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Source: *The Journal of Asian Studies*, Vol. 47, No. 1 (Feb., 1988), pp. 41-90
Published by: Association for Asian Studies
Stable URL: https://www.jstor.org/stable/2056359

Science and Medicine in Imperial China—The State of the Field

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SINOLOGY AND THE HISTORY OF SCIENCE have changed practically beyond recognition in the past half-century. Both have become academic specialisms, with their own departments, journals, and professional societies. Both have moved off in new directions, drawing on the tools and insights of several disciplines. Although some sinologists still honor no ambition beyond explicating primary texts, on many of the field's frontiers philology is no more than a tool. Similarly, many technical historians now explore issues for which anthropology or systems analysis is as indispensable as traditional historiography.[1]

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This is the latest in a series of "state-of-the-field" articles sponsored by the China and Inner Asia Council of the Association for Asian Studies with the aid of a grant from the American Council of Learned Societies. These summaries of issues, progress, and prospects are intended to bridge gaps between subfields in Chinese studies and to make available work on significant topics that is not widely known within the field as a whole. Articles previously published in *JAS* include essays on Chinese literature by James J. Y. Liu (November 1975), on Chinese rebellions and revolution by Frederic Wakeman, Jr. (February 1977), on Chinese archaeology by K. C. Chang (August 1977), on early Chinese history by Cho-yun Hsu (May 1979), on studies of the economy of the People's Republic of China by Dwight H. Perkins (February 1983), and on Chinese painting studies in the West by Jerome Silbergeld (November 1987).

[1] I frequently use the word "science" to include medicine. This loose usage makes discourse about both less tedious than it might be; but I do not consider medicine either an abstract science or a mere collection of techniques. I think of it, ancient and modern, as an art that applies scientific knowledge and techniques. For a definition of "science" generally applicable to premodern and non-Western activity and a list of the traditional Chinese sciences, see below. I use "tradition" and "traditional" on two levels of meaning: to refer to actual lineages of transmission and (with due reservations) as a near-synonym for "premodern." It will be clear that I do not intend it on the second level to ignore historic change.

I am grateful to the American Philosophical Society, the Committee on Scholarly Communications with the People's Republic of China, and the Association for Asian Studies for supporting the research on which this essay is based, and to the Academy of Traditional Chinese Medicine, the Chinese Academy of Sciences, the East Asian History of Science Library, the Cambridge University Library, and the Master and Fellows of St. John's College for their hospitality. Cai Jingfeng, Mary Rankin, David Keightley, and Marta Hanson suggested a

The Journal of Asian Studies Vol. 47, No. 1 (February 1988):41–90.

The study of science and medicine as they were practiced in China between 200 B.C. and the twentieth century has already shown that the dynamics of scientific change are manifested in more ways than the European experience alone can reveal. We can also see that a picture of old Chinese society based solely on literary, philosophical, and religious classics is inadequate.

The work of integrating Chinese Nature-knowledge into these larger frames of cognition—the study of Chinese culture and the history of world science—is already under way. I will outline what recent research has yielded and assess the state and prospects of the field. With this end in mind I will first look at recent trends in the history of science, assuming that the reader will be aware of those in sinology; then at the general shape of the field; and finally at studies of astronomy and medicine, two fields at quite different levels of maturity. I will close with a few general suggestions for more productive research, to supplement observations interspersed through the article.

Since my own view is no more objective than that of any other student of China, let me spell out the limits of this assessment. I was educated in the history of European science and in philosophy, sinology, and chemistry. I am an unabashed dilettante, pursuing, through all the traditional sciences, crafts, and medicine, in every major period from the Han to the present, clues to several questions that fascinate me: how do people in different times and places—different cultures—imagine Nature and mankind's relations with it? What realities and values are reflected in this ideal construction? How is it transformed into concrete technical practice? How does experience of the external world come to be split into specialized domains of knowledge? How do the latter, and the larger vision they inform, change? Reflections on such questions are bound to be comparative. The remarkable character of the Chinese scientific record—technically elaborate, full and unbroken for more than two thousand years, usually precisely dated—makes it an obvious choice to explore.

Scientific Traditions in China

If the conception of science is broad enough to encompass the evolution in Europe from early thought about Nature to that of the present day, it is bound to apply to the diverse Chinese experience. To insist in the history of mathematics on the axiomatic formulation and rigorous demonstration of Euclid excludes the *Nine Chapters on the Mathematical Art* (*Jiu zhang suan shu*)[2] as an object of study, but it also excludes the nongeometric works of Diophantus and his posterity. Europocentric historians of mathematics have never denied that these fall within the scope of investigation. Analogously, to make quantification a necessary condition is to rule out most of today's taxonomic botany and zoology, not to mention vast areas of the social sciences.

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number of improvements.

My first thoughts on this topic were gathered in a plenary lecture at the Third International Conference on the History of Chinese Science, Beijing, August 1984 (Sivin 1985). The section on early astronomy is derived from an evaluation of that field commissioned for the Second Oxford International Conference on Archeoastronomy, Merida, Mexico, December 1985. The full evaluation will be published in the *Proceedings*. An earlier, more extended version of the section on medicine was discussed at the annual meeting of the Association for Asian Studies, Chicago, March 1986. Lectures based on the completed essay were presented at the Collège de France in December 1986 and at research organizations in several Chinese cities early in 1987.

[2] For Chinese primary sources, see the References. I have examined all sources cited here.

A historian's working definition of science might look for systematic, coherent discourse about natural phenomena that strives toward an ideal of abstraction and objectivity. These characteristics mark the sciences off from the endless concreteness of poetic metaphor, as well as from religious frames of meaning built on will, love, and mystical insight. At the same time such a definition does not assume an impenetrable border, for the ancient sciences were not airtight. The ideal could never be realized (nor is objectivity more than an ideal in science today). Still it formed the discourse, giving it consequences that were not literary or religious. Such a definition may be irritatingly soft, but it sums up what is common to all research in the history of science.

As for tradition, to use that word is to insist on ideas and skills that are passed down. We find indeed that in China technical literatures were cumulative, and authors were conscious of their predecessors. They did not acknowledge them merely to exhibit learning or copy them just to fill out habitual structures. Those who worked in the sciences accepted and carried on their forebears' sense of the enterprise, often modifying it in the process. In certain periods innovation was recognized and prized in astronomy and medicine as in many other aspects of Chinese life, but the new became more acceptable to the extent that precedents showed it was not wholly new. Positive responses to Western astronomy and Christianity in the seventeenth century are a case in point (Gernet 1982; Sivin 1973).

Scientific traditions in China, like other traditions of learning, were not schools like those of Athens at its height but rather lineages (*jia*). There are many common elements, but most of the Greek schools did not treat their texts as objects of veneration or demand of disciples a filial piety that ruled out criticism of teachers—as one can see from Aristotle's criticisms of his predecessors (for additional differences, see Nakayama 1984:3–60).

Whether in astrology, carpentry, or pharmacy, what bound the Chinese generations was the duty of transmitting intact a charismatic founding text. The teachings that began sciences were usually said to have been revealed by archaic sages, but later writings could attain scriptural status. Thus a scholar whose authority began a new succession was said to *zi cheng yijia*, "give rise to a lineage of his own." For physicians the founding text was the *Inner Canon of the Yellow Lord* (*Huangdi nei jing*); for those who practiced pharmacy, the *Divine Husbandman's Materia Medica* (*Shen nong bencao*); for builders, the *Canon of Lu Ban*, master carpenter become god (*Lu Ban jing*); for mathematicians, the anonymous *Nine Chapters on the Mathematical Art*.

In alchemy many of the surviving hundred or so texts were presented as revelations. This suggests multiple traditions. Differences of interpretation and emphasis, local variations in epidemiology, and competition for clients ultimately led to the branching of traditions within medicine. In South China the *Treatise on Cold Damage Disorders* (*Shang han lun*, ca. A.D. 200) began a continuing discourse on drug treatment for acute infectious disorders. In the late Song and early Yuan, the *Inner Canon* tradition divided into lineages based mainly on therapeutic strategies (Rall 1970; Li Congfu and Liu Bingfan 1983).

We have good reason, then, to think of self-conscious sciences in China, each with its own history. Let me list them summarily, with their original Chinese names:

Mathematics (*suan*, later *shuxue*)
Mathematical harmonics (*lü* or *lülü*)
Mathematical astronomy (*li* or *lifa*)
Astrology (*tianwen*)
Medicine (*yi*)

Materia medica (*bencao*, usually part of medicine)
Alchemy (*wai dan, fu lian*, etc.)[3]
Siting or geomancy (*dili, kanyu*, popularly *fengshui*)
Physical studies (*wuli, wulei, xianglei, gewu*, etc., a group of loosely related traditions)[4]

History of Science

In its organization as a specialty since the 1950s, the history of science has passed through and has begun to surmount two fads that staked its claim to academic turf but limited it intellectually.

The first of these fashions was a preoccupation with the development of technical ideas in the minds of great men. The scholars who rode the crest of this wave believed that the social statuses, working relationships, economic situations, and political commitments of the geniuses they studied were irrelevant to the progress of knowledge. This progress they saw as a preordained path verging ever closer toward accurate knowledge of the external world. The public and private lives of scientists might distract them from this quest but could not fundamentally affect what constitutes knowledge. What made past scientists geniuses was their ability, conscious or unconscious, to hit on ideas or practices that have survived to become integral parts of modern science. The history of science often became a hunt for precursors of today's conventional wisdom.

Three weaknesses in this approach were often noticed. The first is that sooner or later scholarly ingenuity yielded precursors of the precursors, in what threatened to be endless regression. The second is that one modern generation's positive knowledge for which historians sought "anticipations" often came to be considered trivial by the next or was even rejected. The third is that a fixation on precursors implies that there was no evolution, only people somehow fitfully in tune with the future rather than with their own time.

Thomas Kuhn's *Structure of Scientific Revolutions* challenged the internalist orthodoxy in 1962 but had less influence on specialists at the time than on social scientists. The uses of technology in the Vietnam War and its aftermath led many historians to the astonishing discovery that scientists, like the rest of us, are social animals. Historians began to explore across a broad front the proposition that as the larger society changes, social, economic, and political interests and values change; as they change, they affect decisions about what technical work ought to be done and how it ought to be done. Such scholars tried out, and some found useful, the notion that objective physical reality—a conception that, by the 1960's, philosophy had challenged and anthropology had relativized—was a myth, a particularly strong social convention.

[3] H. J. Sheppard (1981) at long last has provided a definition of "alchemy" based on all the major Eastern and Western varieties, which may finally end skirmishes over which variety is the real thing: "Alchemy is the art of liberating parts of the Cosmos from temporal existence and achieving perfection which, for metals is gold, and for man, longevity, then immortality and, finally, redemption" (p. 188). In China cinnabar played the same role for minerals as gold for metals.

[4] For descriptions of the sciences, see Nakayama and Sivin 1973:xix–xxv. I have revised the list of sciences given here in view of recent studies.

This new externalist history of science meshed with a move toward social analysis in American history departments. It became as productive and respectable as its internalist predecessor. Its cruder practitioners tended to replace the old fantasy of the scientist as lone explorer of the intellectual frontier with a new, equally distorted image of "the scientific community" as visceral defender of the establishment status quo. The solid achievements of externalists have left no basis for the older view of science as great ideas intersecting spontaneously in the void. But from today's point of view internalism and externalism are equally inadequate (Jordanova 1983:83–84).

Over the last decade, the researchers and teachers least wedded to these two orthodoxies have argued to good effect that the subject matter of scientific and medical history is not divided into technical concepts and social interactions. The more recent, broader view of technical activity no longer incorporates several assumptions that were once central. Early science is seen not as an autonomous domain from the start but as an open domain of activity. It is natural to explore its overlap with religion, aesthetics, and other realms (I will return to this point). Historians no longer take for granted that technology was applied science before the late nineteenth century. Rather than assume that craftsmen were empirical scientists in the rough, scholars investigate distinct technological motives and modes of thought.[5]

Those who think about possible models for early science are less likely than a decade ago to take their patterns from mathematical astronomy and physics alone. Nested levels of organization, taxonomic schemata, and other qualitative ways of organizing knowledge, obviously pertinent to early Chinese theory, are generally acknowledged to be useful and appropriate.

Other new characteristics of the history of science result from growth and professionalization. The most influential authors before 1960 were usually educated in science or medicine and wrote with technically trained readers rather than humanists in mind. Historians of science seldom followed academic historians' discussions of issues and methods. But over the last generation the formative contributions (still many, but no longer most, by people trained in science) have come from those who understand the past in its own terms before evaluating its significance for the present.

The move away from earlier fads in the United States has attracted young scholars deeply educated in the humanities who wish to explore in scientific sources the evolution of modern thought and society, the evolving subcultures of technical organizations, and similar issues. Their eclectic orientation has coalesced with trends in Europe to form a transatlantic community of discourse (Thackray 1980). But in Asia the historiography of science has changed very little.

Scholarship on Chinese Science and Medicine

At the forefront, the object of study is no longer a march of progress or a hunt for precursors but an account of how Nature-knowledge is created, used, and altered; how it articulates with a culture's largest structures of cognition, value, and practice; and how it and those structures influence each other. It is historical in the sense that it seeks to explain change, not merely to describe past techniques, theories, or books.

[5] Particularly influential in opening this field of investigation were E. T. Layton, Jr., and Cyril Stanley Smith; the items in the list of references typify their emphasis on concrete reasoning and on the large role of aesthetic motivation. On the other hand, J. A. Bennett (1986) has shown that ca. 1600 in England those who formalized mathematics and those who applied it formed a continuum up and down the social scale.

Development of Scholarship

The history of Chinese science is not a new enterprise. The dynastic histories have often included biographies of technical specialists (physicians and architect-builders as well as magicians and diviners; Ngo 1976; DeWoskin 1983), analyzed past uses of astronomical data (Ang 1979), and so on. Since the Tang, physicians have written about their predecessors, to embody ideals of learning and healing, and to establish as orthodox their own medical lineage.[6] One can find stimulating discussion of contentious historic topics in Xu Dachun's *Topical Discussions of the History of Medicine* (*Yixue yuanliu lun*, 1757). The annotated bibliography of Chinese medical texts compiled by Tanba no Mototane in 1819 is still in print and is used by every researcher.[7]

The writings of Antoine Gaubil (1689–1759) on the history of Chinese astronomy and those of Alexander Wylie (1815–87) on that of mathematics remained important sources for Joseph Needham's survey of the same topics in 1959 (1954–,3:1–168). A glance at the voluminous bibliographies in each of Needham's volumes shows what a great bulk of scattered historical writings, mostly by scientists, engineers, and physicians, had accumulated by 1950. By that time networks of specialists had emerged in China and Japan and had produced not only monographs but also histories of the various sciences.[8]

Their writings had little effect in the West. The Occidental scholars of past generations who penetrated deepest into traditional culture picked up many attitudes of their Republican Chinese counterparts; for instance, the habit of thinking in dynasties, a curiosity largely confined to the Chinese elite, and the assumption that one can generalize about economy, invention, and other technical topics without first becoming familiar with technical literature. Many Orientalists set down firm opinions about why the Chinese were incapable of science, wretched at engineering, and hopeless as physicians, in most instances without reading beyond Confucian and Neo-Confucian classics, the *Laozi*, the *Zhuangzi*, and perhaps a Buddhist document or two.[9] The authors of well-regarded textbooks of Chinese history were until recently still assuring their readers that China never created "science as a persisting institution, a system of theory and practice socially transmitted, consciously developed and used" (Fairbank 1983:75).

Joseph Needham, while working in China during World War II, learned of the Chinese technical heritage from scientist colleagues and began to explore the widespread literature. His towering reconnaissance of Chinese science, technology, and medicine first made educated people in Western Europe and the United States aware of Chinese achievements over the ages. Needham's writings are unified by a highly original combination of initial assumptions, the most important of which are:

[6] The oldest such book known, the *Mingyi zhuan* (Biographies of eminent physicians), by Gan Bozong of the Tang period, is lost and its purpose is unknown. The oldest extant collection of biographies and anecdotes is *Yi shuo* (1189).

[7] *Yixue yuanliu lun* and *Iseki kō*. The latter was compiled by carefully selecting and accurately copying information from earlier works.

[8] Bibliography C in each fascicle of Needham et al. 1954– is a practically exhaustive list of publications in Western languages. Bibliography B enumerates a selection of Chinese sources and a few from Japan, but is relatively complete for publications from the main Asian centers of research (see Table 1 below).

[9] A number of such explanations between 1915 and 1957 are cited in Sivin 1982:54 n. 7.

1. "Mankind is one great family, and the scientific view of the world has clearly transcended all differences of race, color, and religious culture."
2. Science and technology are inseparable, and cross-cultural generalizations should include both.
3. The springs of scientific change can only be understood by attention to extra-scientific factors, ranging from the economic to the religious.
4. "Between the first century B.C. and the fifteenth century A.D. Chinese civilization was much *more* efficient than occidental in applying human natural knowledge to practical human needs," and this superiority reflected more highly developed science and technology.
5. Why despite this superiority "modern science had not developed in Chinese civilization (or Indian) but only in Europe" is thus a central historiographic issue (the "Scientific Revolution Problem").
6. Although the nonhereditary "bureaucratic feudalism" of the Confucian state was "highly favourable to the growth of the natural sciences at the pre-Renaissance level," it inhibited an eventual transformation to science of the modern type.
7. Attitudes found in early Taoist writings encouraged the disinterested empirical observation of Nature, so that "the Taoists" in each period of history were largely responsible for scientific and technological advances. This continued to be so even though the socioeconomic system, as it "sterilised the sprouts of natural science," "converted Taoist proto-scientific experimentalism into fortune-telling and rustic magic."
8. In weighing the many factors that bear on the Scientific Revolution Problem, external factors preponderate: "The analysable differences in social and economic pattern between China and Western Europe will in the end illuminate, as far as anything can ever throw light on it, both the earlier predominance of Chinese science and technology and also the later rise of modern science in Europe alone."[10]

These presuppositions have unified an exploration of scope unequaled in Chinese history or the history of European science. They have given Needham's work a significance that reaches far beyond academia. Because *Science and Civilisation in China* made the world aware of Chinese science, the Chinese government has recognized research in the field as a source of national pride and has generously supported it in recent years.

Needham's assumptions and his conclusions have been challenged, as one would expect in any healthy field. His volumes of the mid-1950s now need to be rewritten throughout as a result of new contributions inspired in part by his work.[11]

Needham's catholicity is not unique in the field. Xi Zezong in the Institute for the History of Natural Science, Beijing, and first Yabuuti Kiyosi and then Yamada Keiji at the Research Institute for Humanistic Studies, Kyoto, have encouraged their working groups to become broadly competent in historical studies of science, medicine, and technology (Yabuuti 1979a). In Asia, the history of science and medicine are not otherwise studied in the same organization. At the Collège de France, Jacques Gernet has recently organized a research group in order to foster a breadth of competence comparable to that found in Beijing and Kyoto. Among its members are

[10] Nakayama and Sivin 1973:4; Needham et al. 1954–,2:33–164, quotation from p. 162; 3:150–68; Needham 1969:190–217, quotations from pp. 190 and 217.

[11] This is not the place for a detailed evaluation of Needham's work and its underlying assumptions, but see the conspectuses in Elvin et al. 1980 and White and Spence 1984 and the critical reflections in Sivin 1978 and 1982. The most penetrating examinations from the points of view of the history of science, sinology, sociology, etc., are listed in Sivin 1982:55 n. 7. For a recent Chinese discussion see Du and Mei 1982. Cullen 1983 contains original reflections on this and many other matters.

Jean-Claude Martzloff (1981a), Karine Chemla (1982), and Catherine Jami (1985), exceptional young historians of mathematics who bring an unprecedented range of technical insight to their sources.

Current Distribution of Scholarship

The distribution of scholars engaged in monographic studies is estimated in Table 1. The total is a small fraction of historians of China worldwide but a significant proportion of active historians of science and medicine. This group supports a number of journals, listed in Table 2.

Members regularly exchange ideas and materials. Triennial international congresses of historians of science regularly include a major session on East Asian science, and international conferences on the history of Chinese science have been held annually since 1982. All of these incorporate the history of medicine.

Most of the roughly seventy historians of Chinese science in Europe and the United States work in universities; only a few would be considered specialists. Most of the outstanding American contributors were educated in history, and an increasing number of budding specialists are taking their degrees in the history of science, with substantial work in Chinese studies. In Europe, where the history of science is barely established, most are still preparing in Oriental studies, and rarely master newer methods in the other field.

In China regular university courses in the history of science began only after 1980, and the scale is still very small. Almost all scholars in the field are full-time researchers in institutes under the Chinese Academy of Sciences, and are trained in science rather than history. There are some prominent scholars outside the Academy of Sciences, such as Ke Jun, the doyen of archaeological metallurgists and former vice president of Beijing University of Iron and Steel Technology; Li Di, a greatly respected polymath, at Inner Mongolia Normal University; and Pan Nai, a leading historian of astronomy, who works for the Municipal Architectural Construction Technology Research Institute in Shanghai. Fan Dainian's "Dialectics of Nature" group in Academia Sinica has been particularly active in importing and experimenting with new methodologies for the history, philosophy, and sociology of science.[12]

In Japan the situation is intermediate between those of China and the West. Most scholars teach, but the Research Institute for Humanistic Studies (Jinbun Kagaku Kenkyūjo), Kyoto, sets the standard. Its seminar on the history of Chinese science has no counterpart in Tokyo.

The history of medicine is structured differently. The study of the classics is still part of the curriculum in China's many colleges of traditional medicine, and many of the professors of clinical medicine, deeply learned in early writings, publish regularly on historical topics. Their writings reflect their professional involvement in what they see as a threatened but vital tradition. The historians in the Academy of Traditional Chinese Medicine provide intellectual leadership and mount large projects to compile reference books and reprint classics, but the field is not at all centralized. The only association, the Society for the History of Medicine, part of the Chinese Medical Association (Zhonghua Yixue Hui, Yishi Xuehui), is affiliated with, and mostly draws members from, the institutions of modern medicine.

[12] The journal *Ziran bianzhengfa tongxun*, originally a vehicle for Marxist philosophy of science, is the best-known publication in the field. A famous example of such experimentation is Jin Guantao et al. 1983.

Table 1. Scholars Whose Primary Research Field is the History of Chinese Science

China

MEMBERS OF PROFESSIONAL SOCIETIES

History of Science Society (Zhongguo Kexue Jishushi Xuehui): total members 840 (historians of Chinese science about 400)
Society for the History of Medicine, Chinese Medical Association (Zhonghua Yixue Hui, Yishi Xuehui): no figures available. This group is affiliated with an organization for the study of modern, not traditional, medicine

ESTIMATED TOTAL SPECIALIST RESEARCHERS AND TEACHERS

History of science and technology: about 400 (science 250, technology 150)
History of medicine: about 500 (mostly practicing physicians)

RESEARCH PERSONNEL AT MAIN INSTITUTE IN EACH FIELD

Institute for the History of Natural Science (Ziran Kexueshi Yanjiusuo), Academia Sinica: 64 (Chinese science and technology, 48)
The China Institute for the History of Medicine and Medical Literature (Zhongguo Yishi Wenxian Yanjiusuo), Academy of Traditional Chinese Medicine: 32

Japan

MEMBERS OF PROFESSIONAL SOCIETIES

History of Science Society (Kagakushi Kenkyūkai): total members about 800 (historians of Chinese science about 10)
Japan Society of Medical History (Nihon Ishigakkai): total members 777 (those primarily studying Chinese medicine about 100, specialists 15)

Taiwan

SCHOLARS DOING RESEARCH IN THE FIELD

22 (there is a Committee for Research on the History of Chinese Science and Technology, formed 1981, with 37 members)

South Korea[a]

MEMBERS OF PROFESSIONAL SOCIETIES

Korean History of Science Society (Han'guk Kwahaksa Hakhoe): total members, 330
Korean Association of Medical History (Tachan Uisa Hakhoe): total members, 25
Total historians of Chinese science: 20

Elsewhere in Asia

SCHOLARS PUBLISHING REPORTS OF RESEARCH IN PRIMARY SOURCES OR ARTIFACTS

Malaysia and Singapore: 3 (3 science)
Hong Kong: 6 (2 science)
Australia: 3 (3 science)

Table 1. (*continued*) Scholars Whose Primary Research Field is the History of Chinese Science

Europe and United States

SCHOLARS PUBLISHING REPORTS OF RESEARCH IN PRIMARY SOURCES OR ARTIFACTS
70 (science 40, technology 12, medicine 18)

NOTE: These figures include scholars who study mathematics, natural science, technology, and medicine. Estimates are from Xi Zezong (science, China), Cai Jingfeng (medicine, China), Sakai Shizu (medicine, Japan), Nakayama Shigeru (science, Japan), Wang P'ing (Taiwan), Jeon Sang-woon (South Korea), and Ho Peng Yoke (Southeast Asia and Australia). Other estimates are my own, based on surveys published in CS 1(1975):4–51, and 6(1983):33–55, and information gathered subsequently. The definition of "primary research field" varies for each part of the world and is specified. Since these criteria are incommensurable, totals would be misleading.

[a]No information is available about North Korea, which sent a delegation of three to the 16th International Congress of the History of Science, Bucharest, August–September 1981.

To summarize from a worldwide perspective, the ongoing shift among technical historians from education in science to education in history has barely begun among those who study China. The specialist journals listed in Table 2 carry only a fraction of publications on Chinese science (including technology) and medicine. Most papers appear in scientific and medical journals in China, and in historical and sinological publications in Europe and the United States. In Japan the much smaller output is mostly published in specialist journals or medical journals.

The great majority of those studying Chinese science are using familiar techniques to elucidate the sources, but some of the scores of books and hundreds of essays published every year are posing new questions and probing for patterns of change.[13]

Issues

Needham's predecessors showed that China had evolved scientific traditions that merit attention. *Science and Civilisation in China*, with its massive comparative documentation and bold arguments, broadcast that message and began revising world history. As we have seen, Needham proceeded to turn the old issue upside down by asserting Chinese superiority across the board for a millennium and a half, and asking why modern science was not a Chinese invention. The heuristic value of this latter question is obvious, but translated into an issue for research, it becomes "why did the Scientific Revolution take place where and when it did?" The obvious main focus of investigation thus shifts to Europe.

But for many before and after Needham who are interested in China, not Europe, the Scientific Revolution Problem provided a shooting gallery in which anyone could fire a few rounds and no one kept score. The concept of inhibition, which as an accomplished biochemist Needham had used sparingly, was adduced with abandon by one writer after another without asking whether a given "modern" feature (rigorous proof, capitalism, etc.) was in fact growing so vigorously in Asian soil that it would have continued to flourish in the absence of the putative inhibiting agent. Such authors were usually ill informed about Europe. For example, they pointed to a backward-

[13] Xi 1983 estimates that in 1982 more than 750 articles on the history of science, technology, medicine, and closely related topics were published in China. One can infer from his survey that 30 to 40 books appeared in the same year.

Table 2. Journals of the History of Chinese or East Asian Science and Medicine

Chinese Science. Philadelphia, 1975–. Irregular.
Historia scientiarum. Tokyo, 1962–. Originally published under the title *Japanese Studies in the History of Science*. Essays in European languages.
Japanese Studies in the History of Science. See *Historia scientiarum*.
Jianzhushi lunwen ji. Collected essays in the history of architecture. Beijing, 1983–. Irregular, 6 vols. to mid-1986.
Kagakushi kenkyū. Journal of the History of Science, Japan. Tokyo, 1941–.
Kexueshi icong. Translations in the history of science. Beijing, 1981–. Translations on every aspect of technical history.
Kexueshi jikan. Publications in the history of science. Beijing, 1958–.
Kexueshi tongxun. The History of Science Newsletter. Taibei, 1982–. Irregular, 4 nos.
Kexueshi wenji. Collected papers in the history of science and technology. Shanghai. Irregular, 14 vols.
Nihon ishigaku zasshi. Journal of the Japan Society of Medical History. Quarterly. New series, Tokyo, 1954– (first published under this title 1941–1945). Essays in Japanese and European languages.
Nongshi yanjiu. Agrohistory research. Guangzhou, 1980–. Irregular.
Nongye kaogu. Agricultural archeology. Nanchang, 1981–.
Tian wen. Zhongguo tianwenshi yanjiu. Celestial questions, studies in the history of Chinese astronomy. Nanjing, 1984–. Irregular.
Zhongguo keji shiliao. Historical materials on Chinese science and technology. Beijing, 1980–. Includes much on modern science.
Zhongguo nongshi. Agricultural history of China. Nanjing, 1981–.
Zhonghua yishi zazhi. Chinese journal of medical history. Quarterly. New series, Beijing, 1980–. Published under this and other titles 1947–1958.
Ziran bianzhengfa tongxun. Journal of dialectics of nature. Bimonthly. Beijing, 1979–. Theoretically oriented journal of philosophy, history, and sociology of natural science.

NOTE: This table includes Chinese journals of agricultural history that regularly carry articles related to science, as well as Japanese journals that include China in their scope but are primarily devoted to Japanese science. Irregular collections as well as periodicals are listed.

looking intellectual establishment or a "feudal" landowning elite in China, without noticing that similar establishments and elites in Europe were unable to stop the social revolution that secularized science. As Nakayama has put it, they "treated science as a structure to be contemplated rather than as a dynamic historical activity involving creation, development, and transmission" (1984:xi).

Those who played this game seldom looked into the assumptions that drew them to it, even when to a normally critical reader their conclusions were patently racist (Lévy-Bruhl 1910; Edmunds 1911; Morgan 1933) or ideologically motivated (Boulding 1976; Wen-yuan Qian 1985). Those outside China have produced endless, contradictory lists of "factors" without exposing themselves to the original scientific literature.[14] Recent discussions in China are often better informed about the Asian sources, but are usually crude in their historiography (Fan Dainian et al. 1983).

[14] Assumptions behind the Scientific Revolution Problem have been analyzed in Sivin 1982.

The last decade's accomplishments can be related to several focal issues (Sivin 1977:xv-xxi). These issues are analogous to those raised in the best current work in sinology and the general history of science.

What were the scientific and technological traditions?

Criteria. The conventional divisions of modern science and engineering are not imposed on the Chinese literature as often as they once were. Chemistry and mechanical engineering were not premodern Chinese divisions of activity or literature. The conceptually elaborate Chinese art of siting or geomancy (*dili, kanyu*, popularly *fengshui*), with a large, neglected literature, does not correspond to any department of modern science. It is akin, rather, to the schemata that landscape architects have been creating to link the aesthetics of topography and buildings (Clément et al. 1982). But that does not say enough. The practice of siting also incorporates rituals through which care for the dead realigns relations among the living (March 1968; Bennett 1978).

Among other faults, positivist categories distract people from asking what the Chinese divisions were. They obscure the fact that the sciences in China were not parts of one body of cognitive knowledge analogous to the premodern natural philosophy of Europe (Sivin 1982:47–51). Yoshida Mitsukuni (1970) has examined the ancient relations of astronomy, astrology, and astral religion worldwide, and has found the clear modern boundaries between them as untenable in China as elsewhere. Mircea Eliade (1956, 1968), after examining on a global scale the worldview of alchemists, has left no basis for supposing that they thought like modern chemists. I have argued that although alchemists applied chemical knowledge, their goals were not cognitive but religious or oriented toward healing (Sivin 1977:108–22).

Many scholars in China, and Needham in the West, have long argued against studying elite traditions alone, but only a few historians of science have delved into alternatives. Paul Unschuld (1985) has written the first scholarly history that considers popular ("demonological") healing and the work of religious curers alongside classical medicine. Ngo Van Xuyet (1976) has to some extent untangled the extraordinarily confused picture of technicians (physicians, architects, prognosticators, etc.) in the early histories by analyzing the political and social conflicts that underlay use of the epithet "*fangshi*," "master of formulas," often mistaken for a determinate social category.

Level. There is much to be lost by looking at any historic activity as though it were uniform up and down the social scale and across the geographical breadth of China. Simplifying assumptions of this kind are unavoidable when first sorting out a domain of craft or science, but sooner or later it becomes possible to leave them behind. As Skinner (1985) has suggested for social and economic history, the macroregion is a sounder basis than China as a whole for historical generalizations covering long stretches of time. Regional analysis is beginning to be applied to technical history, so far only in studies of food and nutrition (Mazumdar 1984; Murray 1985). Recent publications from China, for instance collections of biographical notices of Jiangsu and Sichuan physicians from gazetteers and other sources (Chen Xianfu 1981; Chen Daojin and Xue Weitao 1985) and a province-by-province bibliography of medical writings (Guo Aichun 1984–), are ready to facilitate regional analyses. Since the

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For a classic critique of historic explanations that depend on lists of positive and negative factors, see Merton 1970:x–xi.

history of traditional medicine in modern China was launched in the mid-1970s, many interviews of elderly physicians and studies of provincial medical education have accumulated that will be useful in reconstructing local practice in earlier times. These are found in the historical quarterly *Zhonghua yishi zazhi*, and in *Zhongyi zazhi* and other journals of traditional Chinese medicine.

Relation to politics. Scholars often hold to an ideal picture of science insulated from politics, despite the prevalence for the past century of lobbying and opposed expert testimony on charged public topics. Analysts of early Chinese thought about Nature have tended on the whole to take the ideal more seriously than the reality. The documents in which such basic concepts as yin-yang and the Five Phases (*wuxing*) matured (Graham 1986), from the "Xi ci" appendixes of the *Book of Changes* (early second century B.C.?; Peterson 1982) through the writings of Dong Zhongshu (ca. 135 B.C.) to culmination in the *Tai xuan* of Yang Xiong (ca. 4 B.C.), suggest that political concerns have been inseparable from worldviews. Every discussion, usually explicitly but sometimes tacitly, justifies as natural the central monarchic and administrative order. Each tries to define an orthodoxy that will motivate educated people, once they have correctly related their personal microcosm to the macrocosm, to help their sovereign make the state a counterpart of the universal order of Nature (Nylan and Sivin forthcoming).

Political issues remained in view as a more comprehensive web of correspondences was elaborated in the *Inner Canon of the Yellow Lord* (probably first century B.C.) to aid clinical reasoning. In its dialogues between sage adviser and sovereign, soundness in the somatic and political microcosms depends on identical principles. The similitude of governing and curing (both called *zhi*, "bringing order") remains a theme throughout the history of classical medicine. The idea that illness results from incorrect action or thought, found in records of healing at every level of Chinese society, has political consequences when public authority enforces social definition.

Zhao Hongjun's recent study (1983) of the polemics between Chinese and Western medicine—a book exceptional in its attention to the political dimension—begins its analysis with the late Qing period. It deserves attention from scholars of earlier eras.

Relations to philosophy and religion. Sinologists in recent decades have done away with the notion that Confucianism, Taoism, and Buddhism were abstract and unchanging essences that determined the shape of intellectual history, three piles into which the contents of a given mind can be mechanically sorted by identifying quotations and key words. A couple of decades ago a paragraph on Confucianism or Taoism might have shifted between half a dozen different senses of the word, but such vagueness is dying out (Fukui 1977; Sakai and Fukui 1977; Sivin 1978; Sakade 1986).

By the end of the first century A.D., the search for an orthodoxy based on cosmic order, just mentioned, had intimately united doctrines of Confucius and Laozi. A quotation from the latter no longer implied that a thinker is a Taoist—at least if we use a definition of the word that applies to people rather than disembodied essences. Most of the Taoist movements (which never became a unified religion) were concerned with the figure of Laozi as savior, and ultimately as emanation of the Ineffable. In their eyes the *Laozi* was "a cosmic writ in relationship with the Five Phases (*wuxing*) and only incidentally a philosophical or mystical treatise" (Schipper 1985b:46–47). Few initiates saw anything of interest in the *Zhuangzi*, at least until Tang imperial patronage made the book prominent.

Sinologists now tend to use "Taoist" and similar terms as explanatory categories only when they have some social meaning. That tendency is germane to the study of science. I have mentioned Needham's conviction that Taoism animated much scientific research in China. "Taoist alchemy," "Taoist medicine," and so on are refrains in recent popularizations. Scholars at work in these fields find, however, that many such "Taoist" sentiments have been taken out of context and that "Confucian" and "Buddhist" sentiments are regularly found in the same sources. Reminiscent of a generation ago is a recent monograph on medical ethics organized around an eternal war between practitioners "inside" and "outside" Confucianism (Unschuld 1975, 1979; also in Morita 1985, by "a modern physician"). But this is no longer the norm.

Two exemplary studies ask specific questions about Taoism and alchemy. Michel Strickmann investigates how Tao Hongjing (456–536) used alchemy in founding an imperially sponsored Taoist cult in South China. He concludes that alchemy, medicine, and other arts "emerge more clearly against the backdrop of Chinese society if visualized as separate entities, weaving in and out of Taoist (and other) contexts in the course of history, rather than as somehow being integral parts of a 'Taoism' that depends on them for its definition yet lacks any social dimension" (1979:166). Isabelle Robinet (1979; 1984, 1:21–34) shows that alchemy and other arts of immortality were flourishing in South China before Taoism—that is, the Celestial Masters movement—entered from the north in the early fourth century. The old idea that alchemy was practiced primarily by Taoists turns out to be an artifact of the vagueness with which the word "Taoist" was once used.

Where were the sciences located in society?

No category like *scientia* united the sciences. One could learn from them aspects of the *dao* or of *li*, but these notions reached far beyond the limits of cognition (Sivin 1986a). Many orthodox thinkers were attentive to Nature in their teachings, but there is no counterpart to the Platonic hierarchy of knowledge, graded by certainty, that inspired the European trivium and quadrivium.

The sciences were not part of one overarching structure because they were not subordinated to philosophy in institutions for research and teaching. Nothing inherent ruled out such a relation, as we can see when astronomy came to occupy an important place in late Ming and Qing Neo-Confucian thought and entered the curricula of mid-Qing advocates of "evidentiary research" (*kaozheng*, *kaoju*; Henderson 1984:153–55; Elman 1984:79–85). In the Han each science began with theoretical roots in yin-yang, Five Phases, and other concepts and then grew on these roots without systematic reference to those of the other sciences or to philosophic innovations. Zhu Xi (1130–1200), enthusiastic about all the sciences, was out of date in his knowledge of them. He was on the whole ignored by later technical innovators despite his great authority in orthodox teachings.[15]

The Chinese sciences were not the basis of professions, nor even of coherent occupational groups. Astronomy was largely located in the imperial court because the calendar (that is, accurate predictions of celestial events) was part of the imperial regalia. We find healers scattered from the top to the bottom of the society and across

[15] This judgment about Zhu Xi's knowledge is based on the *Zhuzi yu lei* and other sources. Many pertinent citations have been gathered in Yamada 1978.

the empire, from the functionaries of the Imperial Medical Service to spirit mediums who cured in trance and illiterate herb-gatherers. The officials did not constitute the highest echelon; in both the popular estimation and the view of learned doctors, the celebrities were the amateurs who had made their reputations as statesmen or poets, such as Shen Kuo (or Gua, 1031–95) and Su Shi (1037–1101), or the learned teachers who had founded well-populated lineages of practice. Alchemy appears to have been practiced on the margins of society. As its "internal," meditative form became widespread over the last millennium, the chemical manipulation of minerals and other substances became markedly rarer. The survival of laboratory alchemy and the extent of its use after ca. A.D. 1000 have been inadequately explored.

What were the sources of new ideas, techniques, and problems?

When there is an abrupt change in the way a traditional science defines its problems, its boundaries are the obvious place to look for reasons. The pertinent boundaries may be cultural or social.

The import of new ideas and practices—even challenges such as epidemics—traveling between cultures and over geographical frontiers has been brought home to historians by the global syntheses of William H. McNeill. In *The Rise of the West* he argued that in Western history new impulses have tended to appear at the boundaries between Europe and other cultures; in *Plagues and Peoples*, that the international movement of disease accounts for much social upheaval and political change; and in *The Pursuit of Power*, that the development and spread of armed violence in human populations can be treated as a "macroparasitism" parallel to the "microparasitism" of disease.[16] As for influence on and by China, Edward Schafer (1963) has explored with customary brio the importation of people, ideas, books, and artifacts in the Tang and their impact, and Lynn White (1982) has painted a compendious portrait of the large Asian contribution to the material culture of medieval Europe.

The most novel parts of Needham's volumes have discussed the travel of ideas and techniques to and from China (1954–). He strengthens his arguments whenever possible by taking as his units groups of inventions and ideas that appeared in Europe at the same time. His tendency to assume transmission in the absence of evidence for independent invention has been questioned, but where evidence is available he has meticulously documented borrowings between every major civilization. European technical historians offended by his claims of Chinese priorities can no longer ignore his work, but where it challenges received accounts, they tend to dismiss it rather than produce counter-evidence of the same quality (Reynolds 1983:9–30; Cipolla 1967:40, 152).

There have been few recent contributions on the same grand scale as those of Needham and McNeill, but important studies have thrown light on technical change (or lack of it) resulting from transmission. An abiding puzzlement is the negligible influence on Chinese mathematical astronomy of Indian and Islamic specialists employed in the imperial court between the eighth and seventeenth centuries. So far we have little but opinions as to why this was so, but a few significant pieces of the puzzle have come to light. Yabuuti (1979b) and Yano (1986) have studied treatises used by Indian astrologers in eighth- and ninth-century China. Cullen has discovered

[16] McNeill 1964, 1977, and 1984. On the role of China in world history, see 1984:chap. 2.

the oldest extant table of tangents (generally considered an Indian innovation) in Yixing's great system of astronomical computation (ca. 725). Cullen (1982; see also Ang 1979) provides closely reasoned hypotheses about Indian influence. For interaction with Islamic science, there has been nothing comparably important outside *Science and Civilisation in China* since 1967, when Miyasita Saburo found a set of twelfth-century Chinese anatomical illustrations reproduced in a Persian manuscript of 1313–14.

Despite intense recent activity in studies of Jesuits in China, little additional light has been cast on their scientific activity and responses to it. The most significant study of the last decade is Gernet's *China and the Christian Impact* (1982), which for the first time examines closely and in an integral way, rather than isolating from each other, seventeenth-century Chinese views of European astronomy and Christianity. Pan Jixing (1984) has tied together earlier studies to show the influential role of the Kangxi emperor as an enthusiast of Western science.[17]

Gottfried Wilhelm Leibniz (1646–1716) has been portrayed as a key figure in the influence of China on the Enlightenment, to the point of suggesting that his correspondence with missionaries may have been responsible not only for his organismic philosophy (Needham et al. 1954–, 2:496–505) but also for his binary arithmetic (Wilhelm 1948). Recent studies have situated his ontology firmly in a European matrix and have shown that, in his mathematical notation as well, what he drew from China confirmed ideas already well formed (Leibniz 1977; Mungello 1977, 1979; Leites 1978).

More difficult to cross than boundaries of states are those between social strata. Perhaps the most stimulating area of growth in the sinology of the past two decades has been in studies of popular culture. The main findings bear on the history of science in two ways. First, in late imperial China literacy was much more widespread and less uniform in standard than the conventional wisdom had it (Rawski 1979). Second, a great deal of religious practice and belief that has been called Taoist actually belonged to popular religion. Ancient pedants, who found Taoist movements and popular cults equally reprehensible, muddled them, and the lay faithful were not inclined to divide their beliefs into mutually exclusive compartments. In a field study Schipper (1985b) writes of classical and vernacular liturgies in modern Taiwan performed by distinct priesthoods within Taoism and also in popular cults. In earlier times the ritual and social structures of popular and Taoist practitioners were more distinct (Sivin 1979).

As yet, curiosity about popular culture has had negligible influence in studies of science, but Wang Lixing has been working in this area for some time (e.g., 1983a, 1983b). In a report on healers in present-day Taiwan, Kleinman has proposed an analytic framework adaptable to historical inquiry (1980; discussed below).

A promising new area of exploration is the ethnoastronomy of the Chinese minority peoples, an area in which mythology and calendar computation intersect. This topic was almost completely neglected before the last decade, but government emphasis on ethnic minorities has drawn attention to it. We now have, in addition to scattered studies, a volume that draws together astronomical studies of a variety of peoples, and a substantial historical monograph on the astronomy of the Yi people

[17] Jonathan Spence's splendid "autobiography" of Kangxi (1974) is aware of this interest but does not cite the main source for studying it, the emperor's remarkable book of jottings on science, technology, and natural history, *Kangxi ji xia gewu bian*. The book is translated, partially and not very satisfactorily, in Cibot 1779, criticized by Chen Shouyi 1957. See also Wen 1981.

of Yunnan province (Anon. 1981; Chen Jiujin et al. 1984). Such work has already cast light on less local questions. The authors of the monograph found that the Yi used a solar calendar with ten 36–day months, and suggested that a Confucian text more than two thousand years old would make sense for the first time if it were understood to describe a similar calendar.[18]

Another boundary relevant to technical innovation is the one between theory and practice. In the history of science, it has usually been treated as a distinct interface, largely because of Western parochialism. The mind-body dichotomy and the opposed pull of intellectualism and anti–intellectualism are all part of the European story. Equally to the point is the collapse of learning in Europe, which left classical science to a few cloistered epitomizers and encyclopedists and left most doers illiterate. Galen (129/130–199/200) combined erudition and practice, but for a millennium after his time, few physicians west of Byzantium or north of Salerno based substantial clinical experience on high medical learning.

In Chinese medicine, despite periods of social chaos and the disdain of the literati for manual labor, theory and therapy were never sundered. Even commentaries on the medical classics were with few exceptions compiled by practitioners. Medical case histories were compiled by 100 B.C., and developed into a large literature beginning in the eleventh century A.D. Theory was not a set of abstract doctrines, but the systematic reasoning that underlay diagnosis and therapy. This point has been made with reference to present-day as well as early Chinese medicine (Farquhar 1986; Sivin 1987).

How were the sciences related to other kinds of thought and activity?

I have already mentioned that, in ancient science in all the great civilizations, thought about the external world, however rational, was professedly value-laden. It was not cut off from other sources of value in personal experience—good, justice, beauty, or mystic union with the object of contemplation. Overlaps with magic were firmly established as an object of study by Lynn Thorndike's *A History of Magic and Experimental Science*, published between 1923 and 1958. The roles of magic and occultism in the formation of early modern science remain a topic of lively debate (Westman 1977; Vickers 1984b).

Ethnologists find magical and religious healing a central concern, and they have made signal contributions to the study of Chinese culture for more than half a century (Minakata 1971–75; Hsu 1952; Elliott 1955; Topley 1970; Baity 1975; Kleinman 1980). In studies of early healing as well, this breadth of conception is no longer unusual (Cooper and Sivin 1973; Harper 1982; Unschuld 1985). Schipper has laid to rest Maspero's depiction of "Taoist" meditations as purely physiological in nature, showing that those connected with Taoism in any significant sense were consistently based on a religious view of the body and mystical practices.[19] Schipper (1985a) has also uncovered the structural ambiguities inherent in religious ideas of epidemics and the gods that both bring and cure them, as well as the differences in the ways that

[18] Chen Jiujin 1982. Chen's hypothesis does not dispose of the problem, since the "Yue ling" portion of the *Li ji* is organized according to a scheme of twelve months.

[19] Maspero 1937; Schipper 1978, 1982. Needham et al. 1954–, vol. 5, pt. 5 (publ. 1983) still contrast the "psycho-physiological" character of internal alchemy with the "allegorical-mystical enterprise" of Europe.

popular and Taoist liturgies respond to them. Michel Strickmann (1979) has, with characteristic originality, studied the relation between alchemical drugs and eschatology. A discussion (Sivin 1976) of mysticism and allegory in internal and external alchemy converges with his conclusions.

Studies of how science is related to other aspects of culture have just begun. Needham has perceptively examined the representation of geological structures in Chinese painting (Needham et al. 1954–, 3:592–98 and pl. 92), putting to rest the notion that Cathayan artists were not interested in such matters. Martha Li Chiu (1981) is instructive on the legal implications of medical diagnosis. Although studies of science in Western literature and of the role of scientific writings in European literary history have been most productive, it is remarkable that students of Chinese literature have not yet begun to explore technical books. Hellmut Wilhelm, at least (e.g. 1977), has been attentive to literary and rhetorical aspects of the *Book of Changes*, and has inspired attention to other works in the same tradition, as important for literature as for cosmology (Nylan and Sivin 1987).

Much has been said on the social and political uses of science and medicine in imperial times, but in general such analyses have been crudely reductive and functionalist. One concludes that those who ignore today's social theory are doomed to use outmoded assumptions that have faded into "common sense." Only a few studies of the ancient sciences put to good use current insights in anthropology and sociology, notably Steven J. Bennett (1978) on siting and Martha Li Chiu (1986) on early medical concepts. Methods used in some anthropological studies of contemporary health care mentioned above can easily be applied to early healing (Kleinman 1980, Farquhar 1986).

What were the constraints on change?

It has been more than a decade since anyone has claimed (in a scholarly journal, at least) that Chinese were incapable of abstract scientific theory (Mungello 1972). The ingenuity expended over the years on why Chinese were not capable of geometric proof has also turned out to be wasted, since Wagner showed the existence of such proofs in commentaries on the *Nine Chapters on the Mathematical Art*. The differences between this Chinese approach to proof and that of the Greeks has opened up a new range of interesting problems (Vogel 1968; Wagner 1978, 1979; Li Di 1982; Guo Shuchun 1983). Martzloff (1980, 1981a, 1981b) has called attention to some of the most interesting of these problems by showing that, although the impact of Euclid's *Elements* on seventeenth- and eighteenth-century Chinese was immediate and great, its deductive structure of argument had very little influence.

I suggested some years ago (Sivin 1969) that, if we want to locate the assumptions responsible for discontinuities and revolutionary changes in the exact sciences, we are more likely to find them within the mathematical procedures than in verbal rationalizations. That is also true of explanations for seeming weaknesses. The use of 3 for *pi* in computational astronomy for nearly a millennium after the value was known to ten decimal places seems irrational, but a close analysis of one system shows that the error in the crude value offsets other errors and thereby increases accuracy.[20]

[20] This result devolves from my ongoing study of the *Season-granting System* (*Shou shi li*) of 1279, the greatest synthesis among traditional systems, in collaboration with Yabuuti Kiyosi and Nakayama Shigeru.

Similarly, Chinese "ignorance" of anatomy, with the same scant descriptions and crude illustrations of organs reprinted in one medical book after another, has been explained by Confucian taboos against dissection. This hypothesis ignores the common practice of autopsy (McKnight in Sung Tz'u 1981; Jia Jingtao 1984). Manfred Porkert (1974:107–8), familiar with the Yellow Emperor tradition, has argued that the early Chinese understanding of health and disease was as heavily weighted toward function as that of Galen toward structure. What the organs did, not their design and spatial relations, mattered. There was nothing that a doctor could accomplish by cutting into the abdomen. He was curious about the balance of body functions and the propagation of functional imbalance. The location of an inner lesion was of minor concern. In Europe anatomical knowledge had practically no clinical utility until the middle of the eighteenth century, but it was a source of prestige for learned doctors whose reputations did not depend on practice. In China the unbroken tie between doctrine and practice removed this motivation for the development of anatomy as well.

As these examples indicate, the limits of the traditional sciences are unlikely to be clarified by checking their gross features one by one against those of modern science. Specific comparisons with premodern science in Europe and other cultures are more likely to be pertinent. But a first step is to understand the inherent strengths and weaknesses of systems of ideas in practice, so that we can compare wholes rather than isolated data out of context.

What were the consequences of steadily integrating doctrine and practice in medicine and the physical sciences? How did this integration proceed without an all-encompassing framework of science to enforce cross-fertilization between the sciences? Clearly defined questions directed at the sources may yield parts of an answer that is far from intuitively obvious. We find, for instance, that it was not at all rare for those who pursued the sciences to master more than one tradition—although curiously polymaths were somewhat bunched in the Han and Northern Song eras. The writings of one such polymath, Shen Kuo, do not indicate that he achieved, or even sought, an integrated framework for his diverse knowledge; the one common thread is the varied responsibilities of his career as a high civil servant (Sivin 1975; Sivin 1982:49–50).

A couple of other pertinent constraints have come to light. Nakayama Shigeru, in a book that ranges across millennia and civilizations, has contraposed Chinese and Japanese academic traditions to those of the Middle East and Europe. The former were built on classification, with great tolerance for anomalous data, and the building of authoritative written traditions. The latter were founded on logic, oral debate, and a quest for laws that subsume all experience. Nakayama argues, in fact, that the heritage of the East Asian traditions has encouraged a failure of nerve in Japanese professional groups seeking to stake out a position in international science today (1984:224–37).

Equally interesting are recurrent statements found in technical treatises from ca. 100 B.C. to at least the seventeenth century that the realm of predictability is inherently limited. A full knowledge of the patterns underlying physical phenomena is not attainable by rational and empirical means. Empirical study must be supplemented by meditation, concentration, self-examination, and other ways of learning. This conviction was the rule in medieval Islam and the West (White 1978) and survived in Neo-Platonism to the seventeenth century. Its abiding position in the mainstream of the exact sciences and its expression in bureaucratic documents give it special significance in China (Henderson 1984:246–53, Sivin 1986a).

These constraints and others yet to be discovered are bound to cohere with several long known. One of these, a corollary to the tight linkage of theory and praxis, is the tendency to recast highly abstract inquiries into practical, problem-solving form, characteristic of much modern science but unusual in the early West. Another is that, although abstract concepts such as yin-yang and the Five Phases were used in sophisticated schemata to explain complex relationships underlying change, we often find (especially in siting and medicine) verbal symmetries treated as symmetries of phenomena. Classical yin-yang theory does not demand a reason for needling the left (yang) side of the body when pain is felt on the right (yin) side; the theory *is* the reason. This identification of word and thing played a most ambiguous role in the evolution of European science; its outcome in China needs analysis as subtle as that provided for Neo-Platonism by Vickers (1984a) and others.

What do these constraints portend? The issue is not whether revolutions were possible. Two revolutions have been identified that meet the criteria usual among historians of science (basic change in what forms a problem, in what kinds of data are pertinent, in what constitutes a solution, etc.). In the first century A.D., one revolution abandoned simple cyclic explanations for celestial motions (Sivin 1969). In the middle of the seventeenth century, the other exploited Western astronomical knowledge as soon as it was introduced to transmute the traditional approach to prediction (Sivin 1973). The question is thus not why revolutions did not take place but why, when they did take place, their social consequences were negligible. The assumption that a scientific revolution must have important social consequences is incorrect. We are faced with a new range of questions about the causes of social consequences (Sivin 1982:62–65). The work that will throw light on them has hardly begun.

Particular Sciences

Of the scientific fields enumerated above, only medicine and materia medica, mathematics (Martzloff 1985), and astronomy (including observational data derived from astrological records) are regularly studied. Work on physical studies has not gone beyond an occasional study of a text. Nothing innovative with regard to siting has appeared since Bennett's multi-dimensional survey of 1978, although a field study mainly from South Korea by the Cléments (1982) will help to make up for the paucity of similar work in China.

Alchemy is now little studied worldwide; where once historically minded chemists were fascinated by it, the growing prestige of scholarship on twentieth-century chemistry has encouraged them to explore their own time.[21] Because work on recent science has hardly begun in China, alchemy is still attractive. Chen Guofu has supplemented his pioneering study of early Taoist textual traditions (1949) with a volume devoted to alchemical writings, their dates and technical language (1983). Zhao Kuanghua (1985) and Meng Naichang (1983), along with small groups of associates, have begun chemical experiments essential to understand the meaning and significance of alchemical writings.

Studies of internal alchemy (meditative disciplines of self-cultivation that use alchemical symbolism) have been facilitated by a volume on the subject by Needham

[21] For Western work on alchemy, see Butler et al. 1980 and Sivin 1968:181–83. Shimao 1986 surveys the entire literature.

et al. (1954–, vol.5, pt. 5; see also Needham 1978) and a monograph by Farzeen Baldrian-Hussein (1984). Needham's central purpose is to demonstrate that internal alchemy was a kind of "proto-biochemistry"—a beguiling but extremely partial explanation. Nevertheless the book is rich in data adaptable to other ends.

By far the most important historical findings stemming from laboratory work come from archaeological metallurgy. A strong group of researchers, given intellectual direction by Ke Jun and in close touch with innovators abroad, has made a succession of remarkable discoveries. To mention only a few recent accomplishments, the origins of Chinese cast iron have been clarified, a remarkable Han and Wei malleable cast iron has been explained as due to inclusion of spheroidal graphite, and the lost wax process for bronze casting has been traced to the sixth century B.C., with no significant break in its use from the Chou period to the present.[22]

For examples of problems, trends, and prospects in particular Chinese sciences, I will survey astronomy, a field in which high standards and innovative research have long been visible, and medicine, in which they have been combined only occasionally until this decade.[23]

Astronomy

What makes Chinese astronomy difficult to integrate in world history is precisely what makes it valuable. Its record runs from ca. 1200 B.C. to the twentieth century. Its sophistication is so well known that I need not pause over it. Many foggy platitudes about the reluctance of the Chinese to approach astronomy theoretically and their inability to apply spatial reasoning have been retired by recent scholarship (Ho 1977; Sivin 1981).

Despite a continual passage of scientific ideas and techniques across continents since the Neolithic, Chinese astronomy evolved with little influence from the Old World. The crude observational records of the late second millennium B.C. and the rudimentary ephemerides of the late first millennium do not leave much of a formative role for Mesopotamian influence. We see an evolution practically without gaps from these simple beginnings to the zenith of sophistication in the thirteenth century A.D.

Chinese astronomy is also verbose. We do not have to wonder why astronomers in 100 B.C. or A.D. 1280 moved off in new directions; they tell us in detail. Detailed prospectuses and committee reports explain the relation between observation and computation, and test the reasoning of the innovators.

Verbosity is a virtue in astronomical traditions. What we know of living cultures indicates that their knowledge of the sky is never merely empirical. Behind patterns of data lie metaphysical abstractions that point to a coherent physical reality, and concrete metaphors that tie sky order to social order.[24] China offers a trove of cases in which the abstractions are spelled out and the metaphors explained. These instances

[22] See Barnard and Satō 1975 and Hua et al. 1987; on origins, Tian 1981, Barnard 1983, and speculations in Wagner 1986; on spheroidal cast iron, Hua 1982, Guan Hongye and Hua 1983; on lost wax, Hua 1985, Hua and Wang Ancai 1985. Important collections include Beijing Gangtie Xueyuan 1986, Hua et al. 1986, and issue no. 13 of KW (1985).

[23] For the bibliography of technology and of other fields of science see the relevant volumes of Needham et al. 1954–. Sun 1979 gives an overview. Introductory bibliographies of work in Western languages may be found in Nakayama and Sivin 1973:279–314 and Sivin 1986b.

[24] The first point was made long ago in Burtt 1925. The second is being related to simple as well as elaborate cultures by anthropologists, e.g., Horton 1967, 1982, and Gellner 1973.

can throw light on general patterns that relate assumptions about society and Nature to technical praxis.

Chinese Characteristics

This is not to say that everything we find in China will be true worldwide. The early invention of bureaucracy in China affected astronomy as well as philosophy. It facilitated systematic recording. It reduced the production of the calendar, including the prediction of eclipses and planetary motions, to a step-by-step program for a human computer who was expected only to know basic arithmetic. That was also true of the *Almagest* (Hellenistic Egypt, ca. A.D. 150), but its Chinese counterparts could not approach Ptolemy's predictive accuracy or explanatory power.

To look at another aspect, Chinese astronomy and astrology were locked in an interesting tension. Astrology, like that of Babylonia, was concerned with unpredictable phenomena that warned of danger to the ruling dynasty. Phenomena that were regular and could be computed were not omens. The astronomical official looked for unforeseen events in the sky and interpreted their significance. At the same time he tried to incorporate as many phenomena as possible in a correct ephemeris. The most creative astronomers constantly strove in that way to reduce the range of ominous events, to replace the uncertainty of the sky with a set of regular computational cycles that would make future stargazing unnecessary, as a bureaucratized cosmos no longer challenged the political status quo.

Divination on behalf of individuals (Nakayama 1966) or for military purposes (He Guanbiao and He Bingyu 1985) showed the same abstracting impulse. By the time full-fledged systems of divination were well described, the typical method was based, not on calculating the relations of planets at the time of conception or birth as in the contemporary West, but on counting off the year, month, day, and hour of birth within purely numerical cycles of 60. Since these cycles were constructed by pairing much older cycles of ten days and twelve hours, we have reason to suspect astral origins, although we do not yet have clear evidence for the connection.[25] But if individual fates were originally rooted in the sky, the point is that those cycles were uprooted and made abstract.

Hellenistic horoscopes entered China in the third century A.D. and had a brief vogue there in the eighth and ninth centuries. But horoscopic astrology failed to influence the development of astronomy as it did so decisively in Europe, Islam, and India (Nakayama 1966).

We have recently uncovered a remarkable stratum of popular religion in which, two thousand years ago, men of knowledge danced out the shapes of constellations in rituals that, as they evolved by the Tang, launched the dancers on spirit journeys through the stars. The oldest record of these rituals is in a medical formulary (Schafer 1977:234–69; Harper 1982). These examples will perhaps make clear my point that Chinese astronomy and astrology are in many respects not at all universal.

Issues

Given the richness of the Chinese record, we should be able to shed light on almost any astronomical question. The bulk of research has been devoted to questions

[25] Chao 1946 has yet to be superseded as an introduction, but see also Döbereiner 1980. The best general and comparative study of the relation between divination and astronomy is Nakayama 1966, reprinted in Sivin 1977:94–106. On astronomical connections of early

of what astronomical feats Chinese performed before anyone else. That is an understandable righting of an imbalance, considering how regularly Western histories of astronomy have ignored China, or devoted a few perfunctory pages to it using sources a generation out of date. A fixation on priorities does not help to answer the sorts of questions that students of astronomy ask today. What light might study of China shed on central issues?

When and under what circumstances astronomy began is a question that has no single answer for all civilizations. There are grounds for doubt that Chinese astronomy has a specifiable origin. Putting together the archaeological and historic evidence, I see a number of strands—the observational, the computational, the cosmological, the divinatory, the metaphysical, the mythological, the ritual—emerging gradually, each at its own pace (on cosmology see Needham 1975, Zheng and Xi 1975, and Henderson 1984). These strands joined at the end of the first century B.C. to form the first mature complex that we think of as Chinese astronomy (Sivin 1969). It is tempting to read that complex into earlier times, but without strong evidence anachronism is anachronism.

The aims of astronomy reflect the character of Chinese society, especially its monarchy. The relations of public and private practice similarly mirror the values and structures of the larger society. Chinese government from its rationalization in the Han has been totalitarian in principle, convinced that its mandate to provide public order necessitates regulating—whether by example or by fiat—every aspect of private thought and behavior. In practice, it has lacked the means to control much more than the actions of officials and the education of the elite, and that only very imperfectly. Legislation to prevent all but functionaries from doing astronomy was seldom zealously, and never successfully, enforced. We can find instances over the last two thousand years in which talented scholars avoided astronomy and private experts were harassed. But again and again important calendar reforms were initiated by private individuals. These experts were consistently coopted, given official appointments after the fact. Intensive observation remained centered in the Imperial Bureau of Astronomy not because of a "science policy" but because there was no other source of funds for large-scale, long-term research projects.

How was the sky of the astronomers—conceptually very different from that of peasants or poets—defined by the technical tasks evolved in bureaucratic institutions for political ends? To answer that question, perhaps the most central of all, we need a much better understanding of many complicated problems. Some are technical. Hashimoto Keizō (1979, 1985), for instance, is working on the evolution of Chinese notions about increasing accuracy. Others are social. Yamada Keiji (1980a), to take the outstanding example, has given us a detailed study of the calendar reform that inaugurated the Yuan reunification of China. He investigates the interplay of administrative organization, observation, and mathematical technique. No crucial problem, as these two examples indicate, is purely technical or purely social.

The list of issues could be prolonged indefinitely, but these are enough to suggest how the study of Chinese astronomy might converge with other explorations now afoot in the history of science.

Trends in China

Work in these relatively new directions will continue to draw on the publications of the 150 or so full-time historians of astronomy in China. They are primarily concerned with establishing Chinese priorities, finding precursors of present-day astronomical knowledge. This emphasis is now beginning to change, as new methodologies, and new disciplines such as archeoastronomy, are introduced through correspondence and personal contact. Given the opposed pulls of enthusiasm and institutional inertia, we can expect most work to continue along well-worn tracks, however accelerated by automatic computation. Let me summarize general characteristics of research results seen in recent Chinese publications (Xi 1981, 1983; Sivin 1981).

Predominantly philological studies have resulted in many compilations of observational data. Histories of astronomy tend to summarize sources topically and explain them in modern terminology. Determining patterns of change and their causes is a matter of comparatively minor interest, except of course to demonstrate that the evolution of astronomy conforms to the laws of historical determinism (a less pressing concern these days than fifteen years ago). The emphasis on priorities is reinforced by the expectation of the government, the academic employer of first and last resort, that students of early science contribute to national pride.

Every astronomer is aware of, and many have used, catalogues in Western languages based on Chinese surveys of comets, novas and supernovas, sunspots, auroras, and so on, even detailed earthquake histories for every part of China. Many such compilations cover 3,500 years and are rather full for roughly half that time, drawing records mainly from the standard histories and from encyclopedic works of the Song and after.[26]

These surveys have been made obsolete by a search of broader magnitude, using thousands of gazetteers, carried out by a team of roughly a hundred scholars from 1975 to 1978. It resulted in a register of astronomical phenomena and other data roughly four million characters long (or the equivalent of perhaps eight million English words). China's very limited publication facilities give low priority to voluminous technical reference works of this sort, so the appearance of this book has been repeatedly delayed. A few preliminary publications give some impression of its richness. It is now possible, for example, to see fine detail in the Maunder Minimum and other phenomena for which information was previously lacking.[27]

The Cultural Revolution, which closed the historical institutes and gave most historians of astronomy few options for research besides collaborating with archaeologists, accustomed them to working with images and artifacts. A succession of excavations that have yielded remarkable texts, diagrams, tables of astronomical data, and star maps have made this work highly productive for astronomical studies (Xia 1979, 1980; Xi 1981). Archaeologists and historians have also cooperated in site restorations, such as that of the great Yuan forty-foot gnomon at Dengfeng, Honan (Zhang Jiatai 1976).

[26] Among the best publications of the last generation, see Imoto and Hasegawa 1958, Needham and Ho 1959, Ho 1962, Ho and Ang 1970, Kiang 1972, Wang Dechang 1984, and He Bingyu and Zhao Lingyang 1986. Earlier publications are fully listed in Bibliography B of Needham et al. 1954–, vol. 3. The most detailed of three large compilations of earthquake records is Xie Yushou and Cai Meibiao 1983. Like other ancient observational data, these materials must be used critically. Clark and Stephenson 1977, Stephenson and Clark 1978, and Xi 1986 discuss problems of using ancient data for current astronomical purposes. Huang Yilong [Huang Yinong] is critically sifting earlier claims that connect ancient sightings with modern phenomena (e.g., Huang and Moriarty-Schieven 1987).

[27] On the Maunder Minimum, a period of scanty sunspot observations between 1645 and 1715, see Luo Baorong and Li Weibao 1978, Xu Zhentao 1981, and Cullen 1980, a report on two earlier Chinese publications. The Records of Phenomena project has been described in Zhuang Weifeng 1982. Its first book-length product has finally appeared, a union catalogue of the more than 8,200 local gazetteers from 190 collections used to compile the register of phenomena (Zhuang Weifeng et al. 1985).

Astronomical instrumentation has been well covered in research publications, but a book that will tie these findings together is badly needed.[28] Scholars have been sifting through the immense collections of the Palace Museum, studying both traditional instruments and those imported from the West (Bai and Li 1980; Li Di and Bai Shangshu 1981, 1984). Recent studies of instruments have remained largely descriptive and antiquarian. Few have estimated the precision of the instruments they examine, just as the many publications on systems of computational astronomy have had very little to say about their accuracy. The same can be said of most writings about early European and Islamic instruments. From Maeyama's brilliant error analysis (1975–76, 1977), proving that the Chinese star catalogues usually dated to the fourth century B.C. were based on observations not earlier than 70 B.C., we can see how productive such methods of exploration can be.

A Next Step

The characteristics of Chinese astronomy that I have enumerated make it unlikely that sound contributions will come from anyone unwilling to study seriously both astronomy and China. Collaboration is an obvious way to maximize contributions. I mean collaboration in the scientist's sense: two or more people working together who have learned each other's fields.

The simplest way to attract more useful contributions would be to compile a chronological catalogue of astronomical capabilities. The closest thing to a model of presentation is the systematic outline of early cosmological capabilities by Nakayama (1969:24–43). Much of the information is at hand in histories of Chinese astronomy published in Chinese and Japanese, although the data need to be reorganized for this utilitarian purpose and brought up to date. It ought to be possible to set down what types of observation were being made at a given time, with what instruments, and to what precision.[29] We might interweave with that an account of what was being computed in each period, by what means, and based on what data. We would want to specify what conceptual tools were guiding the design of Chinese models. It would not be wise to include only notions familiar in Europe.

Medicine

Medical anthropology once largely documented the savagery that white Christian Western European men were supposed to have overcome. Medical sociology within living memory was a collection of aids to the professionalization of doctors and nurses. Medical history was devoted to proving that the modern physician merits admiration not only for his own achievements but also for those of his predecessors that anticipated today's knowledge.

[28] See, for instance, Pan Nai 1975 and Yi 1978. The latter article is concerned with the metrological standard used in the design of instruments. A splendid volume of photographs illustrating star maps, instruments, and artifacts pertinent to early astronomy has been compiled by the Chinese Academy of Social Sciences, Institute of Archaeology (1980).

[29] Thatcher Deane (forthcoming) has already compiled a descriptive catalogue of Chinese astronomical instruments between 1670 and 1850 (see also Howse forthcoming). The most comprehensive historical outline of astronomy is Chen Zungui 1980–84, but Wang Yingwei (1962?) is more detailed for ancient systems of computation.

Work in these disciplines now tends to converge on a new set of issues. Current scholarship reminds us that support for the patient's own coping and healing is at least as important a part of the doctor's work as physical and chemical interventions. It indicates that therapeutic success often depends more on understanding the patient's whole physical, emotional, and spiritual state than on wielding high technology. It allows us to recognize that an illiterate faith healer may be more effective than an M.D. when what matters is perceiving and responding to the patient's interpretation of what has happened and why. The medium may appeal more successfully than the physician to powerful symbols that the patient can use to impose order on the chaos of physical and mental suffering (Kleinman 1980:361–63). A coherent view of health care that might be applied to understand any illness in any social circumstance at any time may eventually emerge from the fragmentary investigations of specialists. There are few fields in academia of which that might be said.

The curious undergraduate, who can find hardly any introductory writing in other areas of Chinese science, is swamped in publications on medicine. But the overwhelming majority of these are meant for readers interested in acupuncture, holistic healing, and similar therapeutic matters. Most of the books on traditional medicine that profess to be historical simply leave the normally critical reader suspecting, if I may quote an old review of *The Yellow Emperor's Classic of Internal Medicine*, "that the Chinese had some peculiar concepts of medicine, an idea he may well have had before beginning to read the book" (Hightower 1951:307).

The organization of Chinese health care at any point in the past has never been described in any language. The only full and reliable surveys of medical history are in Chinese and Japanese. Only a handful of papers have attempted to explain changes in therapy or theory. The several translations of familiar medical classics fall below the level of textual and conceptual mastery and linguistic precision now expected in sinology (e.g., Luo Xiwen 1986, 1987). Unschuld 1986b is the best of the complete, and Despeux 1987 the best of the partial, translations.

In order to catch up to the general level of medical historiography, work on China must overcome a number of special difficulties. I will review them before passing on the strengths of the best recent work.

Difficulties

An obvious hindrance to work on Chinese medicine has been the isolation of the People's Republic. Field workers have not had access to the field until recently, and that access is still very limited. In historical studies, the lack of contact between Chinese and foreign historians has impeded both. Scholarly publications are distributed so unsystematically within China that scholars outside the central research institutes are unable to consult many of them. The central systems for ordering foreign publications and for selling Chinese books abroad are even more irrational. Only a small proportion of Chinese publications, even of the most important reference books, reach foreign libraries. Although the mechanisms in Japan are different, the flow of information is equally fitful.

The many general histories of medicine published since that of Chen Bangxian in 1919, with only a couple of exceptions, summarize primary sources. Their authors have had little access to Western historiography or social science. They seldom discuss change before modern times, except to compile from central government sources data on institutions—usually on reorganizations of the imperial medical service or of the curricula for training its doctors.

Since all Chinese historians of medicine were trained as physicians and most practice or teach medicine, their sense of progress rules out interest in most popular ("superstitious") healing. They do not systematically investigate the experience of the patient.[30] Because they see themselves as defenders of a tradition, few are tempted to portray the great physicians of the past as anything but heroic and modern in temperament. But the many skilled Chinese historians (Table 1) are familiar with a literature of daunting size, about eight thousand books that survive as the medical legacy of imperial China. Their clinical training gives them insight into the therapeutic significance of medical doctrine, a matter on which most authors outside Asia have little or nothing to say.[31]

The high volume of Western publications on traditional medicine is not a fluke. In 1972 the media hype that began with Nixon's election trip to China made acupuncture the panacea everyone knows (although it is not considered a cure-all in China). Practically any book with "China" and "medicine" in the title will turn a profit in Europe and the United States. The supply of merchandise for this market has responded to the precedent of ignorance and sloppiness set by most of what passed for scholarship in the 1940s and 1950s.

Strengths to Build On

This assortment of traps for the uncritical reader is balanced by some landmarks. A handful of fundamentally sound and useful general monographs has accumulated over the past couple of decades. On the evolution of medicine, several articles by Lu and Needham (those gathered in Needham et al. 1970 and others listed below) and their history of acupuncture and moxibustion (1980) can be recommended. The chronological survey of the literature in the latter is only a hundred pages long and is problematic in several respects. The study of the propagation of acupuncture abroad is peerless (1980:262–302). A more extended history is promised in later volumes of Needham et al. 1954–. Porkert has explicated certain traditions of premodern medical thought and practice, very different from Chinese practice today (1982b), and has clarified basic theoretical concepts in the same traditions (1974). Other experts do not agree with his stark contrasts between the approaches of Chinese and Western medicine (1982a). Unschuld's "history of Chinese medical ideas" (1985) and his "history of pharmaceutics" (1986a) are broadly conceived, perceptive, and original in important ways. Like his earlier writings, these books are frequently careless in sinological matters. The 1985 volume is based on few primary sources, does not draw on much of the best scholarship, and is simplistic in analysis, but the 1986 book

[30] An exception is in archival studies of medical practice in the Qing palace by Zhu Jinfu, Chen Keji, and their collaborators.

[31] The most useful introductory surveys are Liu Boji 1974, Jia Dedao 1979, Ma Boying 1982, and Zhao Pushan 1983. Of these, Ma stands out for his interest in social aspects of medicine as well as in the evolution of concepts. He is also informative about the institutional growth of modern medicine in China (1982, 3:96–108, 231–35). A survey by the pioneer historian Fan Xingzhun, privately published in 1960 and only now generally available in a revised edition, contains many excellent insights. Although about thirteen thousand titles are listed in the forthcoming revision of Zhongyi Yanjiuyuan and Beijing Tushuguan 1961, Zheng Jinsheng estimates that they represent about eight thousand distinct books (private communication). The meticulous handbooks of Ma Jixing (1982) and Okanishi Tameto (1958, 1974) are only the most prominent contributions to a massive continuing effort to set this large literature in order. Nakayama and Sivin 1973: 302–8 is a critical bibliography of sources in Western languages, supplemented for science in Sivin 1986a.

describes a large part of the *bencao* literature. On the whole Unschuld's books are more stimulating than previous histories of Chinese medicine.

Excellent new contributions have begun to appear with some regularity. To begin at the Asian end, an outpouring of archaeological discoveries since the mid-1960s has given us drugs, medical apparatus, and over a hundred remarkably well preserved ancient cadavers. Three of these have drawn much attention, and one has been minutely studied from the medical viewpoint.[32] Excavation has also yielded documents of the first importance—prescriptions, moxibustion manuals informative about the circulation system, texts on prognostics, illustrations of *daoyin* exercises (more like yoga *asanas* than the postures of present-day *taijiquan*), regimens aimed at immortality, and others. The earliest were interred as grave goods in 168 B.C.[33]

Some remarkable insights, in the first instance from Japan, have shown that several of these newly discovered books are the oldest of their kind. We can now date the *Inner Canon of the Yellow Lord*, the *Huangdi nei jing*, to the first century B.C. or its close vicinity, considerably later than most scholars would have dated it before the Mawangdui excavations. We can also recognize that it is not one book but a collection of diverse writings, many of which disagree and some of which comment on others.[34]

This reevaluation has already led to new insights about the formation of the medical tradition. For instance, although phlebotomy has often been denied a role in the origin of acupuncture, Dean Epler (1980) has pointed out that some writings in the *Inner Canon* speak plainly of bloodletting with needles (see also Meng Lei 1981). He has hypothesized that they were written earlier than parts of the book in which acupuncture merely affects the flow of *qi*.

The consequences of this new view of the *Inner Canon* as a heterogeneous collection reverberate from the beginning to the end of the classical tradition. The first comprehensive syntheses of medical doctrine, we can now see, appeared only in the *Huangdi bashiyi nan jing* (second century?), the *Huangdi jiayi jing* (256/282), and the *Mai jing* (ca. 280). Many concepts used by traditional physicians today appeared or evolved in the fourteenth through the seventeenth centuries, a period shrugged off as decadent by most Western historians of Chinese medicine. All these new insights

[32] On the well-known Lady of Dai, buried 168 B.C, see especially Hunan Yixueyuan 1980, Li Jingwei 1980, Zhao Pushan 1980, and Pokora 1985. The contemporary corpse from Fenghuangshan, Hebei, largely intact, is described in Anon. 1975, and a thirteenth-century corpse in Zhenjiang Bowuguan et al. 1977. In addition to these celebrated cadavers, over a hundred have been excavated since 1949, according to a personal communication from Li Jingwei, who in the essay cited above speaks of "mummies, corpses preserved with wax, and desiccated cadavers."

[33] For an inventory of excavated medical texts and artifacts from the Neolithic to the Ming, see Sakurai 1985. The most important MSS from the burial of 168 (listed in Harper 1982:7–14) have been published in Mawangdui 1985. See the varied research papers in Hunan Zhongyi Xueyuan 1980–81. A collection of ninety-two wooden strips containing prescriptions and other information, probably from the middle of the first century A.D., appears in Gansu Sheng Bowuguan et al. 1975. Seven Mawangdui texts, the Wuwei slips, and two later documents are translated into Japanese with commentary and related essays in Yamada 1985. Harper 1982 is an annotated translation of the Mawangdui formulary (see also Unschuld 1982). These translations are based on tentative transcriptions of the Mawangdui documents. On the relation between *daoyin* and yoga, see Filliozat 1949.

[34] See the writings of Akahori and Yamada, and He Zongyu 1981. David Keegan, in a dissertation in progress, argues that none of the surviving versions of the *Inner Canon* represents even approximately the original arrangement of the text. For good introductions to study of the *Inner Canon* see Ren and Liu 1982 and the briefer Fu Jinghua and Fu Jingchun 1985.

prepare us to begin writing a realistic history rather than more compilations of old myths, old anecdotes, and old summaries.

Since 1980 textual studies of every sort have cascaded from the Chinese presses—not only many general histories but even histories of forensic medicine (Jia Jingtao 1984) and osteological technology (Wei 1983). A cornucopia of anthologies provides aid in finding texts.[35] The proliferation of schools within medicine has been greatly clarified by the late Ren Yingqiu (1980, 1984; see also Li Congfu and Liu Bingfan 1983). Biographies and monographs on aspects of medicine in particular dynasties have appeared in profusion. Many excellent critical editions of early classics have been published (Guojia Chubanju 1980), and even many old manuscripts printed for the first time (e.g., Kosoto 1981). Historical essays are published regularly in a specialized journal of high quality (*Zhonghua yishi zazhi*, Table 2) and a dozen medical journals.

The harvest of sound reference works has been especially rich—dictionaries and encyclopedias of medical literature, ancient authors, concepts, medical disorders, materia medica, and many other subjects; bibliographies; source collections; and abstracts of and indexes to classical texts. These contributions will be surveyed elsewhere (Sivin forthcoming). In the meantime there is an excellent reference handbook (Ji 1986).

Now let me review some recent directions of research, ranging from traditional textual studies to fieldwork on the connections of healing and religion.

Several trailblazing historical monographs have just been completed. Martha Li Chiu (1986), for instance, has analyzed certain categories of mental disorder in the *Inner Canon of the Yellow Lord* and its influence on later medical thought. Her work is nuanced, incisive, and well informed about cultural anthropology and mental health studies. Other work in the same area includes Hans Ågren's (1982) study of traditional concepts of psychiatric interest and Arthur Kleinman's field investigation (1986) of depression in the People's Republic of China, highly pertinent to the early literature.

Charlotte Furth (1986) has surveyed classical gynecological writings to provide the first discussion of medical authors' views of the female condition between 1600 and 1850. She relates these occupational attitudes to lay beliefs on which she is already an authority. Robert Hymes (1987) has studied voluminous local records between the late tenth and the mid-fourteenth century that bear on decisions by members of the elite to take up medical careers. He has found that, for the prefecture studied, the figure of the gentleman physician becomes important in the Yuan period and not earlier. Hymes demonstrates that contradictory speculations about such transitions that appeared in earlier writing can be replaced by conclusions from research.

Particularly significant is a series of short papers published by Miyasita Saburō of Osaka from 1976 to 1980 that finds in the twelfth century major shifts in the choice of drugs used to treat a variety of representative medical disorders, and suggests concomitant shifts in diagnosis over a couple of centuries. Akahori Akira (1986) has assessed trends in medical doctrine and practice in the course of the Han period. Other scholars have begun to study the long-term development of materia medica (Xie Zongwan 1981): Hong Guanzhi (1982), changes in the dosage of drugs; Song Zhixing (1983), changes in the theory of drug functions; Wang Xiaotao (1986),

[35] For instance, Zhou Yimou 1983 for medical ethics; Xu Fulin et al. 1985 for therapeutic errors; Chen Bangxian 1982 for medical materials in the Standard Histories; Qian Yuanming 1986 for other nonmedical sources (Yang 1953 is still valuable); Xiao et al. 1986 for the great Ming encyclopedia *Yongle da dian*; and Duan 1986 and the more compact Liu Zhenmin et al. 1980 for excellent anthologies and introductions to the study of ancient documents. Ren 1980 provides representative texts for medical theory.

changes in drug processing; and Zhou Fengwu (1987), changes in the usage of fifty medicinal plants.

Another important line of research is concerned with the local character of medicine. Special interest attaches to Menghe, Jiangsu, a town long known for its several well-known medical families (Huang Huang 1984; Zhang Yuankai 1985; Fu Fang 1985), and the Zhulin Temple of Xiaoshan, Zhejiang, whose monks have been renowned since the Northern Song for their special approach to the diagnosis and treatment of women's disorders (Zhou Mingdao 1981; Liao 1986; Zhang Yao 1987). Xiong Bingzhen (1986) has investigated the local character of pediatrics in the Qing period. Additional data for local studies are offered in recent publications on Chinese immigrant healers in the American West (Schwarz 1984; Buell and Muench 1984). Many studies of local medical education, particularly in the last hundred years, have appeared recently (e.g., Huang Jinming and Huang Hanru 1985).

Despite the difficulties inherent in field studies of medicine, two breakthroughs deserve notice. The most illuminating work on Chinese medicine in years is a result of Judith Farquhar's year and a half of participant observation in a college of traditional medicine in South China. Farquhar (1986) uses discourse analysis and other anthropological resources as well as textual study to throw light on how knowledge and practice converge in the lifelong experience of the physician. She also provides a brilliant analysis of the conceptions that shape clinical encounters, taking her categories from her material rather than from European precedents.

The second breakthrough is Arthur Kleinman's penetrating exploration of Chinese patients and healers—traditional and modern doctors, trance healers, diviners, and others in present-day Taiwan. His book outlines an elaborate schema for observation, aimed at substituting a model of medicine as a cultural system for the prevalent biochemical model (1980:25). This theoretical argument is accompanied by rich insight, informed by psychiatric experience and sympathetic concern. The writings of Margaret Lock (1980) and Emiko Ohnuki-Tierney (1984) on Japan take up research issues that call for comparisons in premodern China.

Although these studies are not historical, all point the way toward greater penetration in analysis of the past. For example, Kleinman (1980) sheds light on a topic important in late imperial historiograpy: Why and how did patients choose among many kinds of healers, from popular priests to elite physicians? How did these varieties of practice mesh in one plural system of health care?[36] Farquhar (1986) makes an overwhelming case for the centrality of practice in traditional medicine, a matter often overlooked in bookish studies.

A number of other nonhistoriographic works are useful. Kaptchuk 1983, a popular book, is clear and insightful in many respects despite the author's limited depth in Chinese medicine and its history. Students find it helpful as preparation for Porkert's more demanding exposition. Ōtsuka 1976 explains Chinese medicine as seen by the dean of Japanese practitioners; his tradition diverges greatly from contemporary Chinese practice. Wang Yuquan and Song Tianpin 1980 review recent issues in medical therapy; Qiu Renzong 1982, in the philosophy of medicine. The primary literature of materia medica is introduced in Needham et al. 1954–, vol. 6, pt. 1 (1986) and Unschuld 1986a. For contemporary pharmacognosy see C. P. Li 1974 and Zhuang Zhaoxiang, Guan Peisheng, and Jiang Runxiang 1983, and for Taiwan, Yan Kunying 1980a and 1980b.

[36] On modern medical pluralism, see also Kleinman et al. 1975. During the Republican period, from the patient's point of view, the M.D. was merely added to the menu.

Some of the issues ripest for exploration have to do with the relations of medicine to other domains of culture. Several scholars have looked closely at the connection with religion. Schipper, in writings mentioned above (1978, 1982), has described systematically the many significances of the body in Taoist liturgy and visionary meditation. Donald Harper's tour de force of translation and explication (1982) has shown that the oldest known collection of Chinese prescriptions, from Mawangdui, is as significant a source for early Chinese ritual as it is for the beginnings of therapy. Harper (1985, 1987) is continuing to probe the relations of magic, religion, physical cultivation, and medicine. Strickmann (1985) is now studying beliefs about illness in the Supreme Purity movement.

Here are a few additional examples of issues that existing methods and tools can illuminate. First, a few about which various unpersuasive generalizations have already been set down:

1. The role of Confucians in the evolution of medicine. The fact that doctors included conventional moral sentiments or allusions to the *Analects* in their books does not make them Confucian, merely conventional (Sivin 1978). Historians of Western medicine have long since learned to define their social categories and go on to a prosopography. In this case a definition of "Confucian" might specify initiation in a lineage of teaching.

2. Government control of local medical education and practice. It is well known that the imperial government at certain times prescribed provincial curricula, examinations, and standards of practice, and even appointed local medical officials (Needham 1969:379–95). Private sources do not confirm that this legislation was effective (Hymes 1987:9–11, 74–75). We do not know, in fact, how much of it was carried out. Nor do we know whether oft-cited Qing legal prohibitions of acupuncture, etc., were enforced or obeyed.

3. The history of the hospital. Until the twentieth century, European and American hospitals (with some exceptions) were not primarily therapeutic institutions but charitable foundations in which people too poor to be ill at home were given care and, to a varying extent, therapy, until they recovered or died. On the basis of research largely restricted to Buddhist sources, parallels in China have been asserted (Demiéville 1937). But what therapy and nursing were provided, and indeed whether one can speak of the hospital as an institution, remain to be determined. Recent Chinese research has documented the founding of religious and secular hospitals that offered medical care, especially by government (e.g., Chen Zhiya 1980; Gong 1987). How many were actually operated and how long they lasted remain open questions.

Second, an assortment from the enormous set of issues about which nothing of substance is yet known:

1. How did patients experience disease and therapy? The classical and popular literatures, even the large collections of medical case histories, reflect the practitioner's point of view. Literature and drama yield some clues, but a broad search of other sources is needed (for an interesting discussion of issues and possible sources in Qing history see Spence 1975:80–83).

2. How did traditional physicians group symptoms into syndromes and diseases? Nosology differs fundamentally from one culture to another, and illness is a social as well as a biological phenomenon. Students of cross-cultural medicine and psychiatry have been aware for some time of disorders peculiar to one or more cultures (Simons and Hughes 1985), and such disorders have been studied in Chinese environments (Topley 1970; Kleinman 1980, 1986). In recent years the interaction of modern and traditional medicine has blurred the differences in their use of shared technical terms. *Re*, for instance, which in modern medicine means "fever," traditionally referred to the patient's feeling of abnormal inner heat, the opposite of

han, or "chills." Both *re* and *han* would be considered symptoms of fever in the modern sense of elevated body temperature. Recent textbooks of traditional medicine define *re* in the modern sense, along with many other diagnostic concepts (Sivin 1987). A survey on historical principles of ancient terminology is best done while physicians experienced in traditional diagnosis are still available to collaborate. Gao Jinglang has already compiled a historical survey of pediatric terminology (1982).

3. How was the efficacy of drug therapy affected by the nutritional states of patients? Nutrition in imperial times has hardly been studied.[37] It would be naive to assume that even the rich and powerful ate balanced diets. For a patient who has lost much blood or whose diet has been deficient in protein, milk or meat in substantial doses can be a wonder drug.

4. How much did medical care cost? What were healers paid? How did the cost of drugs vary by region and era? How were medical markets organized and articulated? An obvious beginning for such studies is the Maritime Customs Reports of the late nineteenth century, travelers' reports, and accounts of drugs sent from localities to the imperial court as tribute (Gordon 1884; Englisch 1976; Guan Lüquan 1982). Centers of the drug trade have already been studied by, among others, Ni Yunzhou (1984) and Mei Kaifeng and Yu Bolang (1985).

5. What can we learn from medicine about the character of childhood in early China? This topic is as culture-specific as gender. Furth's (1986, 1987) and Leung's (1984) studies of women's ailments, childbirth, and infancy provide a model for historical research using the abundant technical record. Barbara Volkmar in Munich is now mining the pediatric literature and at the same studying contemporary clinical pediatrics as a participant-observer.

Conclusions

What will determine the quality of future studies is the quality of the scholars at work, their ability to meet the best standards in their disciplines—whether one or several, whether anthropology, history, philology, or sociology—and their ability to draw on our evolving understanding of Chinese culture and of science. The rate of advance does not depend on the number of experts. There is no shortage of research in progress on familiar topics. Few specialists are working at the frontiers. Three areas seem to me crucial for increasing the number of innovators: better reference materials, better training, and uniformly high standards of publication.

Reference works can facilitate controlling the primary sources of all the sciences, just as the sinological indexes and concordances of the 1930s and 1940s made philosophical and literary classics readily accessible for any purpose. In addition to the examples already given for medicine, a single index of technical terms and numeric constants in the surviving astronomical treatises would be a manageable task.[38] A small group could easily compile a historical glossary or dictionary of all mathematical terms up to the Ming, or one of all technical language in siting. Hoshi Ayao's glossary-index of early Chinese economic terms (1966) is a possible model.

The history of the Chinese sciences has now evolved to the point that standards exist and regularly are being met. Well-wishers in Europe and the New World might

[37] The dynasty-by-dynasty surveys in Chang 1977 emphasize cuisine and rarely consider nutrition.

[38] I have prepared sample indexes for the astronomical systems of 1127, 1180, and 1280 and will furnish copies to anyone interested in this project.

encourage talented and strongly motivated students to seek out a systematic graduate program that can guide them to mastery of all the pertinent disciplines.

There is a frontier of research. It is well populated and vigorous. Everyone can contribute to extending it.

List of References

Abbreviations

CS *Chinese Science*
GBY *Gugong bowuyuan yuankan*
[Palace Museum journal]
KJ *Kexueshi jikan*
[Publications in the history of science]
KK *Kagakushi kenkyū*
[Researches in the history of science]
KW *Kexueshi wenji*
[Collected papers in the history of science and technology]
NIZ *Nihon ishigaku zasshi*
[Journal of the Japan Society for Medical History]
ZKY *Ziran kexueshi yanjiu*
[Studies in the History of Natural Sciences]
ZYZ *Zhonghua yishi zazhi*
[Chinese journal of medical history]

Classical Sources before ca. 1900

These sources are cited by the earliest known title, since modern nomenclature is not standardized.

Huangdi bashiyi nan jing [Canon of eighty-one problems (in the Inner Canon) of the Yellow Lord]. Anon. Second century A.D.? Usually called by various abbreviated titles such as *Nan jing*. See Unschuld 1986b.

Huangdi jiayi jing ["A-B" canon of the Yellow Lord]. Huangfu Mi. Comp. 256–82. The implications of "A-B" are ambiguous. Usually cited by abbreviated titles such as *Zhenjiu jiayi jing* ["A-B" canon of acupuncture and moxibustion].

Huangdi nei jing [Inner canon of the Yellow Lord]. Anon. The two best-known books by this title, the HNJ *Su wen* and *Ling shu*, were probably written in the 1st century B.C. No available translation is reliable.

Iseki kō [Studies of medical books]. Tanba no Mototane (or Taki Mototane). Completed 1819, printed 1831. Reprint with indexes, entitled *Zhongguo iji kao* [Studies of Chinese medical books]. Beijing: Renmin Weisheng Chubanshe, 1956.

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Xi yuan ji lu [Collected writings on the washing away of wrongs]. Song Ci. Preface 1247. See Sung 1981.

Yi shuo [Medical anecdotes]. Zhang Gao. Preface 1189. See Okanishi 1958:1101–14.

Yinyang shiyi mai jiu jing [Moxibustion canon for the eleven yin and yang vessels]. Anon. Before 168 B.C. In Mawangdui 1985:5–10, 43–45. See Akahori 1979a, 1981; Yamada 1985.

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