Chinese Reference Works* (Cambridge, MA: Harvard University Press, 1971, 3rd edition), p. 105.
43. See Michael Adas, *Machines as the Measure of Men*, pp. 41–68, 79–95.
44. Matteo Ricci, *China in the Sixteenth Century: The Journals of Matteo Ricci: 1583–1610*, p. 41.

tion and importance unprecedented by early modern European standards.[45]

The examination ethos had carried over for a time into the domains of medicine, law, fiscal policy, and military affairs during the Northern Song dynasty. For example, Shen Gua 沈括 (1031–95) wrote that during the Huangyou reign (1049–53) civil examination candidates were asked to comment on a *fu* 賦 (rhyme prose) on astronomical instruments. (A similar *fu* was used in the 1679 special examination administered by the Kangxi emperor). The answers were so confused about the celestial sphere, and the examiners were themselves so ignorant of the subject, however, that all candidates were passed with distinction.[46] In addition, we have assumed that the classical curriculum for Ming civil examinations had refocused elite attention on a classical (*Daoxue* 道學, i.e., "Neo-Confucian") orthodoxy stressing moral philosophy and literary values and away from earlier more specialized or technical studies. Conventional scholarship still contends that technical fields such as law, medicine, and mathematics, common in Tang and Song examinations, were not replicated in late imperial examinations.[47]

When faced with foreign rule (first under the Mongols, 1240–1368, and later under the Manchus, 1644–1911) significant numbers of literati, in addition to the usual number of candidates who failed, turned to occupations outside the civil service such as medicine. In the eighteenth and nineteenth centuries, when demographic pressure

45. Donald F. Lach, *China in the Eyes of Europe: The Sixteenth Century* (Chicago: Phoenix Books, 1968), pp. 780–783, 804. Cf. Kiyosi Yabuuti, "Chinese Astronomy: Development and Limiting Factors," in Shigeru Nakayama and Nathan Sivin eds., *Chinese Science: Explorations of an Ancient Tradition* (Cambridge, MA: The MIT Press, 1973), pp. 98–99. See also George H. Dunne, S.J., *Generation of Giants: The Story of the Jesuits in China in the Last Decades of the Ming Dynasty* (Notre Dame: University of Notre Dame Press, 1962), pp. 129–130, and Benjamin A. Elman and Alex Woodside (eds.), *Education and Society in Late Imperial China, 1600–1900* (Berkeley: University of California Press, 1994), passim.

46. See Joseph Needham, *Science and Civilization in China*, Vol. 3, p. 192. See also Robert Hartwell, "Historical-Analogism, Public Policy, and Social Science in Eleventh- and Twelfth-Century China," *American Historical Review*, 76.3(1971), pp. 690–727, and his "Financial Expertise, Examinations, and the Formulation of Economic Policy in Northern Song China," *Journal of Asian Studies*, 30.2(1971), pp. 281–314. On the 1679 examination, see Benjamin A. Elman, *A Cultural History of Civil Examinations in Late Imperial China* (Berkeley: University of California Press, 2000), p. 548.

47. See, however, Zhang Hongsheng, "Qingdai Yiguan Kaoshi ji Tili(Qing Dynasty Examinations for Medical Officials with Examples)," *Zhonghua Yishi Zazhi(Chinese Journal of Medical History)*, 25.2(1995) pp. 95–96, on Qing examinations to choose a limited number of medical officials, which were based on Ming precedents. See also Liang Jun, *Zhongguo Gudai Yizheng Shilue (Brief History of the Medical Administration of Ancient China)* (Huhehot: Inner Mongolia People's Press, 1995). Calendrical and cosmological questions were required in Ming examinations administered for candidates applying for positions in the Astronomical Bureau. See Thatcher E. Deane, "The Chinese Imperial Astronomical Bureau: Form and Function of the Ming Dynasty 'Qintianjian' From 1365 to 1627," pp. 197–200.

meant that even provincial and metropolitan examination graduates were not likely to receive official appointments, many literati turned to teaching and scholarship as alternative careers.[48] Moreover, examiners used policy questions on natural events and anomalies to gainsay the widespread penetration of popular religion and the mantic arts among examination candidates and to keep such beliefs out of politics.[49]

Careful scrutiny of Ming dynasty examination records reveals that civil examinations also tested the candidates' knowledge of astrology (*Tianwen* 天文), calendrics (*Lifa* 曆法), and other aspects of the natural world, which were referred to as "natural studies" 自然學).[50] The preeminent position of the Four Books and Five Classics was left unchallenged in the orthodox curriculum, but Ming candidates for both the provincial and metropolitan examinations, unlike their Song counterparts, were expected to grasp many of the technicalities in calendrics, astrology, anomalies (*Zaiyi* 災異) and the musical pitch series (*Yuelü* 樂律). The latter was the basis for official weights and measures. Indeed, during the Tang, Song, and Yuan dynasties, works on calendrics and astrology had been banned from publication for security reasons. Only dynastic specialists working on the calendar in the astronomy bureau were allowed such knowledge, even though in practice popularly printed calendars and almanacs were widely available. Such restrictive policies continued outside the precincts of the Ming civil service examinations.[51]

In the early Ming, for example, the Yongle emperor (r. 1402–24) put calendrical and practical studies near the top of what counted for official, literati scholarship. He ordered the chief examiner for the 1404 metropolitan examination (on which 472 graduates drawn from over a thousand candidates were selected and appointed to high offices) to include questions that tested a candidate's "broad learning." The latter

48. Robert Hymes, "Not Quite Gentlemen? Doctors in Song and Yuan," *Chinese Science*, 7 (1986), pp. 11–85, Jonathan Spence, *To Change China: Western Advisers in China, 1620–1960* (Middlesex: Penguin Books, 1980), and Joseph Levenson, "The Amateur Ideal in Ming and Early Qing Society: Evidence from Painting," in John Fairbank ed., *Chinese Thought & Institutions* (Chicago: University of Chicago Press, 1957), pp. 320–341. See also Benjamin A. Elman, *From Philosophy To Philology: Social and Intellectual Aspects of Change in Late Imperial China* (Cambridge, MA: Harvard University Council on East Asian Studies, 1984), pp. 67–137.

49. See Benjamin A. Elman, *A Cultural History of Civil Examinations in Late Imperial China*, pp. 295–370.

50. See Benjamin A. Elman, *A Cultural History of Civil Examinations in Late Imperial China*, pp. 461–485. Cf. Nathan Sivin, "Introduction," in Nathan Sivin ed., *Science & Technology in East Asia* (New York: Science History Publications, 1977), pp. xi–xv.

51. See Lucille Chia, "*Mashaben*: Commercial Publishing in Jianyang, Song-Ming," in Paul Jakov Smith and Richard von Glahn eds., *The Song-Yuan-Ming transition in Chinese history* (Cambridge, MA: Harvard University Asia Center, 2003), pp. 284–328. See also Thatcher E. Deane, "The Chinese Imperial Astronomical Bureau: Form and Function of the Ming Dynasty 'Qintianjian' From 1365 to 1627," pp. 259, 322–324, 399–400.

selected policy questions dealing with astronomy, law, medicine, ritual, music, and institutions, and the emperor was especially pleased with the top policy answer that year. More importantly, the emperor had legitimated "natural studies." Thereafter such questions regularly appeared on Ming civil examinations.[52]

Typical of the naturalistic outlook favored in written examinations, policy questions and answers were often pervaded by a distancing orientation to natural calamities and were clearly opposed to what were called "disjointed" (*Buhe* 不和) interpretations of nature. Limitations in the human understanding of the natural operations of the cosmos, according to both examiners and candidate, had to be recognized. Otherwise, to impute human meaning and intent to calamities, as prognostication and the mantic arts presumed, was to humanize heaven and translate human knowledge into human fear and ignorance. Furthermore, the usual appeal to the personal agency of the sage-kings as men who confronted the events of their time and rectified them indicated that notions of fate that implied resignation in the face of calamities were unacceptable for orthodox literati operating in the public domain. What mattered was not the supernatural origins of floods or droughts but rather what concrete policies were followed to deal with them as natural events. Governance by men took precedence in a world in which the complete workings of heaven were beyond one's understanding.[53]

We see in the incomplete efforts by Ming literati to naturalize anomalies and supernatural events by appealing to the operation of yin and yang, the five phases, and *qi*, which carried over to the Qing, an interesting parallel to the early modern European transformation of supernatural miracles and monsters as prodigies into naturalized phenomena. Katharine Park and Lorraine Daston, have described how the treatment of monsters and attitudes toward them in Europe evolved in the sixteenth and seventeenth centuries, and how their religious significance was gradually diminished. Changing attitudes towards anomalies and monsters thus can serve as a barometer for different outlooks concerning natural and supernatural causes, which the Jesuits used in discussions with Ming literati about God and miracles to defend Christianity's superiority. In contrast to the monism of *qi* that most Chinese affirmed as psycho-physical reality, the Jesuits presented a numinous world of a personal God, angels, and the eternal souls of the dead.[54]

52. See Zhang Hongdao and Zhang Ningdao. *Huang Ming Sanyuan Kao (Study of the Provincial, Metropolitan, and Palace Civil Examination 'Optimi' during the Ming Dynasty)*. late Ming edition, after 1618, p. 2.3b.
53. See Benjamin A. Elman, *A Cultural History of Civil Examinations*, pp. 346–360.
54. See Qiong Zhang, "About God, Demons, and Miracles: The Jesuit Discourse on the Supernatural in Late Ming China," pp. 6–23, about Chinese demonology and Jesuit exorcism. For the Jesuit critique of *qi*, see Qiong Zhang, "Demystifying *Qi*: The Politics of Cultural Translation and

Originally treated by Europeans as divine prodigies contrary to nature, monsters became after 1500 more and more natural wonders. Subsequently in the seventeenth century, Francis Bacon in his *Novum Organon* set the research agenda for including them in natural history. Prodigies as anomalies served Bacon as a means to explain the secrets of nature. Monsters eventually lost their autonomy as prodigies and were integrated by French specialists in the Parisian Académie des Sciences into the medical disciplines of comparative anatomy and embryology. Instead of prodigies monsters became counter-examples to normal embryological development, and thus examples of medical pathology, in which nature's uniformity undergirded the exceptionalism of monsters.[55]

Similarly with regard to the treatment of miracles in Europe, Daston describes how "the debate over the evidence *of* miracles became a debate over the evidence *for* miracles." In moving from "signs" to "facts," miracles as preternatural (what rarely happens) or supernatural (God's unmediated actions) phenomena eventually lost much of their religious meaning. By focusing on the natural causes for deviating instances, Bacon and others made the anomaly and the miraculous central to scientific discourse. The goal in seventeenth century naturalism was to explain whenever possible the natural causes of marvels and prodigies as parts of natural philosophy and not as pure miracles.

In addition, in those cases where miracles seemed a plausible explanation for an anomaly, the European intellectual community began to require reliable "evidence *of* miracles." Experts were now needed to distinguish fraud in sifting through "evidence *for* miracles." According to Daston, faith in the pure evidence of a miraculous event was short-lived when the evidentiary problem was to distinguish a true miracle from a false one. Ignorant enthusiasts or purposive charlatans rather than Satan could now be blamed for such claims, and even the Church began to distinguish divine signatures from forgeries, which now required a panel of Church leaders to sift through the evidence. In the process, miracles themselves lost their evidentiary power and their autonomy when the Council of Trent stiffened the requirements to distinguish between religion and superstition. The Church in effect strengthened the hands in Europe of political and religious authorities as arbiters of miracles.[56]

Interpretation in the Early Jesuit Mission to China," in Lydia Liu ed., *Tokens of Exchange: The Problem of Translation and Interpretation in the Early Jesuit Mission to China* (Durham: Duke University Press, 1999).

55. Katharine Park and Lorraine Daston, "Unnatural Conceptions: The Study of Monsters in Sixteenth-Century France and England," *Past and Present*, 92 (1981), pp. 20–54.
56. Lorraine Daston, "Marvelous Facts and Miraculous Evidence in Early Modern Europe," *Critical Inquiry*, 18 (1991), pp. 93–124.

Just as the sixteenth and seventeenth centuries in Europe undermined the categories of the supernatural and miracles among Protestants and Catholics, so orthodox Chinese literati were also setting limits in official circles to the use of anomalies as political or religious signs. In Europe among the learned and powerful elites, however, the evidentiary requirements there, as Daston notes, implied far less confidence in the authenticity of supernatural events. Yet, both China and Europe saw any emotionally charged enthusiasm for the marvelous as a possible sign of deception and ignorance. For both, the dangers of false prodigies among the intellectually heterodox or politicized rabble-rousers were very real.

But among late imperial Chinese elites, and the Jesuits in China, the supernatural never diminished among them as much as among more secular, Protestant elites in Northern Europe as a counterpart to the natural world. The 1558 civil examination demonstrates that the naturalization of unusual phenomena among Ming literati, as for the Catholic Jesuit missionaries still tied to a medieval vision of the natural world, remained incomplete.[57] By way of contrast, among Protestant men of science the boundary between the natural and the artificial dissolved into the notion of God as a great artisan, who could be mimicked by the great artist or man of science. The mechanization of nature was the result. Nevertheless, even in Protestant Europe the "non-natural" persisted as a legal category governing familial and sexual relationships when moral sanctions were used for the most outrageous and heinous crimes such as patricide.

The new mechanical philosophy interrupted the development of naturalism because this view of matter included an inert and barren view of matter, which was infused with the supernatural activity of God. Newton observed that stability of the solar system was maintained by divine activity in mechanical philosophy; it could not be accounted for by the laws of mechanics alone. The miraculous nature of gravity depended on theological considerations as an integral part of early Newtonianism.[58]

Divine Activity in Scholastic Philosophy thus continued into the Newtonian era. Indeed, Aristotle had excluded divine providence from his naturalism, Acquinas had added a notion of the supernatural process to resolve the conflict between Aristotle and Christianity. The Protestant reaction against naturalism led by Luther and Calvin had maintained the principle of immanent divine causation, while at the same time attacking the Scholastic distinction between the natural and supernatural. Calvin in

57. On the Jesuits, see Qiong Zhang, "About God, Demons, and Miracles: The Jesuit Discourse on the Supernatural in Late Ming China," pp. 35–36.
58. Keith Hutchison, "Supernaturalism and the Mechanical Philosophy," *History of Science*, 21 (1983), pp. 297–299.

particular rejected occultism and stressed that inert matter required the spiritual excitation of natural impulses. But Newton's theory was preferred because it brought God into continuous activity with creation, unlike Leibniz's naturalism, which was infused with godless monads.[59]

The new naturalism evolved in association with mechanical philosophy. We cannot view the scientific revolution as a purely naturalistic movement. The legacy of the new mechanical philosophy yielded important parallels between natural and political philosophy, such that the new divine right of kingship became enmeshed in question of God's participation in running the world.[60] Finally, as Daston tells us, naturalization as an intellectual and cultural process does not explain the late-seventeenth century shifts in the meanings of nature in Europe because the process was not a product of specific achievements of the scientific revolution. She maintains that the keys to the imposition of a rationalized order on natural concepts came from theology and jurisprudence, and that the authority of nature alone would not have sufficed to justify European political regimes in the seventeenth and early eighteenth century. The reinterpretation of nature, that is, the naturalization of anomalies and miracles, still required divine props—a physico-theology—for its authority. Until nature was universalized as neutral and amoral, portents and prodigies could not be reduced to nonissues.[61]

So too in China, as long as the literati vision of a rational and orderly cosmos within which the macrocosmic interactions of the heavens and earth informed the microcosmic patterns of differentiation and organization in the creation and evolution of all things in the world, the naturalization of anomalies in Ming and Qing times still required the cultivation of moral perfection of all learned scholars and officials. Only the sage could truly "investigate things and extend knowledge," just as in England only the early Fellows of the Royal Society possessed the circumstances, education, cultural heritage, and moral equipment of the early modern English gentleman to engage rightfully in the new practice of empirical and experimental science.[62]

59. Keith Hutchison, "Supernaturalism and the Mechanical Philosophy," pp. 299–325.
60. Keith Hutchison, "Supernaturalism and the Mechanical Philosophy," pp. 326–333.
61. Lorraine Daston, "The Nature of Nature in Early Modern Europe," *Configurations*, 6 (1998), pp. 149–172.
62. Steven Shapin, *A Social History of Truth: Civility and Science in Seventeenth-Century England* (Chicago: University of Chicago Press, 1994), pp. 122–123.

5. Examinations, Literati Learning, & Natural Studies in the 18th Century

Given our present understanding of how the Jesuits depended on astronomy to gain influence in the imperial Bureau of Astronomy, and the avid interest early Manchu emperors had in Western astronomy, we would expect that such influence, as in the Ming, would have carried over to the civil examinations. It is likely, however, that the Manchu throne sought to monopolize this potentially volatile area of expertise within the confines of the court. The contemporary calendrical debates between Jesuits and literati-officials, which challenged the Yuan-Ming calendrical system during the Ming-Qing transition, gave the imperial court pause about allowing possibly divisive questions on the calendar to appear in civil examinations.[63]

The collapse of the Ming dynasty and its Qing successor under non-Han rule created opportunities until 1685 for experts in astronomy-astrology and music to break out of their subordinate positions and to challenge a discredited Ming elite for political power under a new Manchu ruling elite. The increased cultural importance of astronomical expertise, when the new dynasty had to reformulate in expert terms its calendrical and musical raison d'être as quickly as possible, probably outweighed, or at least challenged for a time, the cultural distinction accumulated by literati via mastery of classical studies. Court scholars such as Li Guangdi 李光地 (1642–1718) actively patronized specialists in calendrical calculations and made the musical pitch series a high priority in their officially financed research.[64]

Not until the 1680s, when the Manchu dynasty had mastered its political and military enemies, did the intellectual fluidity of the early decades of the Qing begin to disappear, leaving Han literati and Manchu elites in a precarious balance at the top (and calendar specialists again in the middle) of the political and social hierarchies, which lasted into the nineteenth century. In the process, policy questions on the third session of the provincial and metropolitan examinations virtually ceased to include natural studies. Perhaps the hard-fought court victory of classical orthodoxy by the 1680s, manipulated by a shrewd Manchu emperor, precluded in civil examinations the successful literati accommodation with the natural studies that had marked Ming civil

63. See Jonathan Spence, *Emperor of China: Self-portrait of Kangxi* (New York: Vintage Books, 1974), xvii–xix, pp. 15–16, 74–75. On the Yang Guangxian 楊光先 (1597–1669) 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*, 14 (1997), pp. 7–34.
64. Arthur Hummel (ed.), *Eminent Chinese of the Qing Period* (Taipei: Cheng Wen Publishing Co., Ltd., 1972, reprint), pp. 473–475.

examinations.

What we do know is that by 1715, the Kangxi emperor successfully banned focus in the civil examinations on study of astronomical portents and the calendar because they pertained to Qing dynastic legitimacy. He could not restrict such interest among the literati community outside the civil examination bureaucracy, however. The emperor, for example, decreed in 1713 that thereafter 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 put off limits to examiners and examination candidates. The ban on natural studies was stipulated within a general effort by the court to keep the mantic arts and discussion of auspicious versus inauspicious portents out of general public discussion.[65]

In place of the banned natural studies, historical geography in particular prospered as an acceptable examination field of Qing scholarship, although map-making was kept secret by the throne. The Yongzheng emperor, however, changed the Kangxi emperor's policy a bit by admitting imperial students with specializations in astrology into the dynastic schools.[66] Both emperors and their literati officials were responsible for curricular changes in civil examinations, emperors through their private concerns and examiners through their scholarly interests. Such bans, however effective in the civil examinations, did not carry over to literati learning, where a decisive sea change in classical learning was occurring. Clearly there were limits to imperial power outside the government. Philological studies developed and evolved during the eighteenth and nineteenth centuries because published works on the Classics were part of a dynamic classical research enterprise whose goals were not "scientific" or "objective" per se but instead were tied to a new literati commitment to use the language of the ancient Classics as an impartial means to recapture the ideas and intentions of the sage-kings of antiquity.

Qing scholars made astronomy, mathematics, and geography high priorities in 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, after less overt attention during the Ming dynasty

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65. See Xi Yufu et al., *Huangchao Zhengdian Leizuan (A Classified Compendium of the Administrative Statutes of the Qing Dynasty)* (Taipei: Cheng Wen Publishing Co., Ltd., reprint, 1969), 191, pp. 7b–8a. For discussion of these court compilations, see Benjamin A. Elman, *From Philosophy To Philology: Social and Intellectual Aspects of Change in Late Imperial China,* pp. 79–80.
66. See Ji Huang (嵇璜) et al. *Qingchao Tongdian (Collected Statutes of the Qing Dynasty)*, in *Shitong (The Ten Comprehensives)* (Shanghai: The Commercial Press, 1936), 18, p. 2131.

until the coming of the Jesuits in the sixteenth century, evidential scholars such as Dai Zhen 戴震 (1724–77), Qian Daxin 錢大昕 (1728–1804), and Ruan Yuan 阮元 (1764–1849) successfully incorporated technical aspects of Western astronomy and mathematics into the literati framework for classical learning. Qian Daxin, in particular, acknowledged this broadening of the literati tradition, which he saw as the reversal of centuries of focus on moral and philosophic problems: "In ancient times, no one could be a literatus (*Ru* 儒) who did not know mathematical calculation . . . Chinese methods [now] lag behind Europe's because *Ru* do not know mathematics."[67]

The impact of evidentially based philological research made itself felt in the attention *kaozheng* scholars gave to the Western fields of mathematics and astronomy first introduced by the Jesuits in the seventeenth century. Such interest had built upon the early and mid-Qing findings of Mei Wending 梅文鼎 (1633–1721), who was sponsored by the Manchu court once his expertise in mathematical calculation and calendrical studies (*Lisuan* 曆算) was recognized. Mei had contended that study of physical nature gave scholars access to the "principles" (*Li* 理) undergirding reality. In essence, Mei saw Jesuit learning as a way to boost the numerical aspects of the Song-Ming notion of moral and metaphysical principle.[68] At the same time, however, the imperial court and Mei Wending prepared preliminary accounts stressing the native Chinese origins (*Zhongyuan* 中原) of Western natural studies. Such origins made it imperative for Mei to restore and rehabilitate the native traditions in the mathematical sciences to their former glory. Under imperial patronage during the Kangxi reign mathematical studies were upgraded from an insignificant skill to an important domain of knowledge for literati that complemented classical studies.[69]

For example, Chen Yuanlong's 陳元龍 (1652–1736) *Gezhi Jingyuan* 格致鏡原 (Mirror origins of investigating things and extending knowledge), was published in 1735, and in the 1780s it was included in the Imperial Library. A repository of detailed information divided into thirty categories culled from a wide variety of sources, the *Gezhi Jingyuan* represented a post-Jesuit collection of practical knowledge by a well-placed scholar in the Kangxi and Yongzheng courts that narrowed the focus of Hu Wenhuan's late-Ming *Gezhi Congshu*, much of which had already been lost, to cover almost exclusively the arts and natural studies. Special attention was given to the origins and evolution of printing and stone rubbings, in addition to topics dealing with geography, anat-

67. Qian Daxin, *Qianyan Tang Wenji (Collected Essays of the Hall of Subtle Research)* (Taipei: The Commercial Press, 1968), 3.335, *juan* 23.
68. See John Henderson, "The Assimilation of the Exact Sciences into the Qing Confucian Tradition," *Journal of Asian Affairs*, 5.1 (1980), pp. 15–31.
69. See Limin Bai, "Mathematical Study and Intellectual Transition in the Early and Mid-Qing," *Late Imperial China*, 16.2 (1995), pp. 23–61.

omy, flora and fauna, tools, vehicles, weapons and tools for writing, as well as clothing and architecture.[70]

Overall, Ruan Yuan's compilation of the *Chouren Zhuan* 疇人傳 (Biographies of astronomers and mathematicians) while serving as governor of Zhejiang province from 1797 to 1799, reprinted in 1849 and later enlarged, marked the climax of the celebration of natural studies within the Yangzi delta literati world of the eighteenth century, which had been increasing since the late seventeenth century. Containing biographies and summaries of the works of 280 *Chouren* 疇人, including thirty-seven Europeans, this work was followed by four supplements in the nineteenth century. Limin Bai has noted how 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 Juan Yuan was a well-placed literati patron of natural studies in the provincial and court bureaucracy, his influential *Chouren zhuan* represented the integration of the mathematical sciences with evidential studies. Mathematical study was no longer independent of classical studies.[71]

6. Final Comments

Such evidence from the eighteenth century gainsays the usual conclusions that Western and Chinese scholars have drawn concerning the "failure" of the Macartney mission to open China to European trade and science in 1793. Joanna Waley-Cohen has reevaluated the Qing dynasty's so-called "blindness" to world developments in the eighteenth century and revealed how this erroneous assessment grew out of Western technological superiority after the nineteenth-century industrial revolution, which was then read back into the 1793 Macartney mission to China by later historians and diplomats. This misassessment in Western attitudes toward China, Waley-Cohen argues, was also due in part to the Qing court's need under the Qianlong emperor to reassert the "public Chinese attitude of superiority toward foreigners" in the factionalized court politics of 1793, even though the emperor at the same time avidly employed Jesuit experts in the arts of warfare for late-eighteenth-century military campaigns against rebels within the empire. Moreover, the Qing court welcomed the advice of Jesuits in

70. See Chen Yuanlong, *Gezhi Jingyuan (Mirror of Origins Based on the Investigation of Things and Extending Knowledge)*, in *Siku Quanshu*, vols. 1031–1032. (Taipei: The Commercial Press, 1983–86, reprint). I have also used the 1735 edition of this work available in the Library of Congress.
71. Arthur Hummel (ed.), *Eminent Chinese of the Qing Period*, p. 402. See also Limin Bai, "Mathematical Study and Intellectual Transition in the Early and Mid-Qing," pp. 23–30.

their midst concerning cannon-building and empire-wide cartography.[72]

The earlier "modernization narrative" that described British imperial expansion colliding with a "sinocentric" Qing state unsympathetic with the needs of scientific knowledge should be amended.[73] Furthermore, the Qianlong emperor's famous letter to George III gainsaying Western gadgets should not be read as the statement of a Manchu empire completely out of touch with historical reality. As Waley-Cohen also shows, the emperor's famous letter to the British king was not a categorical rejection of Western technology, which has become the standard interpretation. Coming before the industrial revolution, the scientific trinkets the Macartney mission brought to China were contested by the court.

When contextualized, the emperor's reaction to the Macartney mission can be understood in light of the mutual misunderstandings that swelled from the overstated claims Macartney made about the pre-industrial revolution gadgets cum gifts—a replica of the solar system, for example--he had brought for the emperor (who did not think the planetarium so fabulous). Later emperors who found English military firepower irresistible in the 1839–42 Opium War and thereafter were dealing with a different set of technological circumstances.[74] That literati scholars had incorporated mathematical study into evidential research and made natural studies a part of classical studies is another piece to the puzzle concerning the fate of natural studies and technology in late imperial China since the Jesuits first made their presence felt in the seventeenth century.

During the transition from the last imperial dynasty to the Republic of China, new political, institutional, and cultural forms emerged that challenged the creedal system of the late empire and refracted the latter's cultural forms of knowledge, such as traditional Chinese medicine. Just as the emperor, his bureaucracy, and literati cultural forms quickly became symbols of political and intellectual backwardness, so too traditional forms of knowledge about the natural world, were uncritically labeled as "superstition" (*Mixin* 迷信, lit., "confused belief"), while "modern science" in its European and American forms was championed by new intellectuals as the path to objective

72. Joanna Waley-Cohen, "China and Western Technology in the Late Eighteenth Century," *American Historical Review*, 98.5 (1993), pp. 1525–1544.
73. See the still "orientalist" account in Alain Peyrefitte, *The Immobile Empire*, trans. Jon Rothschild (New York: Knopf Publishers, 1992), which is based on his *L'Empire immobile ou Le Choc des mondes* (Paris: Fayard, 1989). Peyrefitte notes that Roger Darrobers, Pierre-Henri Durand, and Sylvie Pasquest translated the unpublished documents from the Manchu court that he was able to bring back from Beijing.
74. See James Louis Hevia, *Cherishing Men From Afar: Qing Guest Ritual and the Macartney Embassy of 1793* (Durham and London: Duke University Press, 1995).

knowledge, enlightenment, and national power. Even those who sought to maintain Chinese traditional medicine by modernizing it according to Western standards of rigor, however, also played a part in the denigration of past medical practices.[75]

The dismantling of the native traditions of natural studies, among many other categories, that had linked natural studies, natural history, and medicine to classical learning from 1370 to 1905 climaxed during the cultural and intellectual changes of the New Culture Movement. When their iconoclasm against classical learning and its traditions of natural studies climaxed after 1915, New Culture advocates helped replace the imperial tradition of *Gezhixue* with modern science and medicine. This concluded a millennium of elite belief in literati values and five hundred years of an empire-wide classical orthodoxy that had encompassed the Chinese natural studies and local technologies. Socially, classical credentials no longer confirmed gentry status or technical expertise, so sons of gentry turned to other avenues of learning and careers outside officialdom, particularly the sciences, modern medicine, and engineering. Literati increasingly traveled to Shanghai, Fuzhou, and other treaty ports to seek their fortunes in arsenals and shipyards as members of a new gentry-based post-imperial Chinese intelligentsia that would become the seeds for modern Chinese intellectuals.

Culturally, the longstanding affinity between literati learning and natural studies was also severed between 1905 and 1915. In other words, the linguistic monopoly of that official, classical knowledge by cultural elites no longer mattered as much socially or politically. As elites turned to Western studies and modern science, fewer remained to continue the traditions of classical learning that had been the basis for imperial orthodoxy and literati statuses before 1900. The millennial hierarchy of literati learning, based on the Four Books and Five Classics, study of the Dynastic Histories, mastery of poetry, and traditional natural studies was demolished in favor of modern science and its impact via Darwinism on social and historical studies.[76]

After 1911 a remarkable intellectual consensus emerged among Chinese and Western scholars that imperial China had failed to develop science before the Western impact. Even the Chinese protagonists involved in the 1923 “Debate on Science and Philosophy of Life” accepted the West as the repository of all scientific knowledge and

75. See Peter Buck, *American Science and Modern China* (Cambridge, UK, New York: Cambridge University Press, 1980), pp. 91–121.
76. See James R. Pusey, *China and Charles Darwin* (Cambridge, MA: Harvard University Press, 1983), passim.

only sought to complement such knowledge with moral and philosophical purpose.[77] The consensus until the 1960s then drew on heroic accounts of the rise of Western science to demonstrate that imperial China had no science worthy of the name. Both Western scholars and many—but not all—Westernized Chinese scholars and scientists so essentialized European natural studies into a universalist ideal that when Chinese studies of the natural world, her rich medieval traditions of alchemy, or pre-Jesuit mathematical and astronomical achievements in China were discussed, they were usually treated dismissively and tagged with such epithets as "superstitious," "prescientific," or "irrational" to contrast them with the triumphant objectivity and rationality of the modern sciences. Because China had had no industrial revolution and had never produced capitalism, therefore the Chinese never produced science either. This "frame" of analysis carried over to India and Japan as well.

77. See Wang Hui, "From Debates on Culture to Debates on Knowledge: Zhang Junmai and the Differentiations of Cultural Modernity in 1920's China," paper presented at the Workshop "Reinventions of Confucianism in the 20th Century," sponsored by the UCLA Center for Chinese Studies-under the auspices of the University of California Pacific Rim Research Program, Los Angeles: January 31, 1998. See also Charlotte Furth, *Ting Wen-chiang: Science & China's New Culture* (Cambridge, MA: Harvard University Press, 1970).

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明清時期中西科技的比較研究：以耶穌會傳教士爲主

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摘　要

過去一個世紀以來，歐洲人宣示西方科學的全面勝利。自 1954 年起，李約瑟（Joseph Needham）便強調歐洲現代科學的發展是一枝獨秀，然而他也認同傳統中國在 17 世紀之前的科學技術成就。在李約瑟回答「前現代的中國人爲何不發展現代科學」這敏感問題之後的幾十年，我們漸漸認同，將重點放在「中國人錯失現代科學發展」確實具有啓發性，但卻是史學上的誤導，不得不重新評估科學史該如何全面重寫。

這篇文章著重在中國人何以未曾於歐洲的「牛頓世紀」裡學到任何東西，並且直到鴉片戰爭（1839–1842）之前，依然使用自己的分析方式做數學運算。仍有些論點以 1793 年訪問中國的馬戛爾尼使團爲例而堅稱，是清廷太過於保守以致於未能在新興的近代世界有所斬獲。以事後之見而言，這些觀點無庸置疑。然而中國方面是受了許多外部因素影響，比如 18 世紀中葉，中國與歐洲的耶穌會瓦解，這也能解釋爲何亞洲的牛頓革命來得這麼遲，並且不在 18 世紀發生。

關鍵詞：科學史，科技，耶穌會士在中國，馬戛爾尼使團

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