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Source: *Isis*, Vol. 73, No. 4 (Dec., 1982), pp. 529-544
Published by: The University of Chicago Press on behalf of The History of Science Society
Stable URL: https://www.jstor.org/stable/232145
Accessed: 09-08-2018 17:04 UTC

The Scientific Community in Early Modern China

*By Jonathan Porter**

BY OPENING UP NEW VISTAS of early Chinese technical innovation and scientific creativity, recent studies in the history of science and technology in traditional China have prompted comparisons with the Scientific Revolution in Europe.[1] Superficially, at least, the paths taken by scientific development in Europe and China were not far apart. The emergence of modern science in Europe in the seventeenth century followed the gradual recovery after the fifteenth century of the neglected Greek scientific tradition, in a period of intellectual and social ferment.[2] Similarly Chinese science experienced a renaissance in the seventeenth century following a period when earlier achievements were temporarily neglected from the fourteenth century on. Stimulated by the open intellectual climate of the late Ming (1368–1644) and early Ch'ing (1644–1911), and by the Jesuits' introduction to China of Western cosmological theories and computational methods, this new interest—especially in astronomy and mathematics—led to a rediscovery and reexamination of earlier indigenous scientific thought. The influence of the West on Chinese science is nevertheless problematical. Although Joseph Needham suggests that from this point science as practiced in China was no longer specifically Western or Chinese but had become "modern science," Nathan Sivin has shown that the Jesuits actually withheld Copernican astronomy from the Chinese and continued to promote the obsolete cosmology of Ptolemy and Tycho Brahe until the mid-eighteenth century. Even so, as Sivin has observed, the reorientation in Chinese scientific thought led to a limited scientific revolution from the seventeenth century on.[3]

Yet the growth of science in Europe and China followed divergent paths in modern times. Was Chinese science somehow retarded at the point that we should expect to witness a scientific revolution comparable to Europe's? Or was the development of science in China distinguished by a fundamentally different historical logic? Perhaps the question of China's allegedly retarded development in science is really misconceived: it is not the "failure" of China to experience the

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This study was supported in part by the American Council of Learned Societies and the National Endowment for the Humanities. I am indebted to Nathan Sivin, David Reynolds, James Reardon-Anderson, and John Henderson for constructive comments.

[1]See Joseph Needham, *Science and Civilisation in China* (7 vols. projected; Cambridge: Cambridge Univ. Press, 1959–); Mark Elvin, *The Pattern of the Chinese Past* (Stanford: Stanford Univ. Press, 1973); Joseph Needham and Ray Huang, "The Nature of Chinese Society: A Technical Interpretation," *Journal of Oriental Studies*, 1974, *12*(1 & 2): 1–16.

[2]See Marie Boas, *The Scientific Renaissance, 1450–1630* (New York: Harper & Row, 1962).

[3]Needham, *Science and Civilisation*, Vol. III, pp. 437, 448–449; Nathan Sivin, "Wang Hsi-shan," in *Dictionary of Scientific Biography*, Vol. XIV, pp. 159–165.

European scientific revolution, but China's characteristic pattern of scientific activity which requires explanation.[4]

Two kinds of hypotheses may be adduced to explain the divergent development of science in Europe and China. The first analyzes differences in the internal, theoretical orientation and conceptual content of science. The second deals with the influence of the external, social environment and social organization of scientific activity and scientists. This study adopts the second, asking whether from the mid-seventeenth century on practitioners of science in China belonged to an identifiable community within which they interacted. Did they perceive themselves as "scientists?"[5]

THE CH'OU-JEN CHUAN

To answer these questions, this article examines the biographies of Chinese astrologers, astronomers, mathematicians, calendricists, and scholars associated with the mathematical sciences during the Ch'ing period, collected in the *Ch'ou-jen chuan* (疇 人 傳 "Biographies of Mathematical Scientists") and its supplements. The first edition of the *Ch'ou-jen chuan* was compiled between 1795 and 1799 by Juan Yuan 阮 元, a seminal figure in the Chinese scientific community of the late eighteenth and early nineteenth centuries, and published in 46 sections or *chüan* in 1810. Three subsequent additions over the next century brought the final collection to 63 *chüan,* comprising biographies and names of 675 Chinese and 205 Western scientists from antiquity to the end of the nineteenth century.[6] For the Ch'ing period alone the complete collection contains 177 discrete biographical entries with more than 240 names. Elimination of those names for which no additional information is given leaves 240 useful biographies.

Although Needham suggests that the *Ch'ou-jen chuan* was the closest approach

[4]See A. C. Graham, "China, Europe, and the Origins of Modern Science: Needham's *The Grand Titration,*" in Shigeru Nakayama and Nathan Sivin, eds., *Chinese Science: Explorations of an Ancient Tradition* (Cambridge: MIT Press, 1973), pp. 45–69.

[5]Words such as "science" and "scientist" must be applied loosely and cautiously before the 19th century; to use them otherwise obviates the very rationale behind such studies as the present one—to understand how science developed in different societies. See S. B. Barnes and R. G. A. Dolby, "The Scientific Ethos: A Deviant Viewpoint," *European Journal of Sociology*, 1970, *11*(1):14–18; Thomas S. Kuhn, review of Joseph Ben-David, *The Scientist's Role in Society: A Comparative Study* (Englewood Cliffs, N.J.: Prentice-Hall, 1971), in *Minerva*, 1972, *10*:169, 177–178; and Steven Shapin and Arnold Thackray, "Prosopography as a Research Tool in History of Science: The British Scientific Community 1700–1900," *History of Science*, 1974, *12*:1–28, on pp. 1–3.

[6]See A. W. Hummel, ed., *Eminent Chinese of the Ch'ing Period (1644–1912)* (2 vols.; Washington, D.C.: Library of Congress, 1943–1944), p. 502. The first supplement, *Ch'ou-jen chuan hsü-pien* 疇 人 傳 續 編, edited by Lo Shih-lin 羅 士 林 in 6 *chüan*, was published in 1840. The *Ch'ou-jen chuan san-pien* 三 編, edited by Chu K'o-pao 諸 可 寶 in 7 *chüan* appeared in 1886, and the *Ch'ou-jen chuan ssu-pien* 四 編, edited by Huang Chung-chün 黃 鍾 駿 in 11 *chüan* in 1898. The editions used for this study include Juan Yuan *et al.*, eds., *Ch'ou-jen chuan* (4 vols.; Shanghai: Commercial Press, 1955); Juan Yuan *et al.*, eds., *Ch'ou-jen chuan* (7 vols.; Taipei: Commercial Press, 1965); and Huang Chung-chün, ed., *Ch'ou-jen chuan ssu-pien* (Shanghai: Commercial Press, 1955). The first two, which include Juan Yuan's original edition and the *hsu-pien* and *san-pien* supplements, appear to be identical in every respect, including pagination. (*Ch'ou-jen chuan* is hereafter cited as *CJC*.) Little has been written in Western languages on the *Ch'ou-jen chuan:* see L. Van Hee, S.J., "The *Ch'ou-Jen Chuan* of Yuan Yuan," *Isis*, 1926, *8*:103–118, Yoshio Mikami, "The *Ch'ou-Jen Chuan* of Yuan Yuan," *Isis*, 1928, *9*:123–126. (A more biased and inaccurate description than Van Hee's, whose main virtue was to prompt Mikami's critique, is hard to imagine.) Needham briefly describes the collection in *Science and Civilisation in China*, Vol. I, p. 50, and Vol. III, p. 3. In Chinese see Wang P'ing 王 萍, "Juan Yuan yü *Ch'ou-jen chuan*" 阮 元 與 疇 人 傳 [Juan Yuan and the *Ch'ou-jen chuan*], *Bulletin of the Institute of Modern History, Academia Sinica* (Taiwan), 1974, *4*:601–611.

Table 1. Distribution of principal specialization in the *Ch'ou-jen chuan*

Specialization	Number	Percentage
Mathematical sciences	203	84.6
Mathematics	(103)	(42.9)
Astronomy and mathematical astronomy	(100)	(41.7)
Historical calendrical studies	12	5.0
Geography	7	2.9
Technology	3	1.2
Other	15	6.3
Total	240	100.0

to a history of science in traditional China, the work is by no means a comprehensive review of the fields of knowledge recognized in either Chinese or Western science.[7] Because Juan Yuan's principal scientific interests were in astrology and astronomy (*t'ien-wen* 天文), mathematical astronomy (*li-suan-hsüeh* 曆算學), calendrical science (*li-hsüeh* 曆學), and mathematics (*suan-hsüeh* 算學), the majority of the subjects of the biographies are primarily specialists in the exact sciences.[8] Other fields associated with these during the Ch'ing period—geography, engineering, linguistics, harmonics, law, divination, medicine, military affairs, economics, and even foreign affairs (*yang-wu* 洋務)—also appear in the biographies. With the exception of geography and engineering, however, these secondary specialties are usually discussed only in association with the principal fields. The distribution of principal specialties among the 240 subjects in the *Ch'ou-jen chuan* is shown in Table 1.[9]

Juan Yuan compiled the *Ch'ou-jen chuan* in order to correct what he perceived to be an unbalanced depreciation of indigenous Chinese science by modern Chinese mathematicians and astronomers who had adopted Western computational methods and cosmology. The *Ch'ou-jen chuan* would restore the proper perspective by demonstrating that the two systems should in fact be reconciled as one.[10] In making this contention Juan Yuan also implied that Western science had an ancient Chinese origin.

[7]Needham, *Science and Civilisation*, Vol. I, p. 50. The term *ch'ou-jen* was by the Ch'ing a rather archaic rubric for specialists of various types. One meaning of *ch'ou-jen* includes two basic connotations: a vocational or ascriptive class of persons, and persons whose knowledge is transmitted from generation to generation (*CJC*, *ch'ou-jen chieh* [explanation of *ch'ou-jen*], pp. 1–4). In this sense it denotes an occupational category of persons commanding a cumulative tradition of specialized knowledge. Furthermore, since the term originally seems to have meant one who measures land (a surveyor), and since it was associated with the cognate *ch'ou* 籌, to calculate, it came to denote mathematicians and astronomers ("surveyors of the heavens") in particular, as well as those specializing in quantitative knowledge in general (*CJC*, *ch'ou-jen chieh*, p. 4; Needham, *Science and Civilisation*, Vol. III, p. 3; and Mikami, "*CJC*," p. 123). Thus in the functional sense applied by Juan Yuan, *ch'ou-jen* designates a loose class of specialists commanding primarily various forms of quantitative knowledge.

[8]For an excellent descriptive taxonomy of Chinese science, see Sivin's preface in Nakayama and Sivin, *Chinese Science*, pp. xix–xxv. The *Ch'ou-jen chuan* includes all of the "quantitative"sciences distinguished by Sivin.

[9]Astronomy or astrology, mathematical astronomy, and mathematics are not always easily distinguishable, and many quantitative scientists worked in more than one field; therefore individuals have been somewhat arbitrarily assigned to the single category that seemed to represent best their principal field of work.

[10]*CJC*, *fan-li*, p. 4.

The introduction of Western science had precipitated a cultural crisis in the late Ming. But conservative reaction to Western scientific methods in the seventeenth century had been conditioned by the political influence of the Jesuits and the uncertain implications of their "new science." It was only at the end of the eighteenth century, after Copernican cosmology was belatedly introduced, that the full significance of the cosmological foundations of Western science became obvious to the Chinese.[11] Juan Yuan and other students of both Western and Chinese science after the mid-seventeenth century were disturbed because the new theories seemed to predicate China's cultural inferiority. Thus they advanced the theory propounded earlier by Mei Wen-ting (1633–1721) and the K'ang-hsi emperor (reigned 1662–1722): that the achievements of ancient Chinese science, although the knowledge and practice of them had later degenerated in China, had given birth to Western science, which the Jesuits had now brought back to China. Although Western mathematical astronomy undeniably surpassed contemporary Chinese scientific methods in precision and empirical validity, it had been prefigured by ancient Chinese science. "Chinese and Western [science] while nominally different are essentially the same."[12]

This tendentious motive for compiling the *Ch'ou-jen chuan* suggests two sources of possible bias: systematic bias in the selection of subjects, and polemical bias in the content of the subjects' biographies.

Are the *Ch'ou-jen chuan* biographies an objective historical source, or are they distorted by a polemical bias? Juan Yuan was following a well-established tradition of biographical compilation in China. It was customary in such enterprises to lift whole portions intact from other biographical sources. Juan describes his sources in a general way in his introduction and cites them specifically at the end of each biography. Moreover, he describes his editorial criteria. The writings and contributions of the subjects in their scientific fields are recorded in detail, and basic biographical data are included wherever possible, but unrelated activities and achievements are only outlined.[13] Juan Yuan seemed to believe that merely to restore the contributions of scientists would suffice—that the record would speak for itself. Any editorial commentaries he felt necessary he appended, clearly identified, at the end of some biographies. Furthermore, the collection includes subjects who do not fit Juan Yuan's ideological preferences and subjects on whom so little information is available that their work cannot fit any ideological interpretation.

Juan Yuan and his colleagues clearly had an axe to grind. But if the *Ch'ou-jen chuan* is consequently not a work of disinterested scholarship, its polemical bias is confined to the editorial commentaries. The accuracy of the biographical data, on which this study is based, remains unaffected.

Is the *Ch'ou-jen chuan* an exhaustive collection of specialists in the mathematical sciences, or is it an arbitrary selection of prominent figures only? Two observations are relevant here. First, since the successive supplements do not begin where the previous ones ended but overlap chronologically, the compilers appar-

[11]Wang P'ing, "Juan Yuan," pp. 609–611. See also Sivin, "Wang Hsi-shan," pp. 160–162. On the theory of the Chinese origin of Western science, see George C. Wong, "China's Opposition to Western Science during the Late Ming and Early Ch'ing," *Isis*, 1963, *54*:29–49; Nathan Sivin, "On 'China's Opposition to Western Science during the Late Ming and Early Ch'ing'," *Isis*, 1965, *56*:201–205; and Sivin, "Wang Hsi-shan."

[12]Wang P'ing, "Juan Yuan," p. 610, quoting Juan Yuan.

[13]*CJC*, *fan-li*, p. 2.

Table 2. Chronological scope of *Ch'ou-jen chuan* editions

Edition	Range
Ch'ou-jen chuan (1810)	Antiquity to ca. 1799
Ch'ou-jen chuan hsü-pien (1840)	Sung dynasty to ca. 1840
Ch'ou-jen chuan san-pien (1886)	Early Ch'ing to ca. 1885
Ch'ou-jen chuan ssu-pien (1899)	Antiquity to ca. 1890

ently undertook successive searches for names omitted from earlier collections, besides adding biographies of more recent subjects (see Table 2). Second, the dearth of information in many biographies, which approaches triviality in some cases, suggests that the compilers indeed scraped the bottom of the barrel. Clearly they did not select their subjects on the basis of eminence.[14] Less clear is how thoroughly the editors searched for all possible subjects. Given that there is no evidence that their search was systematic, the collection may be arbitrary to some extent. Bearing these caveats in mind, I will tentatively treat the *Ch'ou-jen chuan* as a relatively complete population of specialists in the exact sciences, at least for the Ch'ing period (for which the effort of compilation was both more intense and chronologically more immediate than for earlier periods), not as a selection based on subjective or arbitrary criteria.

For the purposes of the present study, our interest is not confined to the great men of science—the pathbreakers and seminal figures alone—but extends to the marginal men of science as well, those who, if they were not pushing back the frontiers, were still not "failed" scientists. This approach parallels that taken by Steven Shapin and Arnold Thackray in their prosopographical study of British science in the same period.[15]

SCIENCE AS A SOCIAL INSTITUTION

The distinction between the achievements of scientists as individuals and the organization of science as a social system is fundamental to the sociology of science. Accordingly, before examining the social organization of scientific activity in China, we must identify the elements that describe the social structure of science.[16]

A social institution may be defined by three associated conditions: the basic importance of the activity as a social goal; the performance of the activity in definite, continuous, and organized patterns; and the existence of normative principles regulating the activity.[17] Adopting these criteria to the institutionalization

[14]That only 81 of the 240 names for the Ch'ing period are found in Hummel's *Eminent Chinese of the Ch'ing Period* supports this conclusion.

[15]Shapin and Thackray, "Prosopography," p. 8.

[16]For the conceptual framework used in this article see esp. Ben-David, *Scientist's Role in Society* (cit. n. 5), esp. pp. 13–14, 16–17, and Ch. 2. See also Norman W. Storer, introduction to R. K. Merton, *The Sociology of Science: Theoretical and Empirical Investigations* (Chicago: Univ. Chicago Press, 1973), pp. xvii–xviii; Robert Merton, *Social Theory and Social Structure* (New York: The Free Press, 1968), pp. 585ff; Norman W. Storer, *The Social System of Science* (New York: Holt, Rinehart & Winston, 1966); and Bernard Barber, *Science and the Social Order* (London: George Allen & Unwin, 1953).

[17]S. N. Eisenstadt, "Social Institutions," in *International Encyclopedia of the Social Sciences*, Vol. XIV, pp. 409–421. Eisenstadt also uses "patterns of behavior" for "activities."

of science in seventeenth-century England, Joseph Ben-David suggests a definition of institutionalized science which includes the recognition of scientific activity as a distinct function possessing an inherent value, and the autonomous role of the scientist; the existence of internal norms governing scientific activity appropriate to its goals; and the adaptation of other institutions to scientific activity.[18] The classic definition of the norms of science—universalism, communism, disinterestedness, and organized skepticism—was proposed by Robert Merton. But more recently critics have shown that as imperatives governing the behavior of scientists, Merton's norms are probably not tenable. A better approach is to abandon the problematic conception of normative structure in favor of the ideology of scientific interaction: the self-image of scientists as a community engaged in a common enterprise.[19]

These considerations suggest several criteria for assessing the social organization of scientific activity in China. The social institution of science includes both formal organizations, such as schools, academies, government agencies, and professional associations devoted to scientists and their careers, and the informal structure of scientific activity. The informal structure may be characterized by four parameters:

Value. The inherent social significance or importance of scientific activity or its product.

Function. The recognition of scientific activity as a form of specialization functionally distinct from other activities, and the ascription of definite status to the role of scientists as individuals.

Community. The self-image of scientific activity reinforced by mutual recognition and interaction among scientists in a common enterprise.

Continuity. The sustained transmission and cumulation of scientific knowledge.

These aspects may exist independently of one another: science may be informally institutionalized without being organized into formal institutions.

THE SOCIAL ORGANIZATION OF CHINESE SCIENCE

Few formal organizations devoted to science existed in the early Ch'ing. The principal one was the Imperial Astronomical Bureau *(Ch'in-t'ien-chien),* a department of the central government whose primary function was the preparation of the official calendar. Apart from this bureau and a few subsections of other agencies such as the National Academy *(Kuo-tzu-chien),* there were no public or private associations of scientists comparable to the Royal Society in seventeenth-century England. This study therefore evaluates instead the more important informal social structure of scientific activity, guided by the four parameters listed above.

Value. Astronomy and mathematics in China had always possessed an important political function: mathematical astronomers (the boundary between mathematics and astronomy is not always readily distinguishable) prepared the official calendar, which regulated the ceremonies that provided cosmological legitimation for the emperor's role as harmonizer of the natural and human orders. But whereas

[18]Ben-David, *Scientist's Role,* pp. 75–77; cf. Storer, *Social System,* p. 4.

[19]Merton, *Sociology of Science,* pp. 268–278; M. J. Mulkay, "Sociology of the Scientific Research Community," in Ina Spiegel-Rösing and Derek de Solla Price, eds., *Science, Technology and Society: A Cross-Disciplinary Perspective* (London: Sage, 1977), pp. 97–108; Barnes and Dolby, "Scientific Ethos," pp. 7–8, 12–13.

in the Han period, when the imperial system was being set up, mathematical astronomy was implicated in the political symbolism and polemics related to the contemporary political struggle, by the Ch'ing period this was very much less the case. The political issues surrounding the formation of the imperial system had long since been resolved—at least in their more explicit form—with the institutional changes accompanying the growth of autocracy after the early Ming. Wolfram Eberhard has suggested that Han astronomers, in spite of the inherent potential of their scientific knowledge, failed to develop an autonomous systematic science; thus the practice of science was inhibited because it was largely confined to the service of political goals, and otherwise remained a peripheral activity. It is probably truer to say, as Nathan Sivin observes, that attempts by the Han astronomers to maintain a balance between the exigencies of predictive accuracy and a priori metaphysical assumptions produced difficulties so intolerable that they finally abandoned the attempts and separated technical tasks of computation from cosmological speculation.[20]

Although Chinese astronomers changed their computational methods readily in the constant quest for greater precision, by the end of the seventeenth century preparing the calendar had become a routinized bureaucratic function of the Imperial Astronomical Bureau, and the influence of Jesuit astronomers there and in the court had helped to remove it from political manipulation. Choice of computational techniques continued to have political motivation, to which the persistence of the theory of the Chinese origin of Western science testifies, but now the motives were cultural independence and pride rather than imperial legitimacy.[21] The mainstream of astronomical and mathematical investigation increasingly shifted to practitioners—mostly amateurs in the sense that they were not officially or professionally trained and employed—who were only occasionally or peripherally associated with the Imperial Astronomical Bureau. Moreover, applications of the exact sciences during the Ch'ing went considerably beyond merely symbolic political functions. Mathematics, geography, and technology were increasingly recognized in their own right. Persons knowledgeable in these fields were sought out for a variety of special tasks and services, and honored and rewarded accordingly.[22]

Thus by the Ch'ing the mathematical sciences had acquired a measure of autonomy; they were largely free from direct official control and ideological goals, on which their value no longer depended. Not that scientific activity was immune from constraint or attack: conservative scholars like Yang Kuang-hsien, for instance, sometimes assailed the subversion of traditional values which they saw in the adoption of Western scientific ideas and techniques and their synthesis with traditional science. Yet when in 1664 and 1665 Yuan Kuang-hsien attacked the Jesuit missionaries led by Adam Schall von Bell in the Imperial Astronomical Bureau, he was inspired as much by antiforeignism and opposition to Christian faith and practices and by resentment against the Jesuits' political influence as by

[20]Wolfram Eberhard, "The Political Function of Astronomy and Astronomers in Han China," in J. K. Fairbank, ed., *Chinese Thought and Institutions* (Chicago: Univ. Chicago Press, 1957), pp. 66–68; N. Sivin, "Cosmos and Computation in Early Chinese Mathematical Astronomy," *T'oung Pao*, 1969, *55*:64–69.

[21]This problem is examined in Jonathan Porter, "Bureaucracy and Science in Early Modern China: The Imperial Astronomical Bureau in the Ch'ing Period," *J. Oriental Stud.*, 1980, *18*:61–76.

[22]See, e.g., *CJC*, pp. 509, 522, 669–670; *CJC ssu-pien*, pp. 91, 95, 97. See also Rita Hsiao-fu Peng, "The K'ang-hsi Emperor's Absorption in Western Mathematics and Astronomy and His Extensive Applications of Scientific Knowledge," *Bulletin of Historical Research* (Graduate Institute of History, National Taiwan Normal University), 1975, *3*:349–442.

the content of their new scientific methods. In the end the issue was not decided on political grounds. The Jesuits were ultimately vindicated, and Yang disgraced, when the objective accuracy and value of the Jesuits' science was substantiated.[23]

If anything, this was eloquent testimony to the growing cultural autonomy of Chinese science, not to its subordination to cultural orthodoxy. The same kind of conservative antagonism, accompanied by personal attacks, attended the emergence of the new science in late sixteenth-century Europe: "Educated in one system, such critics hated the idea of having to accept another or, even worse, having to balance the merits of one system against another. This was especially true when the new system involved a violation both of common sense, and of the apparent order and harmony of the universe." Hostility is, in fact, a much more likely response to modern science, with its challenge to common sense and its claim to autonomous truth, than to traditionalistic science, which—both in Han China and ancient Greece—comfortably integrated the natural and human orders.[24]

Chinese scientists also complained of orthodox Confucian depreciation of scientific activity. But they lamented particularly the failure of Confucian scholars to include scientific knowledge—especially mathematics and astronomy—in their training. Their complaint reflected the growing differentiation of naturalistic from humanistic knowledge, which in early times had been linked in a unified cosmology, as they had been in the West.[25] It is itself, then, evidence of an emerging sense of the value and independence of science; it would not have been possible so long as science was thought to be only a marginal compartment of knowledge. The Confucians, moreover, did not so much depreciate the content of science as express the traditional suspicion that roundly cultivated Confucian literati held for mere technical specialization. This also is a familiar feature of the development of modern science in the West.

Interest in science was by this time increasing, not declining. Further, cosmology was becoming separated from empirical natural philosophy. John Henderson has identified a significant transformation in world view in the seventeenth- and eighteenth-century radical critique of traditional cosmographical thinking. Whereas traditional cosmographers attempted to make empirical facts fit preconceived cosmological models, Ch'ing commentators observing discrepancies between them denied the truth of traditional cosmograms. "They insisted, moreover, that the concrete reality that cosmograms purported to order or represent was of primary importance; the cosmographical schemata were true or useful only insofar as they corresponded with this primary reality."[26] To claim that science was widely appreciated for its own sake in Ch'ing society would be an exaggeration, but neither was science so regarded in England during the Scientific Revolution.

[23]Hummel, ed., *Eminent Chinese*, pp. 890–891; John D. Young, "An Early Confucian Attack on Christianity: Yang Kuang-hsien and His *Pu-te-i*," *Journal of the Chinese University of Hong Kong*, 1975, *3*(1): 168–174.

[24]Boas, *Scientific Renaissance*, pp. 40–41, 101; quoting p. 10. Cf. Kyoshi Yabuuti, "Chinese Astronomy: Development and Limiting Factors," in Nakayama and Sivin, *Chinese Science*, pp. 91–95.

[25]*CJC*, p. 666; *Ch'ing-shih pien-tsuan wei-yuan-hui* 清史編纂委員會 [Editorial Committee for the History of the Ch'ing], *Ch'ing-shih* 清史 [History of the Ch'ing](8 vols.; Taipei, 1961), p. 5487. Medieval European science was fixed in a continuum of knowledge that included mysticism, magic, astrology, and alchemy; Boas, *Scientific Renaissance*, pp. 19–21; cf. Ben-David, *Scientist's Role*, pp. 30–31.

[26]John B. Henderson, "The Early Ch'ing Critique of Traditional Chinese Cosmography," unpublished paper (1978), pp. 1, 6–9, quoting p. 10.

To be sure, nothing like the receptive public who read Descartes and Locke existed in China.[27] Yet if science lacked a popular following, a core of individuals—mathematicians and astronomers, amateur natural philosophers, and humanists—did value science as an end and identified with it as a movement.[28] Thus although scientific activity in seventeenth- and eighteenth-century China had not yet become a unified enterprise any more than it had in Europe at the same time, the compilation of the *Ch'ou-jen chuan* suggests that such a conception was emerging by the end of the eighteenth century. It was then becoming possible to see a common orientation behind diverse intellectual activities grouped under the crude rubric *ch'ou-jen*, at a time when, again as in Europe, there was as yet no agreement about what the activities should be called.[29]

Function. The exclusion of science from the curriculum of the Confucian scholar, which in fact reflected an increase in scientific activity and a growing differentiation of naturalistic from humanistic knowledge, reflected also the progressive differentiation of the role of the scientific specialist from that of the humanistically and politically oriented scholar-official. Changes in the structure and content of the civil service examination system no doubt encouraged this process. By the Ming and Ch'ing periods most kinds of technical knowledge had been eliminated from the examinations, which now placed overwhelming emphasis on rigidly formalistic literary style. To prepare successfully, the aspiring official had to practice assiduously and repress any interest in unrelated fields.

Besides such negative factors as literary fashion and pragmatic career considerations, positive reasons also encouraged this differentiation of roles. Above all, the increasing cumulative complexity of scientific knowledge—especially after Western science was introduced at the end of the Ming—coupled with the growing interest in scientific activity which the *Ch'ou-jen chuan* documents, imposed a measure of specialization on its adherents.[30] The biographies frequently observe the demands that specialized knowledge made on their subjects. They single out penetrating mastery of a special field for particular approbation and urge the necessity of concentrating on one or two fields only and acquiring more than merely superficial acquaintance with a technical subject.[31] Just this differentiation and specialization of knowledge prompted the differentiation of the scientific role in the West.[32]

A rough measure of the differentiation between scientific and literary roles can be made by tabulating the numbers of official positions held by Ch'ing scientists in the *Ch'ou-jen chuan* (Table 3). A significant majority (141 or 58.7%) achieved

[27]Hugh Kearney, *Science and Change 1500–1700* (New York: McGraw-Hill, 1971), Ch. 8; Ben-David, *Scientist's Role,* p. 77.

[28]For examples see Henderson, "Early Ch'ing Critique," p. 33; Willard J. Peterson, "Fang I'chih: Western Learning and the 'Investigation of Things,'" in William T. deBary, ed., *The Unfolding of Neo-Confucianism* (New York: Columbia Univ. Press, 1975), pp. 400–401.

[29]See Kuhn, rev. of Ben-David, p. 169. Cf. Nathan Sivin, ed., *Science and Technology in East Asia* (New York: Science History Publications, 1977), introduction; Sydney Ross, " 'Scientist': The Story of a Word," *Annals of Science,* 1962, *18*:65–71.

[30]*CJC,* p. 639; *CJC ssu-pien,* p. 80.

[31]*CJC,* pp. 513, 547, 654–655; *Ch'ing-shih* (cit. n. 25), pp. 5487, 5501. A corroborative exception here is Yang Kuang-hsien, whose biography singles out his incomplete command of mathematics; *CJC,* p. 450.

[32]See Bernard Barber, "The Sociology of Science," in *International Encyclopedia of the Social Sciences,* Vol. XIV, p. 96; Everett Mendelsohn, "The Emergence of Science as a Profession in Nineteenth-Century Europe," in Karl Hill, ed., *The Management of Scientists* (Boston: Beacon Press, 1964), p. 40; and Florian Znaniecki, *The Social Role of the Man of Knowledge* (1940; New York: Octagon Books, 1965).

Table 3. Official positions Held by Ch'ing scientists

Number of official positions held	Number of subjects	Percentage	Cumulative percentage
0	141	58.8	58.8
1	53	22.1	80.9
2	20	8.3	89.2
3	5	2.1	91.3
4	6	2.5	93.8
5	2	0.8	94.6
More than 5	13	5.4	100.0
Total	240	100.0	

their reputation without ever obtaining an official appointment. When those who held only one official position (presumably not successful officials) are included, the proportion is considerably larger (194 or 80.8%). Those who held five or more official appointments and thus can be considered career officials number only 15 or 6.2%.

A comparison between scientific and nonscientific productivity, measured by numbers of titles credited in each category, yields another indicator of specialization among Ch'ing scientists. Of the 240 subjects, 168 or 70.0% had at least one scientific work to their credit (Table 4), whereas only 85 or 35.4% had one or more nonscientific titles (Table 5). Considering only the low to moderately productive scientists (having only one to five titles each) in each category, 148 (61.7%) had one to five scientific titles, while 59 (24.6%) had one to five nonscientific titles. As a group, then, Ch'ing scientists were significantly more productive in scientific fields than they were in other fields, and in terms of publications, scientific activity was more widely distributed among them than were other fields of activity.

The 168 authors with at least one scientific title produced a cumulative total of 568 titles, for a mean of 3.4 titles per author. This figure is not far from the theoretical mean of productivity of approximately 3.5 titles per author in modern Western scientific literature.[33] Comparing the distribution of scientific titles with Derek Price's empirical "law of productivity," we find that the symmetrical form of the expected distribution is roughly preserved for Ch'ing scientists (the top two or three men produced approximately one quarter of the titles, and those with two or three titles produced another quarter), but the point of symmetry for Ch'ing scientists is somewhat lower (about 5 papers per man rather than 10 as in the ideal case). This suggests that 5 titles should be taken as dividing high from low producers among Ch'ing scientists.

Before the mid-nineteenth century, whether in China or in the West, it was still common for an individual to combine scientific specialization with humanistic interest or an official career. In the West a distinct scientific role was only imperfectly visualized, and the category of professional scientist not at all: men of science were amateurs pursuing science as an avocation along with their other

[33]Derek J. de Solla Price, *Little Science, Big Science* (New York: Columbia Univ. Press, 1965), pp. 45–49.

Table 4. Scientific productivity of Ch'ing scientists

Number of titles	Number of subjects	Percentage
0	72	30.0
1–5	148	61.7
6–10	13	5.4
11–20	6	2.5
More than 20	1	0.4
Total	240	100.0

Table 5. Nonscientific productivity of Ch'ing scientists

Number of titles	Number of subjects	Percentage
0	155	164.6
1–5	59	24.6
6–10	10	4.2
11–20	9	3.7
More than 20	7	2.8
Total	240	100.0

interests. Indeed, the word "scientist" was not coined until 1834 and met with much resistance at first.[34] Many of the seminal contributors to science in Europe were broadly educated scholars active in diverse fields, humanists as well as "scientists"; Descartes, Liebniz, Boyle, and Lomonosov come to mind. China was no different, as the careers of men like Mei Wen-ting, Tai Chen, and Juan Yuan attest. But Juan Yuan's conception of the *Ch'ou-jen chuan* as a history of scientific activity and the appropriation term *ch'ou-jen* for specialists who were more than merely skilled craftsmen imply that the scientific role did exist at least in embryonic form.

Community. A sense of cohesiveness and mutual recognition among the cultivators of mathematical science accompanied the differentiation of scientific activity in the Ch'ing. The biographies reflect their subjects' distinct self-image as scientific specialists and a sense of identity with an intellectual community.[35] The best evidence for this assertion is the importance that associations between scientists assume in the narratives, associations based on commitment to common interests rather than on political or family affiliations. Scientists sought out other scientists, as mentors, acquaintances, or collaborators. Most prominent scientists in any period were acquainted—even if sometimes only slightly—with each other.

Figure 1 depicts associations between Ch'ing scientists. A number of points may be observed here.

- Of the 240 Ch'ing scientists in the population, 123 or slightly more than one half are represented in Figure 1, connected by 168 separate associations. This figure is based on associations explicitly mentioned in the biographies. Since it is likely both that some of the remaining scientists were also associated with the 123 shown here, and that more associations existed than the biographies mention, this represents a *minimum* measure of cohesiveness.
- Although family affiliations were important in a few cases (11 associations),

[34]Ross, "'Scientist,'" pp. 65–66, 71–82; Mendelsohn, "Emergence of Science"; and R. H. Knapp and H. B. Goodrich, *Origins of American Scientists* (Chicago: Univ. Chicago Press, 1952), pp. 269–270.

[35]For the use of the term "community," see Shapin and Thackray, "Prosopography," pp. 11–13. They see the scientific community as loosely embracing at least three broad levels of participation: those who published a work of scientific research; those who did not publish, but actively or formally associated themselves with science or disseminated scientific knowledge; and cultivators of science who patronized, applied, or disseminated scientific knowledge, but who neither published science nor actively associated themselves with science. The modern association of the term with professionalization and formal institutions is inappropriate here.

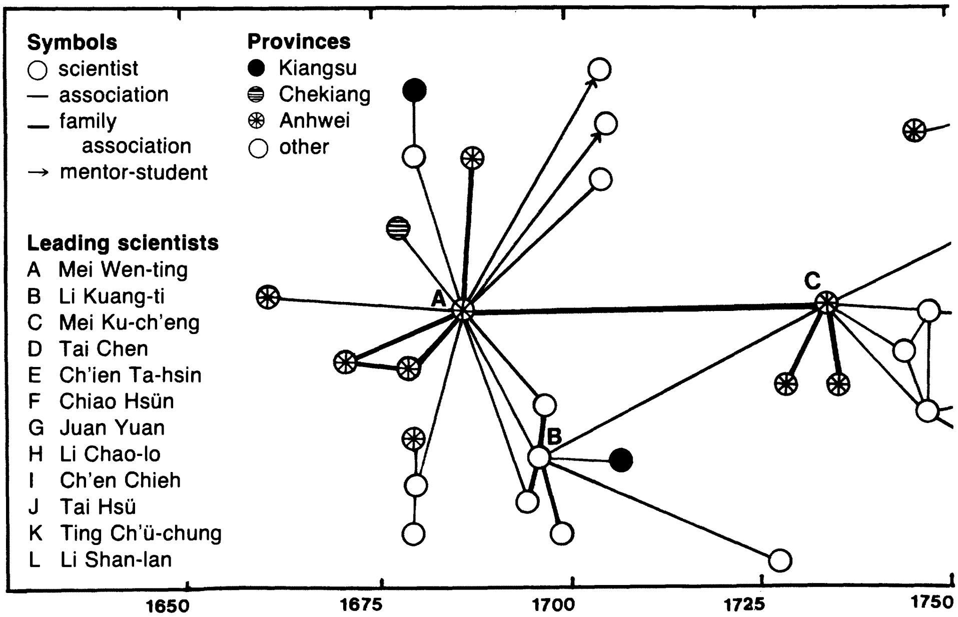


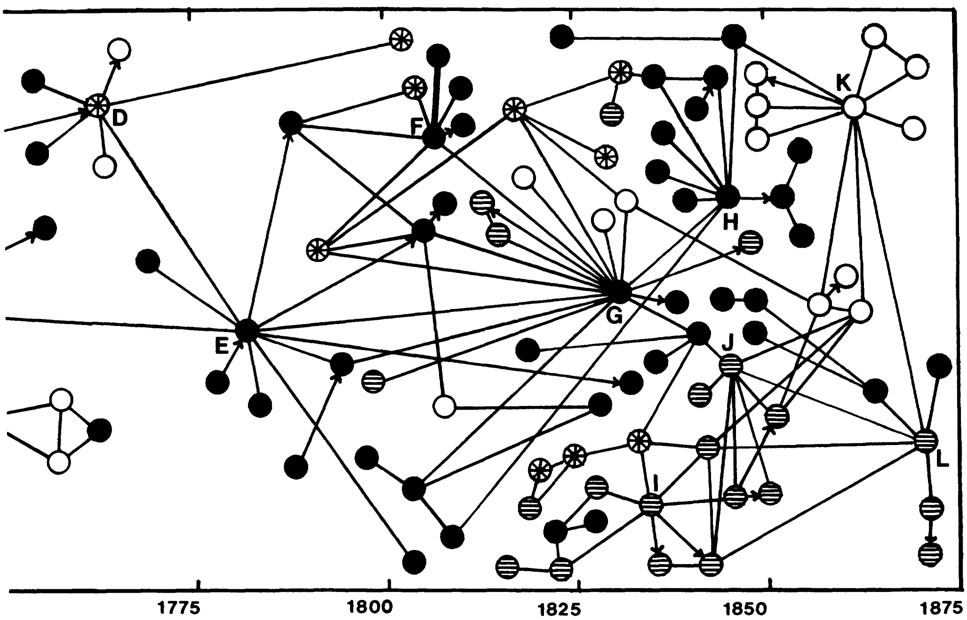
***Figure 1.** Associations between Ch'ing scientists.*

the great majority of associations recorded were not based on family relationship (157 associations).

- Scientists were associated in a continuous network from the beginning to the end of the Ch'ing. The placement of each scientist in the chronological scale of Figure 1 accords approximately to the period of his greatest scientific activity.
- The associations become increasingly complex toward the end of the period, as further interconnections among a variety of scientists elaborate the nuclear arrangements of scientists around a few individuals. Furthermore, these individuals are linked to one another by one or more principal axes of professional association, extending throughout the Ch'ing period (more on this below).
- The social origins and background of Ch'ing scientists must be left to a separate study, but the regional affiliations of scientists are worth a look in passing.[36] Figure 1 displays the origins of the scientists from the three most heavily represented provinces, Kiangsu, Chekiang, and Anhwei. Of the 240 scientists, 169 originated from Kiangsu (82), Chekiang (50), and Anhwei (37). The contiguous portions of these three provinces south of the Yangtze River formed the region known as Kiangnan, which was the intellectual, cultural and social center of gravity of China, as the outstanding success of its inhabitants in social and academic circles throughout the Ch'ing period shows.[37] Figure 1 documents another trend indicative of the growing independence of science: the early prominence of Anhwei—based largely on a family dominance—gave way to the central position of Kiangsu, and later of Chekiang as well.
- Extensive networks of scientific associates and students distinguish several

[36] I am at work on a quantitative analysis of the social origins of scientists and the social environment of scientific activity in the Ch'ing.

[37] Ho Ping-ti, *The Ladder of Success in Imperial China* (New York: Wiley & Sons, 1964), pp. 226–234.



particularly seminal figures. These persons occupy the principal axes of professional association. It is beyond the scope of this study to consider scientific merit, but some of these focal individuals were less brilliant innovators than patrons or popularizers, especially Mei Wen-ting, Ch'ien Ta-hsin, Juan Yuan, and Ting Ch'u-chung. This fact in no way diminishes the significance of such communities for creating a sense of social identity. These associations also provided an essential framework for scientific education and communication and were often the agency by which scientific work achieved publication. Scientific communities surrounding well-known scientists or humanist patrons were not peculiar to Chinese scientific activity. They also appeared in sixteenth- and seventeenth-century Europe, where they prefigured the rise of formal scientific academies.[38]

Not every scientist, of course, belonged to such networks. Yet even while the isolated specialist missed the recognition of his peers, he worked within a scientific tradition. The only available measures of the strength of these practitioners' identity with a scientific community are such indirect indications as associations and intensity of specialized productivity. But although not a few cases of scientific dilettantism appear in the biographies—persons who probably did not perceive themselves as men of science—it seems safe to conclude that the substantial majority maintained viable self-images as scientific specialists.

The self-image of the Chinese scientist was reinforced by a sense of commitment to a common enterprise. Although some scientists worked exclusively within either the renascent Chinese science or the new science of the West, many were eclectic in their orientation.[39] The few who vigorously opposed the new science,

[38]Boas, *Scientific Renaissance*, pp. 241–242.

[39]See, e.g., *CJC*, pp. 632, 639, 802; *Ch'ing-shih*, p. 5501. On eclecticism in the 17th century see Willard J. Peterson, "From Interest to Indifference: Fang I-chih and Western Learning," *Ch'ing-shih wen-t'i*, November 1976, *3*(5):70–80, on pp. 76–78.

mainly out of cultural loyalty or for political ends, were exceptional cases, only marginally identifiable as scientists.[40] Many others seemed to find little difficulty reconciling their cultural identity with their appreciation for Western science. The Yang Kuang-hsien affair may have severely tested their commitment. But that Adam Schall was vindicated on the basis of the empirical validity of his work also vindicated commitment to science. Once again, similar challenges appear in the history of modern science in the West.

Ch'ing scientists also valued the recognition and esteem of their professional colleagues. The importance of priority is a constant refrain in the *Ch'ou-jen chuan*. The biographies mark the value of esteem not only by giving credit to the influential roles of salient individuals but also by stressing the need to accord proper recognition to obscure scientists.[41]

Continuity. Of all the criteria the evidence is perhaps clearest on this one. Ch'ing scientists explicitly recognized that their activity rested on a tradition. Once again the term *ch'ou-jen* may be invoked here: the connotation of transmission from one generation to the next was fundamental to its use in the *Ch'ou-jen chuan*. The term frequently appears in the context of the master-student relationship, where the continuity of knowledge is stressed. Continuity alone is not enough: if it had entailed merely the transmission of a fixed canon, as with a religious tradition, it would not have supported the growth of scientific activity. But Ch'ing scientists were also acutely aware that, like Newton, they stood on the shoulders of their predecessors—that their work was inherently cumulative.[42] Each age exceeded the preceding one in refinement of theory and precision of technique, and at no stage was the process complete.

CONCLUSION

By the late seventeenth century scientific activity in China evinced many characteristics of a continuous and systematic social activity. In several respects the social structure of science was not unlike that in Europe during a comparable stage of the Scientific Revolution. The value of science—particularly mathematics and astronomy—was increasingly appreciated apart from its role in symbolic legitimation of the emperor. With the differentiation of scientific from humanistic knowledge, practitioners of the mathematical sciences now increasingly perceived them as a distinct and autonomous activity based on independent and objective criteria of validity.

Yet if science was increasingly recognized as an autonomous social activity, it was not yet perceived as a form of knowledge having inherent goals, as a distinct way to understand and perhaps to master the physical universe through the discovery of abstract laws of nature. Nor, it seems, did a generalized conception of science exist which embraced not only distinct subdivisions like astronomy and mathematics but a general methodological orientation as well.

[40]Again, Yang Kuang-hsien is a case in point; another is Yang's contemporary Ho Wen-piao; *CJC ssu-pien*, p. 77.

[41]On professional recognition see Storer, *Social System*, pp. 20–23. On priority, see, e.g., *CJC*, pp. 691, 692, 793, 815; for recognition see, e.g., *CJC*, p. 446; Min Erh-ch'ang 閔爾昌 ed., *Pei-chuan-chi pu* 碑傳集補 [Supplement to Collected Biographical Epitaphs] (60 *chuan;* Taipei rpt., n.d.), 42.2b, 43.30a.

[42]*CJC*, pp. 712, 714, 736, 756, 768, 802.

As demands imposed by the cumulative complexity of scientific knowledge grew, some of those identified with scientific activity began to follow distinct careers. But in spite of this increasing distinctiveness of scientific activity, the social status of scientists remained imperfectly differentiated, and often linked to nonscientific activity. Moreover, science lacked some of the criteria of a "profession," particularly formal agencies for recruitment and training of scientists.[43]

On the other hand, as a group Chinese scientists constituted a cohesive community. Scientific activity exhibited a systematic pattern of interaction which reinforced the identity of its members with an intellectual community and promoted the development of scientific knowledge. The scientist's self-image was further enhanced by his sense of participation in a common enterprise. A strong sense of the continuity and cumulative nature of scientific knowledge prevailed throughout the scientific community.

This summary suggests one way in which the patterns of scientific development in Europe and China differed. The systematic social organization of science in China appeared strongest in respect to the internal social cohesion and continuity of scientific activity and the community of scientists, whereas it remained weakest in respect to the adaptation of the social environment to science—the self-perception of scientific activity was better articulated than its perception from without.

Unlike Europe, science in China did not achieve the momentum of a radical social and intellectual movement within the larger social system. Whatever the reasons for this—the strength of traditional social ideology and social stratification, political unification and integration, and economic inflexibility come to mind—to say that China "failed" to achieve the conditions requisite to a scientific revolution has little relevance. The point is that the pattern of scientific activity in China exhibited significant characteristics of a systematic social institution like those found in Western science, while differing in other important respects.

One answer to why a sustained scientific movement only began in China when the West again intruded in the nineteenth century lies in the wider political and ideological climate prevailing in China after the mid-seventeenth century. Although the infusion of new Western science spanned this period, the mood of intellectual ferment and political crisis which had provided the initial impetus for the scientific revival gradually waned. Many early Ch'ing scientists were identified with "Han learning," the intellectual movement that sought to revive "original" Han Confucianism in opposition to the officially sponsored Sung learning based on thirteenth-century Neo-Confucianism. In the aftermath of the fall of the Ming some scholars, including scientists, embraced this movement as a symbol of their loyalist protest against the Manchu conquest. Yet after the early Ch'ing, Han learning never offered a truly viable or lasting foundation for an alternative political and ideological orientation. In the eighteenth century it had become a conservative scholastic movement devoted to textual exegesis and historical linguistics.[44]

The controversy that accompanied the transition from the Ming to the Ch'ing had been a fertile source of intellectual alternatives and stimulation—including

[43]See Storer, *Social System*, pp. 17–19.
[44]Albert Feuerwerker, *State and Society in Eighteenth Century China: The Ch'ing Empire in its Glory* (Ann Arbor: Univ. Michigan Center for Chinese Studies, 1976), pp. 29–30.

especially an eclectic interest in empirical and practical knowledge.[45] When by the early eighteenth century this mood of intellectual uncertainty faded in the light of the successful Ch'ing political and social unification, scientific activity was well on its way to becoming institutionalized, but it was no longer infused with the energy of a radical movement.[46] It did not again emerge as a movement until the mid-nineteenth century, when the Western assault on China brought a new political crisis and renewed critical debate.

[45]See Peterson, "From Interest to Indifference," pp. 77–80.

[46]Joseph Ben-David adduces strikingly similar conditions to explain that England lost its leadership in science by the 18th century because science in England had passed beyond the movement phase, when it is in the process of becoming institutionalized, to its institutional stage; *Scientist's Role*, pp. 77–83. Mikami explains the stagnation of science in China from the late 17th to the mid-19th century as a result of the reaction against Western science based on the traditional Chinese feeling of superiority. But the explanation begs the question: the sense of cultural superiority had not previously presented an obstacle to eclecticism or to the introduction of Western learning. The explanation for these changes must be sought instead in the political and social context of science; see Sivin, "On 'China's Opposition to Western Science,'" p. 201.