THE PICTURE OF THE TAOIST GENII PRINTED ON THE COVER of this book is part of a painted temple scroll, recent but traditional, given to Mr Brian Harland in Szechuan province (1946). Concerning these four divinities, of respectable rank in the Taoist bureaucracy, the following particulars have been handed down. The title of the first of the four signifies 'Heavenly Prince', that of the other three 'Mysterious Commander'.

At the top, on the left, is Liu *Thien Chün*, Comptroller-General of Crops and Weather. Before his deification (so it was said) he was a rain-making magician and weather forecaster named Liu Chün, born in the Chin dynasty about +340. Among his attributes may be seen the sun and moon, and a measuring-rod or carpenter's square. The two great luminaries imply the making of the calendar, so important for a primarily agricultural society, the efforts, ever renewed, to reconcile celestial periodicities. The carpenter's square is no ordinary tool, but the gnomon for measuring the lengths of the sun's solstitial shadows. The Comptroller-General also carries a bell because in ancient and mediaeval times there was thought to be a close connection between calendrical calculations and the arithmetical acoustics of bells and pitch-pipes.

At the top, on the right, is Wen *Yüan Shuai*, Intendant of the Spiritual Offcials of the Sacred Mountain, Thai Shan. He was taken to be an incarnation of one of the Hour-Presidents (*Chia Shen*), i.e., tutelary deities of the twelve cyclical characters (see Vol. 4, pt 2, p. 440). During his earthly pilgrimage his name was Huan Tzu-Yü and he was a scholar and astronomer in the Later Han (b. +142). He is seen holding an armillary ring.

Below, on the left, is Kou *Yüan Shuai*, Assistant Secretary of State in the Ministry of Thunder. He is therefore a late emanation of a very ancient god, Lei Kung. Before he became deified he was Hsin Hsing, a poor woodcutter, but no doubt an incarnation of the spirit of the constellation Kou-Chhen (the Angular Arranger), part of the group of stars which we know as Ursa Minor. He is equipped with hammer and chisel.

Below, on the right, is Pi *Yüan Shuai*, Commander of the Lightning, with his flashing sword, a deity with distinct alchemical and cosmological interests. According to tradition, in his early life he was a countryman whose name was Thien Hua. Together with the colleague on his right, he controlled the Spirits of the Five Directions.

Such is the legendary folklore of common men canonised by popular acclamation. An interesting scroll, of no great artistic merit, destined to decorate a temple wall, to be looked upon by humble people, it symbolises something which this book has to say. Chinese art and literature have been so profuse, Chinese mythological imagery so fertile, that the West has often missed other aspects, perhaps more important, of Chinese civilisation. Here the graduated scale of Liu Chün, at first sight unexpected in this setting, reminds us of the ever-present theme of quantitative measurement in Chinese culture; there were rain-gauges already in the Sung (+12th century) and sliding calipers in the Han (+1st). The armillary ring of Huan Tzu-Yü bears witness that Naburiannu and Hipparchus, al-Naqqash and Tycho, had worthy counterparts in China. The tools of Hsin Hsing symbolise that great empirical tradition which informed the work of Chinese artisans and technicians all through the ages.

SCIENCE AND CIVILISATION IN CHINA

Joseph Needham
(1900–1995)

'Certain it is that no people or group of peoples has had a monopoly in contributing to the development of Science. Their achievements should be mutually recognised and freely celebrated with the joined hands of universal brotherhood.'

Science and Civilisation in China VOLUME 1, PREFACE.

*

Joseph Needham directly supervised the publication of seventeen books in the *Science and Civilisation in China* series, from the first volume, which appeared in 1954, through to Volume 6.3, which was in press at the time of his death in March 1995.

The planning and preparation of further volumes will continue. Responsibility for the commissioning and approval of work for publication in the series is now taken by the Publications Board of the Needham Research Institute in Cambridge, under the chairmanship of Dr Christopher Cullen, who acts as general editor of the series.

The Duke of She asked Tzu Lu what he thought about Confucius, but Tzu Lu returned him no answer. 'Why did you not say', said the Master, 'he is simply a man so eager for improvement . . . that he forgets his sorrows and does not observe that old age is at hand?'

Confucius, *Analects*, VII.xviii, tr. Soothill

中國科學技術史

李約瑟著

JOSEPH NEEDHAM

SCIENCE AND CIVILISATION IN CHINA

VOLUME 7

PART II: GENERAL CONCLUSIONS AND REFLECTIONS

BY

JOSEPH NEEDHAM F.R.S., F.B.A.

WITH THE COLLABORATION OF

KENNETH GIRDWOOD ROBINSON AND
RAY HUANG (HUANG JEN-YÜ)
AND INCLUDING CONTRIBUTIONS BY THEM

WITH AN INTRODUCTION BY

MARK ELVIN

EDITED BY

KENNETH GIRDWOOD ROBINSON

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This book is dedicated to the many scholars who have worked as collaborators on the Science and Civilisation in China Project over the last half century.

CONTENTS

ILLUSTRATIONS

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ABBREVIATIONS

A/AIHS	*Archives Internationales d'Histoire des Sciences*
AHOR	*Antiquarian Horology*
AJS	*American Journal of Sociology*
AM	*Asia Major*
ARB	*Annual Review of Biochemistry*
ARO	*Archiv Orientalni* (Prague)
ASTJ	*Astronomical Journal*
AX	*Ambix*
BIHM	*Bulletin of the (Johns Hopkins) Institute of the History of Medicine*
BLSOAS	*Bulletin of the School of Oriental and African Studies*
BMFEA	*Bulletin of the Museum of Far Eastern Antiquities* (Stockholm)
CEN	*Centaurus*
CHS	*Chhien Han Shu*
CNOW	*China Now*
COMP	*Comprendre* (Soc. Eu. de Culture, Venice)
CR/MSU	*Centennial Review of Arts and Science* (Michigan State University)
CRR	*Chinese Recorder*
CS	*Current Science*
CSCI	*Chinese Science*
CSMJ	*Chinese Medical Journal*
DAE	*Daedalus*
EASTM	*East Asian Science, Technology and Medicine*
EW	*East and West* (Quaert. Rev. Pub. Instituto Ital. per il Medio e Estremo Oriente, Rome)
HEJ	*Health Education Journal*
HJAS	*Harvard Journal of Asiatic Studies*
HOR	*History of Religions*
HOSC	*History of Science*
IJE	*International Journal of Ethics*
IMPAC	*Impact of Science on Society (UNESCO)*
IQB	*Iqbal* (Lahore), later *Iqbal Review* (Journal of the Iqbal Academy or Bazm-i Iqbal)
JAN	*Janus*
JAS	*Journal of Asian Studies*
JBASA	*Journal of the British Astronomical Association*
JCE	*Journal of Chemical Education*
JCP	*Journal of Comparative Philosophy*
JEH	*Journal of Economic History*
JESHO	*Journal of the Economic and Social History of the Orient*

JHI	*Journal of the History of Ideas*
JOSHK	*Journal of Oriental Studies* (Hong Kong University)
JPOS	*Journal of the Peking Oriental Society*
JRAI	*Journal of the Royal Anthropological Institute*
JRSA	*Journal of the Royal Society of Arts*
JUB	*Journal of the University of Bombay*
JWCI	*Journal of the Warburg and Courtauld Institutes*
JWH	*Journal of World History*
LH	*L'Homme (Revue Française d'Anthropologie)*
MBLB	*May & Baker Laboratory Bulletin*
MH	*Medical History*
MJA	*Medical Journal Australia*
MXTD	*Marxism Today*
N	*Nature*
NS	*New Scientist*
OSIS	*Osiris*
PAAAS	*Proceedings of the American Academy of Arts and Sciences*
PHR	*Philosophical Review*
PHY	*Physis* (Florence)
PRMS	*Proceedings of the Royal Microscopical Society*
PRSB	*Proceedings of the Royal Society (Ser. B)*
PRSM	*Proceedings of the Royal Society of Medicine*
PTKM	*Pen Tshao Kang Mu*
QRB	*Quarterly Review Bio.*
RBS	*Revue Bibliographique de Sinologie*
RHSID	*Revue d'Histoire de la Siderurgie* (Nancy)
RKP	*Routledge and Kegan Paul*
SAM	*Scientific American*
SBE	*Sacred Books of the East series*
SCC	*Science and Civilisation in China*
SCI	*Scientia*
SOAS	*School of Oriental and African Studies*
SOB	*Sobornost*
SPCK	*Society for the Promotion of Christian Knowledge*
SPPY	*Ssu Pu Pei Yao*
SS	*Science and Society* (New York)
STIC	*Science and Technology in China*
TCKM	*Thung Chien Kang Mu*
TCULT	*Technology and Culture*
TT	*Tills and Tillage*
UNASIA	*United Asia* (India)
VA	*Vistas in Astronomy*
W	*Weather*
ZVRW	*Zeitschrift f. d. vergleichende Rechtswissenschaft*

SERIES EDITOR'S PREFACE

This is the concluding part of the final volume in the formal sequence of *Science and Civilisation in China*, although it is by no means the last book in the series to be published. But since it will stand in the last place on the shelves of many libraries, something by way of a provisional concluding word is called for.

By now readers of this series will be well aware of the distinction between what Joseph Needham used to call the 'seven heavenly volumes' amongst which the topic areas of the series are distributed, and the much larger number of physical 'earthly volumes' published as separate parts. Behind that lies the original conception of a work to be published in a single volume, which was the proposal first agreed between its author and Cambridge University Press over half a century ago. When that proved inadequate, a seven-volume plan was adopted, and it was on that basis that the moderately sized Volume 1 appeared in 1954. But when the immense bulk of Volume 3 had passed through the press, it became clear that further subdivision was a practical necessity, and so Volume 4 appeared in three parts, each one being physically and intellectually weighty enough to stand as a life's work for a less ambitious and energetic scholar.

Volumes 5 and 6 continued the process of subdivision. To some extent this was the result of Needham's own creativity, increasingly seconded by a team of talented collaborators. But as time went by, the role of these collaborators tended to change from that of co-workers gratefully acknowledged on a title-page to that of independent authors in their own right. The first example of these to have a whole book to herself was Francesca Bray, author of Volume 6, part 2, on Agriculture. In that case the plan from the outset was that a whole book needed to be written on such a major topic. But this was not always the case: there were instances when a topic originally planned as the equivalent of a major chapter grew in the hands of an enthusiastic collaborator until another physical part had to be added to the corresponding volume. Anyone who looks at the sequence of varied and fascinating scholarly publications that resulted from this process will surely agree that on the whole this process of growth was an overwhelmingly positive phenomenon.

Volume 7 was subject to this process in its turn, but with less obvious effects. As the editor of this volume, Kenneth Robinson, explains in his preface, once the actual publication of Volume 7 began to be discussed the initial eagerness of collaborators exercised a continual pressure towards expansion of the author's original modest plan for a concluding survey of social factors in the development of science, medicine and technology in China. Given Needham's increasing age, the end result of this would have been a number of 'earthly volumes' by other hands, with which Needham himself would have had no very close authorial connection. But as Kenneth Robinson recounts, the end result of what was at times a convoluted process was much simpler than at one time seemed likely. Volume 7 appears in two parts, the first of which was

published some years ago with Christof Harbsmeier's discussion of language and logic, and the second of which, largely by Joseph Needham himself, is now before us.

There is however something missing in that short summary, and indeed in the account given by Kenneth Robinson himself. Anyone who knew Joseph Needham will remember him as a fountain of physical and intellectual energy, a man who continued regular work at his desk until the last day of his life. But that life began in 1900, and did not end until 1995. Although much of the material for this volume had been in draft for several decades, a great deal of work on it still remained to be done in the closing years of Needham's life, and it was clear that without the help of a devoted collaborator much would have been left in a state unready for the press. Without Kenneth Robinson to fill that role this book could not have appeared. He was in fact the first of Needham's collaborators to be credited as author of a separate part of the text of *Science and Civilisation in China*, in this case the section on Acoustics in Volume 4, part 1, which was begun in 1949, and his association with the project continued for much of the second half of the 20th century. It was therefore very fitting that he should be the last of Needham's collaborators to work directly with him in producing a text and in readying it for press, as he has done so devotedly in recent years. There is more to be learned from such a close working association with a great mind than can be expressed in conventional academic writing. We are fortunate, therefore, that in the Soliloquy that concludes the main text, Kenneth Robinson has given us some of the lasting impressions made by many conversations with Joseph Needham in the closing years of his life. This is not the place for a biographical sketch that might help to explain the circumstances that so obviously produced the right collaborator at the right time. For the moment it is sufficient to say that Kenneth Robinson's help with this volume was yet another of the strokes of good fortune that combined with Joseph Needham's personal dedication to make *Science and Civilisation in China* possible in its present form. Few others could have filled this role so effectively, so tactfully, and so tirelessly, and readers of this volume owe him a considerable debt of gratitude. As Series Editor, I will simply say that the job could never have been done without him.

When the author of such a vast work as this says his last word to his readers, some historical reflection on the significance of his achievement is surely appropriate. Those of us who have worked to bring this volume to press in the years since Joseph Needham's death are perhaps too close to the whole enterprise to provide this. What was needed was to find a scholar who was intimately concerned with and deeply learned in many if not all of the areas covered by Needham's writing, but was distant enough from the work of the *Science and Civilisation in China* project to view it objectively, while acknowledging it as one of the great intellectual phenomena of the 20th century. I am sure that the ideal candidate has been found in the person of Professor Mark Elvin. The reader who wants to know, in the end, what difference it all made can turn to 'Vale atque ave' with confidence.

Christopher Cullen

VOLUME EDITOR'S PREFACE

This is formally the last volume in the *Science and Civilisation in China* series, by Joseph Needham, although volumes that precede it in numerical sequence are still in press or in preparation at the time of writing. When he first thought seriously about the *Science and Civilisation in China* project in the intervals of his work in war-time China, Needham originally aimed to write a single book. By 1948 this plan had expanded to seven volumes, but later he realised that it would probably require some thirty volumes to cover all the topics envisaged, not so much because of the number of topics, but because of the wealth of information his wide-ranging researches revealed.

He aimed to write eighteen of these himself and to delegate twelve to specialists. But of these eighteen volumes there were six which he was not able to finish, or in some instances even to start. These were three of the four volumes initially planned on the institutes of medicine, and two on the social background of China in relation to science, the second of which would have ended with his General Conclusions.

The volumes which he actually wrote were: Volume 1: Introductory Orientations; Volume 2: History of Scientific Thought; Volume 3: Mathematics and the Sciences of the Heavens and the Earth; Volume 4, part 1: Physics; Volume 4, part 2: Mechanical Engineering which concluded with some thirty pages concerning Chinese inventions and discoveries relevant to aeronautics; Volume 4, part 3: Civil Engineering and Nautics; Volume 5, part 2: the first of four volumes on alchemy and the beginning of chemistry, this one being mainly concerned with 'the magisteries of gold and immortality'. Part 3 of Volume 5 traced the development of synthetic insulin from cinnabar elixirs. Part 4 was concerned with the development of chemical apparatus and theories from their alchemical beginnings, and the last of the four, part 5 of Volume 5, was concerned with physiological alchemy and its contribution to modern psychology. This made ten volumes. Two more were Volume 5, part 7, on 'The Gunpowder Epic' which was, however, in large measure the work of Ho Peng-Yoke (Ho Ping-Yü), one of his most productive collaborators, and Volume 6, part 1, the first of two volumes on botany. Volume 6, part 6, represents what he completed on the subject of medicine.

The average length of time spent in bringing a volume to publication was 3.3 years, though this takes no account of the time spent on preliminary work and research before the final writing began. Very often portions of the work were first published as scientific papers. Needham was, for example, working on the text of Volume 4, part 1, in 1948, fourteen years before it was published, and six years before even Volume 1 was published by Cambridge University Press. The eighteen volumes which Needham intended to write himself were therefore likely to require approximately sixty years of work, plus the immense labour of preliminary research. The extent of this labour can be judged by the fact that when I asked him in the mid-1970s how he was getting on with the volume on botany, he replied, 'At present

it's a green blur'. He once wrote to a friend, Mr Hu Tao-Ching 胡道靜[1]: 'It has been my experience all along that whenever I embark on a new chapter, we find that the subject is full of misunderstandings, mistranslation, erroneous ideas, and what are just plain errors. Gradually the true picture emerges as one works on.' By 1983, however, when we saw his botany text being made ready for printing, it was no longer a green blur. On the contrary, Needham had sorted out the different Chinese systems of plant classification, comparing them with European systems to such good effect that this volume on botany made an important contribution to the writing of the present volume in the article: 'Literary Chinese as a Language for Science'.

As Needham was forty-seven when he started writing the final text for *Science and Civilisation in China*, Volume 1, he could not have hoped to complete the eighteen volumes he eventually envisaged before he had reached the age of 107. What he was not to know until much later was that the scientific treasures to be discovered in the mountain of Chinese literature were so great that they could not be brought completely to light in seven volumes, or even in eighteen, but that eventually twenty-nine volumes would be needed to contain them, despite the fact that some intended subjects were abandoned as impracticable.

Needham was granted ninety-four years for his amazingly productive life. He continued working on his General Conclusions till only two days before he died. But *Science and Civilisation in China* was only part of his total output. He had some 250 works to his credit in addition to the volumes of *Science and Civilisation in China*. Gregory Blue lists some 385 'Publications' in his very useful *Joseph Needham – A Publication History* (*Chinese Science*, 14, 1997, pp. 90–132). These cover new books of his own, translations, contributions with other authors, books he had edited, and well over 150 scientific papers.

We may now consider his dilemma. As Needham delved ever deeper into his subject, more and more sources for the precious ore which he was seeking kept opening up. Was he to leave it, as an archaeologist finding King Priam's golden treasure might bury it again for fear that he would not have time to assess it properly, or was he to bring it into the light of day and trust that future archaeologists would finish his work where he had left off? All Needham's instincts were for bringing what was hidden into the light of day, and trusting posterity to make a true evaluation of it. Therefore each volume in turn became more bulky than the last. Volume 1 was a reasonably slender book of 248 pages of text. But Volume 2 had more than doubled with 503 pages, and Volume 3, with its 683 pages and very extensive supplementary pages, had become so heavy that, as Needham said, 'it was too big to read comfortably in one's bath'. So it was decided that in future each volume should be a reasonable size. This good resolution was followed in Volume 4, part 1, which had only 334 pages of text, but by Volume 4, part 2, this good intention was abandoned, for it now had 602 pages, and Volume 4, part 3, broke all records with 699 pages of text.

[1] See Li Guohao *et al.* eds. (1982), frontispiece.

Then it came to Volume 5 whose subject was chemistry and its applications. The introduction to chemistry through alchemy in four volumes made it quite certain that Needham would not be able to finish the work himself, for the alchemical volumes would require thirteen years for their publication, by which time Needham would be eighty-four. Gunpowder, botany, four medical volumes and two concluding volumes on the social background still barred the way to a quiet retirement. Delegation became essential.

He had first delegated to me the sub-section in Volume 4, part 1, on acoustics in 1949 with the words: 'acoustics is my blind spot. I'd like you to fill it with perhaps twenty pages.' In the end it came to just over 100, and that was before the subject had been opened up by archaeologists with the wonderful discovery of complete sets of bells establishing the frequencies of the notes of the traditional scale.

This expansion persisted throughout. Once something previously unknown in the West was discovered Needham was reluctant to let it go again. Consequently several collaborators who were asked to contribute portions of a volume ended up by writing complete volumes themselves. Eventually sixteen volumes would be completed by fifteen collaborators.

Fresh problems began to arise. That whole books were being produced by authors who had been invited to contribute just one section of a book was not in itself necessarily contrary to Needham's wishes, but a different situation arose when the work submitted by that author did not fit into the general plan or where it contained ideas which Needham found unacceptable.

Needham had originally listed a number of factors that he felt formed part of the social background enabling or disabling the rise of science. These included the geography of China, fiscal and economic circumstances, language, logic, concepts of time, the role of religion, the consequences of class attitudes, competition, nature and man, and many others. He hoped to retain overall control of the final volumes in which these factors were considered, but to be helped in the task by specialists who would contribute sections that would fit into the general plan. This was not possible. By the time he was eighty and ready to give his mind to the writing of the last volume, while also writing the Institutes of Medicine, a wide generation gap had opened up between himself and the best of the young sinologists. In the year 1980, I was invited to come from Hamburg to help Needham and his collaborators finish the remaining volumes. Needham at that time still intended to be in strict control of Volume 7. There were difficulties, however. It was found impossible, for example, to persuade a modern geographer to write about his subject in such a way that the geography of China could be seen to be influencing the way scientific thinking developed. A volume was produced, but while excellent in itself it was a historical geography of China, not part of the *Science and Civilisation in China* series as Needham saw it.

A more difficult situation arose, however, when Professor Derk Bodde, one of a group of six scholars who, Needham hoped, would help him in the writing of Volume 7, unexpectedly presented him with a substantial manuscript which followed very completely and precisely the outline which Needham had drawn up for Section 49

of Volume 7, 'Intellectual and Social Factors'. In it Bodde put forward many views which Needham found quite unacceptable. Yet he hated saying 'No', and, as he explained later, when the leading American sinologist offers you as a gift a work on which he has spent more than a year, you can hardly refuse to accept it. Needham felt that Bodde's work would be far better published as an independent contribution to scholarship, but sought a compromise, and said he would be pleased to have it published as part of Volume 7, provided that certain changes could be made in the writing. There was the rub. I was called in to sort out the differences of view between the two giants of the sinological world. This situation in which I found myself is neatly summed up in the Burmese proverb: 'Where elephants fight the grass is trampled'.

The two main differences in points of view were (1) the role of the classical language of China in relation to science, and (2) whether the Chinese could be said to have any real science at all. These were areas in which compromise was not possible. When it became obvious that compromise would not be possible, Needham had a new idea. H. G. Wells' *Outline of History*, which had been written in 1920, was met with a great deal of criticism. In 1931 Wells revised it, but following an original method. When he came to a passage with which a critic disagreed, Wells included the criticism in his text as a quotation, and then added his own riposte. Needham felt that this method would admirably suit Derk Bodde's text. Where he disagreed with Bodde, he would insert the reasons for his disagreement, and if so desired would include Bodde's further argument. A beginning was made on these lines, and it would certainly have made an unusual and interesting book, but the crisis came when Bodde asked Needham to withdraw a passage of close argument as it would upset the friends he had been quoting. Needham refused and Bodde then withdrew his entire contribution. In this way the Gordian Knot was cut, and the work of parcelling out portions of Volume 7 to specialised writers began.

At first it looked as if it would be possible to do this following Needham's original plan. The role of logic was an important part of it, and the great Polish logician Janusz Chmielewski had not only agreed to contribute a section, but had already submitted the first forty-two pages of his text. During the year 1983 it became clear that Professor Chmielewski would not be able to complete his undertaking due to the pressures he was under in Warsaw. It was suggested that he might have an assistant to work with him. Perhaps he would suggest and recommend a suitable younger logician. He recommended Dr Christoph Harbsmeier, who visited Chmielewski, discussed the work and agreed to take entire responsibility for it. He started work in September 1983. His contribution, like so many others to *Science and Civilisation in China*, rapidly increased from a section of a volume to a complete book that in 1998 became Volume 7, part 1.

An article on Language and Science in traditional China had been begun as soon as disagreement on this topic with Derk Bodde had become clear. It began as a 'riposte' in the H. G. Wells tradition, was first conceived as forming part of a volume together with the work on logic, then became separated, and was to form a volume on its own. But after Needham's death it became important to get the whole

work published as soon as possible. The text on language has therefore been included in the present volume in a shorter form than originally envisaged.

The redesigning of Volume 7 had by the mid-1990s resulted in the following plan, which represents the concept of the volume at its greatest length:

Part 1 'The Nature of Chinese Society in Comparative Perspective.' This would fall into six sections by different authors.

Part 2 'Language and the Foundations of Scientific Civilisation in Ancient China.' This eventually resolved itself into 'Language and Logic in Traditional China', written by Christoph Harbsmeier.

Part 3 'Language and Science in Traditional China', to contain 'a reconsideration of some characteristics of Chinese Science' by Christopher Cullen, and 'Literary Chinese as a Language for Science' by Kenneth Robinson working closely with Needham.

Part 4 'The World View of the Literati', to cover concepts of Time, History, Religion, Education and Political Organisation.

One by one items in this ambitious scheme of things had to be abandoned, either because Needham found the work that was submitted was unacceptable, or because the author was unable to complete it, or decided to withdraw it. In some cases work that had been completed and accepted had to be abandoned when the failure of other contributions withdrew vital elements from the structure. One decisive factor was that the history and sociology of science were in a state of turmoil from which they have not yet emerged, and if a work was not published soon after it was written it was likely to be out of date. The old secure concept of 'world science' which had been part of Needham's background had vanished.

It was about this time that HRH The Duke of Edinburgh, Chancellor of the University of Cambridge, visited The Needham Research Institute, and interested himself in the progress of the project. 'And how long will it take to finish it?' he enquired. On being given a rather conservative answer, 'At least ten years', he exclaimed, 'Good God, man, Joseph will be dead before you've finished', a very true appreciation of the situation. If it had been possible for Needham effectively to write Volume 7 himself, using others to reinforce or supplement his own writing as he had done earlier in his life, Volume 7 might have been presented with the consistency of a scientist writing in the mid-20th century. But by the time he was eighty it was too late. Much had to be abandoned. Western views on China itself were changing, as Needham stresses on page 203 of the present volume, and these views have continued to change not only in the West but in China itself. There is, therefore, no possibility of presenting any definitive judgement on the role of China in world history, but only the views of a great scientist and polymath in the mid-20th century.

The staff of the Needham Research Institute now found themselves in the position of the young man in Pope's *Essay on Criticism* for whom – Hills peep o'er Hills, and Alps on Alps arise.

The policy agreed on was not to attempt some of the major hills, on which Needham had written only briefly, and which would require much work from him

if they were to be updated and brought to the level of his published work. Time, Religion and Education fell into this category. But some of his existing writings could be brought together into Volume 7, part 2, preserving as much as possible of what he had originally intended Volume 7 to be, and some could be updated if he had the help of an academically trained secretary; for it must be remembered that in his closing years, though his mind remained lucid and his memory astonishing, Needham had great difficulty even in moving from one chair to another, and even more difficulty in speaking and in making himself understood, due to the effect of the medicines he took to control Parkinsonism. But a secretary, working closely with him day by day, could often understand what he had said, and could read what he had written, when others were baffled.

When Needham died in March 1995 none of the material that he had intended for Volume 7 was in a condition ready for the press. In some cases there were in existence a number of inconsistent drafts without a clear indication of which was to be the final text, and in other cases a section of text required the searching out of a great mass of references that were no doubt in Needham's capacious memory, but which had only been entered into his typescript in an abbreviated and sometimes cryptic form. As Series Editor and Volume Editor respectively, Christopher Cullen and I sat down together to decide what was to be done. Of decisive importance for us in deciding what should be included in Volume 7 was a document which Needham had composed in 1981 and revised in 1987 in the form of a 'testament' in which he had set out his wishes as regards those of his writings which should be included in the event that he died without being able to see Volume 7 through the press. It is substantially this material that now forms Volume 7, part 2. To this has been added the interesting chronological list of Chinese discoveries and inventions that Needham extracted from earlier volumes of *Science and Civilisation in China* and elsewhere during his work for this volume in the last years of his life. Needham himself acknowledged the provisional nature of any such list, and no doubt some items in it are open to discussion. But many readers will find this compilation stimulating and perhaps useful in beginning investigation of other volumes of *Science and Civilisation in China*. I should like to point out that in editing Needham's text we have not made any attempt to eliminate occasional evidence that this material was not written yesterday. China has changed rapidly over the last decade, but Needham's views expressed in these writings largely relate to a China before these changes occurred. Likewise, respect for the integrity of the author's text has made us reluctant to make cuts when some parts of Needham's argument are common to various sections of this book.

As editor of this volume, I was fortunate in having been frequently engaged in close discussion with Needham in the closing years of his life on all the topics with which Volume 7 deals, so that it was possible, though not always easy, to decide which of the variant versions of his text was the one he intended as his last word. It was also easier than it might have been (though not very easy) to locate the material needed for some of the lacunae in his references. The resulting task has been time-consuming, but I

hope the reader will consider it worthwhile: I am confident that apart from the section of this volume in which I and others are specifically named as co-authors what the reader has here is emphatically and authentically Joseph Needham, speaking here in the closing stages of one of the greatest scholarly projects ever undertaken.

Kenneth Robinson

VALE ATQUE AVE

Coming to the end of Joseph Needham's *Science and Civilisation in China* can only be compared, as an experience, to reaching the final page of Gibbon's *Decline and Fall of the Roman Empire*.[1] One looks back at the journey taken, almost disbelieving its immensity. Parts of the landscape stand out clearly in the sunlight of memory. Others are already covered over by the mists of uncertain recollection. One knows, however, that one could return there easily enough if the need arose. What is harder to recall is the different state of mind with which one started out long ago.

One's conception of the world has been transformed. In the case of Gibbon, by a vision of the slow passage from antiquity to the Middle Ages, from our ancient Mediterranean *imperium* to the doubly divided inheritance of today: eastern and western Europe, and Christendom – or ex-Christendom – and Islam. In the case of Needham, by the revelation of a Chinese cultural universe whose triumphs in mathematics, the sciences, and technology were often superior, and only rarely inferior, to those of western Europe until about 1600. That contributed astonishing riches of practical invention to the origins of the modern age, the proper understanding of whose nature subverts the analytical logic of the standard model of modern Western history for those interested enough, and historically modest enough, to see why.

The present volume, edited by Kenneth Robinson, and partly co-authored by him and Huang Jen-Yü, offers us a last chance to look a little deeper at how Needham thought about his work on the history of Chinese science in the wider context both of Chinese society and culture, including the surprising capacity of the old Chinese literary language for technical precision when it needed it, and of comparisons between China and Europe. Some of this material is new, notably that on language. Some of it, for the *cognoscenti* at least, is old though not easily available, and revised and updated here in varying degrees.

It has to be said that, as scholarship has advanced, not everything that Needham wrote, forty or more years ago, on the social and economic history of China now seems as solidly based as the greater part of his reconstructions of Chinese technical practice and scientific theory. The reader needs to exercise a certain caution here, searching at times less for information than for inspiration. But the challenge of arguing with him is invariably well worth taking up, in these areas as elsewhere. He saw a number of pivotal problems before anybody else did, and struggled to discover answers with such psychological energy that even those we now tend to judge as partial failures are illuminating. In the scientific domain, of course, he grasped that the question of why something like 'modern' science did not arise in imperial China was a serious one, even if it has since provoked efforts either to bypass it or to recast it

[1] Which I read in 1954–5, mostly while travelling on the London Underground. It took over a year to finish. Reading *SCC* has taken much longer as the volumes have appeared *seriatim* since 1954, and, even so, I certainly would not claim to have looked at every page.

in a fashion more amenable to testing.[2] But even his famous theory that Chinese social structure in *all* of imperial times could be described as 'bureaucratic feudalism' – on which I already differed with him in the early 1960s on the grounds that the changes over 2,000 years were too great to allow any single such label, if rigorously defined, to be applied equally to all periods – has a heuristic value. To put a complex point a little too simply, the phrase embodies a long-lasting characteristic tension in the cultured classes of Chinese society: that between a deep belief, universalistic at least within the Chinese oecumene, in general ideals applied generally, and a comparably intense attachment to certain specific particularistic and personalistic loyalties.

Perhaps, to use metaphorical language, one can say that some of the mountains that grew from his work have been more eroded with the passing of time than others. But the orogeny was extraordinary.

The Chinese Perspective on the West

What is hard to come to terms with, almost half a century after the appearance of the first volume in 1954, is the limited assimilation of Needham's work into the bloodstream of the history of science in general; that is, outside the half-occluded universe of East Asian specialists and a handful of experts sensitive to the decisive contributions of comparisons.[3] For these to be useful, there has to be enough in common between two domains to make comparisons and contrasts relevant, and enough different to make such juxtapositions reveal critically distinctive aspects of one or the other. Though one should acknowledge the claims of Islam and India, it is China, outstandingly, that has this quality *vis-à-vis* Europe, and vice versa. It is ungracious to start what should be a celebration with negative comments, but this continuing neglect needs insisting upon. Opening an issue of *Nature* not so long ago,[4] I found an essay by Adrian Johns that argues that 'the social structures of [modern European] science were invented to cope with an explosion of printed information'. No one aware that printing was invented in China in or around the +9th century[5] could possibly countenance such an argument, at least in such a simple form, yet it seems that no one on the editorial staff of *Nature* knew or remembered enough to raise the question of the Chinese counter-case with the author.[6] One might say, with wry respect to Morris Low, that the only fault in his otherwise excellent recent

[2] As by Sivin (1982) and Elvin (1993–4), respectively.

[3] Pre-eminently, at the time of writing, Geoffrey Lloyd. See Lloyd (1996). Floris Cohen's survey of historiography of the Scientific Revolution is also exceptional in devoting a long section to Needham's work. While his analysis depends on an unqualified distinction between 'science' and 'technology' that I, at least, find open to question, his appreciation of the key role of the Chinese case in helping to disentangle probable patterns of causation is as exemplary as it is rare. See Cohen (1994).

[4] Johns (2001). Johns' *The Nature of the Book* (Johns (1998)) is subtler. He rightly insists that it was not the technology of printing as such that was crucial, but the interactions of the potential of this technology with a variety of changing social and cultural circumstances (pp. 19–20). But the absence of any understanding of, or even awareness of, the partial parallels and probable differences between Europe and the other, and older, great print culture, that of China, makes even this rich work seem one-dimensional.

[5] Barrett (1998). [6] The underlying idea is derived from Eisenstein (1980).

special issue of *Osiris* is its title, *Beyond Joseph Needham*.[7] The majority of historians of science are still, usually wilfully, on the wrong side or at best, as in the case of my old friend Alistair Crombie, daunted by the immensity of the task of coming to serious terms with Needham's work even though aware of its importance.[8]

Addendum: The Practical Knowledge of Probabilities

Liu Tun 劉鈍 and Wang Yang-Tsung 王揚宗 have recently published an anthology of pieces by both Chinese and non-Chinese scholars on the issue that concerned Needham.[9] Liu Tun cites and includes recent analyses that discuss the two main pre-Needham debates on the absence in imperial China of a home-grown modern science. The first was that among the Jesuits and interested French scholars in the 18th century; the second was that started by Chinese intellectuals during the first third of the 20th century in the context of concern with China's modernisation. This latter played a role in shaping Needham's own early ideas on the subject, and he knew most of the participants. Liu also gives references to, and some items from, the extensive discussions on the 'Needham Problem' that have re-emerged in China since about 1980. The collection further features many translations of recent Western scholarship, including pieces by distinguished historians of Chinese science such as Sivin, Blue and Hart, some sociology, and pages from contemporary mainstream Western historians of Western science such as John Schuster and Floris Cohen, plus Alexandre Koyré from an earlier generation. This book, which is a most valuable resource, appeared too late to be properly incorporated into the argument of this introductory survey. Overall, though, it tends if anything to reinforce one's impression that points of contact through which a live intellectual current is flowing between members of this mainstream and those inspired by the discoveries of Needham and his colleagues have remained, to date, disappointingly few.

Crucially, intermittent inadequacy, or even the collapse, of the arguments of historians, the high quality of whose contributions one is generally happy to acknowledge, can often be linked with a disregard of the Chinese case. A simple example occurs in David Lindberg's *The Beginnings of Western Science*.[10] He sees the 'burst in creativity in lyric poetry and philosophy' in ancient Ionia, the fountainhead of later European sensibilities, as being first and foremost the result of a 'critical factor', namely 'the availability of fully alphabetic writing and its wide dissemination among the Greek population'. Yet ancient China, beginning at much the same time, had superb lyric poetry and philosophers some of whose work is still alive today, especially, perhaps, that of Chuang-tzu. And China used a *non*-alphabetic script.

[7] *Osiris*, **13** (1998).
[8] A comment based on years of participation in his seminar at Trinity College, Oxford, and several talks at his home in Boar's Hill shortly before his death.
[9] *Chung-Kuo Kho Hsüeh Yü Kho Hsüeh Ko Ming. Li Yüeh-Se Nan Thi Chi Hsiang Kuan Wen Thi Yen Chiu Lun Chu Hsüan.* 中國科學與科學革命。李約瑟難題及相關問題研究論著選 [Science and scientific revolutions in China: Selected research on the Needham Problem and related topics] from the Liaoning Education Press in Shenyang (2002).
[10] Lindberg (1992), p. 27.

While this argument as stated is thus dead, there is still an important issue to be examined. Science, more than any other human pursuit, is situated at the interface between symbols and reality. The power or inadequacy of a symbolic system is not a trivial question. We all know how a new notation can transform our ability to grasp a difficult concept.[11] What the comparison with China can help us do is to look for subtler characterisations than the crude and unhelpful 'alphabetic' or 'non-alphabetic' when exploring this interface. Numerals such as '1', '2', '3', etc., are not alphabetic. No one would, I think, essay the argument that this makes them inherently less useful than 'one', 'two' and 'three', etc. It has recently been maintained, however, that the Chinese '一', '二', '三', etc., were inferior to '1', '2' and '3', etc., which, given that they were similarly used in a decimal place-value system, seems more than a little unconvincing.[12] The European algebraic notation developed by Viète, Recorde (inventor of the '=' sign), Stevin and others is a different matter.[13]

Subtler, and more interesting, is the oversimplification committed by Edward Grant in *The Foundations of Modern Science in the Middle Ages*.[14] Grant uses the 'university' as a magic variable that set medieval western Europe apart from the rest of the world as regards the origins of modern science. This is not a trivial argument, but thus stated it is wrong. There were analogues to universities in China, though not many. Perhaps the best-known example, though not the earliest, is the *Thai-hsüeh* 大學, or 'Great School', run by the government during the Sung dynasty. It had both mathematics and medicine in its curriculum, and examinations.[15] Both in the Southern Sung and later dynasties the 'academies' (*shu-yüan* 書院) also offered a mixture of instruction, debate and training for the imperial examinations that changed over time.[16] What Grant needs to do, if his argument is to carry conviction, is to sharpen up the focus and ask what it was about the *Western* university that was significantly different from these Chinese institutions as regards fostering the growth of scientific styles of thinking. My personal view is that this would not necessarily prove impossible to do. My point is that Grant does not see that it needs to be done. So we still cannot see clearly what it was, *precisely*, that might have made the difference.

I have chosen the two foregoing authors because I have found their work in general interesting and valuable. My criticism is motivated by a friendly dismay, and not by a sense of hostility.

Familiarity with the patterns of Chinese premodern science also helps disentangle the confusions that surround our conceptualisation of the coalescence of scientific 'modernity'. Most of us have enjoyed the opening sentence of the introduction to Steven Shapin's recent little paperback: 'There was no such thing as the Scientific Revolution, and this is a book about it.'[17] But such a delightful, and insightful, witticism is no substitute for analysis. If we use the analytical framework of Crombie's

[11] Nowhere more spectacularly in medieval times than in the creation of a musical notation that permitted singers to sing directly from a score music that they had not previously heard. See Langellier (2000), on Guido d'Arezzo.

[12] In Huff (1993), p. 288. [13] Crombie (1994), p. 519. [14] Grant (1996).
[15] Wang Chien-Chhiu (1965). [16] Grimm (1977). [17] Shapin (1996), p. 1.

'styles of scientific thinking',[18] it is possible to compare China and Europe in a controlled way that avoids the sillinesses at times associated with arguments as to whether some idea was 'prescientific', or 'protoscientific', or perhaps 'modern', or, then again, not. Saying this does not imply any unconditional adherence to Crombie's ideas.[19] It is drawing attention to a method that offers a fruitful way of *disaggregating* a question into more manageable subquestions, namely how far premodern Chinese thinkers had developed the various styles of thinking that have in the long run, as they have combined with each other, proved crucial to the growth of a distinctively 'modern' science. This combination might even be used as the basis of a secure definition of the development of increasing degrees of such 'modernity'.

As I have shown,[20] as of about 1600, China possessed in varying degrees *all* of the styles of thought identified by Crombie as the eventual key components of science – the 'postulational' (like Euclidean geometry), the 'experimental', 'hypothetical modelling', 'taxonomy', the 'probabilistic', and 'historical derivation' (the prototype of which, in Europe, was the study of the genesis and diversification of the Indo-European languages) – with the apparent exception of the probabilistic, which hardly yet existed at this time even in Europe. By this date these styles were mostly less strongly formulated in China than in Europe, but they were there. The revolution in Europe after 1600, in so far as there was one, lay mainly in the *acceleration* with which these styles of thought both developed, and interconnected, rather than in any fundamental qualitative innovation – probability excepted. By 1750 China was far behind in almost every one of these domains – the 'historical' being perhaps the only doubtful case if we recall the sustained scholarly programme (in a more or less Lakatosian sense) to reconstruct the filiation of ancient Chinese pronunciations of characters as these pronunciations changed over time.

Another way of looking at the issue of continuity versus radical change in 17th-century European scientific thinking is to re-read Newton's *Principia* adopting the imagined mind-set of a scholar (of any nationality) sufficiently steeped in the Chinese tradition to be able to look at Europe, even if only momentarily, with the eyes of a cultural outsider. I tried this seemingly, but only seemingly, disingenuous thought-experiment recently with Bernard Cohen and Anne Whitman's lucid new translation.[21] It is a totally unrigorous procedure, but the result makes a sort of sense. Such a person's first reaction would almost certainly be that this is a book conceptually deeply rooted in *European* antiquity, as with its diagrams that seem so Euclidean at first sight and its pervasive use of ratios, combined perhaps with some later medieval notions, like that of acceleration, invented some time before 1235 in Merton College.[22] His second reaction would be one of awe at the wizardry with which the lines of these diagrams take on imaginary motions in the mind, approaching their own extinction, and conjuring up limits and the concepts of the calculus. Seen, in the imagination, from the other end of Eurasia it is both traditionally and recognisably

[18] Crombie (1994). [19] There is a lucid and careful critique in Iliffe (1998).
[20] Elvin (1993–4). [21] Newton (trans. 1999). [22] Crombie (1994), vol. 1, pp. 412–14.

European and breathtakingly new. An old and needless conflict thus to some extent dissolves. The capacity to translate ourselves at will to a different conceptual perspective on our own local history by means of an imaginative absorption into that of China is one of Needham's most fruitful, and underappreciated, gifts to the field.

These are impressionistic remarks, as befits an introduction and perhaps only permissible in such a context. What I hope they suggest is that there are, still, argument-sharpening comparisons and perspectives accessible to Western historians of Western science if they will familiarise themselves in a serious and sophisticated way with the world of premodern Chinese science opened up by Needham and his collaborators.

The adjectives 'serious' and 'sophisticated' matter. Credit must be given to scholars who have recently attempted a comparative analysis, such as David Goodman and Colin Russell in their Open University textbook, *The Rise of Scientific Europe: 1500–1800*, which is in many ways admirably multiple-angled in its approach, and Toby Huff, *The Rise of Early Modern Science. Islam, China, and the West*, which raises the majority of the key issues, even if it does not always probe deeply enough.[23] Apart from a number of avoidable factual errors,[24] they suffer, however, from two systemic defects. The first of these is an inability to use the prism of chronology to split the light from the Chinese past into periods with distinct characteristics. Thus Huff states that,

> the Chinese state in theory owned all the land and mineral wealth of the country, so that even mining operations . . . were operated as government monopolies. . . . Likewise all banking innovations such as letters of credit . . . , long-distance facilitation of exchange, and so forth, were taken over as state monopolies. There was no scope for entrepreneurial innovation, and thus disinterested learning . . . was discouraged *because* these avenues of advancement were closed without state sponsorship.[25]

Leaving aside the issue of theoretical eminent State domain, which was important up to and during the +1st millennium but rarely later, the points in the first two sentences applied to *some* sectors at *some* periods, and in *some* places, but virtually never universally. There was plenty of private mining from Sung through to Chhing times;[26] and private instruments of credit were extensively used during the Sung as they were under the Chhing, which also saw the rise of private financial institutions like the 'money shops'.[27] Under the Chhing the long-distance transfer of funds was handled above all by the Shansi banks, which were technically private though in a sort of symbiotic relationship with the government. The last sentence in the quoted passage is, however, untrue. The Chinese economy during most of the last

[23] Goodman & Russell (1991), and Huff (1993).

[24] One example will serve. Goodman & Russell (1991), p. 7, state that the Chinese empire had 'reached its furthest extension in the sixth century AD. . . . It was . . . at this time that the Muslim Empire, expanding northeast from Persia, encountered the Chinese and defeated them.' It was of course not the +6th century but the late +7th and the +8th centuries. The key battle, at the Talas River, was in +751. See Blunden & Elvin (1983), pp. 92–3. In the +6th century Islam did not even exist, and a 'Chinese empire' recrystallised only after the +580s, with the Sui dynasty.

[25] Huff (1993), pp. 312–13. My italics. It is worth repeating that, like the other works criticised above, this book has merits that justify the provision of the sinological qualification and correction that follow.

[26] Golas (1999). [27] *Chhien-Chuang* 錢莊.

millennium fizzed with entrepreneurial activity. This is apparent from, for example, Shiba Yoshinobu's *Commerce and Society in Sung China*, and the materials cited in my own books, *The Pattern of the Chinese Past* and *Another History* (1996),[28] but there is plenty of other evidence, both primary and secondary. Given this, which is a fact that cannot reasonably be disputed by anyone who is informed, the logic of Huff's 'because' becomes the crux of the issue. If it is a valid statement of a historical causal relationship, then there must have been abundant 'disinterested learning' in China during the middle and later empires. If there was not, then it is false. His and the reader's choice.

It should be noted here that the pioneering nature of Needham's work meant that he himself, half a century ago, could not develop a fully integrated chronological approach to the development (and the setbacks) of Chinese science and technology in their full historical social contexts. Practical reasons obliged him, and his collaborators, to begin by treating the subject topic by topic and so create an *Encyclopédie* in the best sense of that word, often profound and provocative, but compartmentalised. It also seems likely that he was personally uncomfortable with the prospect of exploring a logic of Chinese historical development that might prove too different from the immobile and Eurocentric formulae of the Soviet and Chinese Marxism of his time, though Marx himself, one suspects, with his independence of mind, might well have relished the task, given adequate information to work with.[29]

As I have already noted, Needham acknowledged but at the same time evaded the issue by comprehensively defining the imperial Chinese system over two millennia as 'bureaucratic feudalism', a new term in this context, and one which is discussed at several points in the present volume. The problem with this label, as I suggested to him in private correspondence and discussion in the early 1960s, is not only that any tightly constrained and testable definition that one constructs for this concept is unlikely to work equally well for all periods, but that its adoption tends to negate *a priori* the possibility of recognising significant changes.[30] The once justifiable excuse of the constraint of insufficient information has, moreover, ceased to apply for some time now; and one of the long-term objectives of present and future historians of Chinese science has to be precisely to *restructure* the mass of information made available by Needham, and by his collaborators, and his successors, and critics – by no means disjoint sets of persons – into a synthesis more sensitive to the long-term changes in Chinese society and culture.

The second defect in the two comparative studies just mentioned is a disinclination both to analyse the meanings of key terms and to show how they might fit into an explicit argument focused on the development, or non-development, of scientific thinking in various socio-intellectual contexts. Here we can take as an example the

[28] Elvin (1973) and (1996).

[29] Joan Robinson (1942), in *An Essay on Marxian Economics* long ago pointed out how extensively Marx changed his ideas from those in volume I of *Das Kapital* to those embodied in the fragments published as volume III, ending up by seeing 'underconsumption' as the most likely cause of crises in capitalist economies.

[30] Needham papers in the Needham Research Institute.

idea of 'proof'. Huff sees as foremost among 'the main defects of Chinese mathematical and scientific thought' that it 'lacked the logic of proof as well as the concept of mathematical proof'.[31] Goodman, in Goodman & Russell (1991), concurs: 'A . . . shortcoming of Chinese science is the absence of the idea of proof, so important in Western science since the time of the ancient Greeks'.[32] The issue here is not the absence, or presence, in premodern Chinese mathematics of the ideal of proof in the sense of a consistent system of primitive terms, a set of axioms, and more or less fully formalised rules for generating well-formed propositions and 'true' theorems as exemplified in a Western tradition running from before Euclid down to Hilbert. Apart from the flickers of almost Boolean logic in the Mohist canon 2,000 years before Boole,[33] it is generally agreed that this is a fair statement of the case. The issues are, rather, the following:

(1) In four out of the six of Crombie's styles of scientific thinking, 'proof' in this sharply defined sense is not relevant to scientific advance at what we might loosely call an 'early modern' level. This comment applies to modelling, experimentation, taxonomy and historical derivation, though not of course to the postulational style nor, with some reservations, to probabilistic thinking. With respect to particular fields, it clearly plays little or no part in chemistry, the earth sciences or the life sciences at this level. The case can also be made that it is of little importance even for the early history of some parts of physics, such as magnetism. If it was so crucial an element, one would have expected to see marked differences in China between the domains where the absence of 'proof' mattered and where it did not. So far as I can tell, if we examine the period 1550 to 1750, this was not the case, or only weakly so.

(2) If we take as a rough working rule, to simplify a subtle discussion, the notion that 'theorems are discovered but proofs are invented', in what specific crucial aspects as regards discovery did what we may term 'Euclidean-Hilbertian proof' in Western mathematics differ from what I would describe as the 'sequences of co-ordinated demonstrations' that we find in the best traditional Chinese mathematics? Works like the *Chiu Chang Suan Shu* 九章算術 (Nine chapters on mathematical procedures), with its +3rd-century commentaries by Liu Hui 劉徽, at least come close at times to what Karine Chemla has called 'algebraic proof within an algorithmic context'.[34] They are not just numerical cookery books. Even if we do not, yet, easily go all the way with Chemla's challenging formulation, there is a need for an examination of the particularities in this domain, rather than unexamined generalities. Moreover, Sung and Yüan mathematics was still capable of important discoveries, such as aspects of modular algebra and the theory of determinants.[35] The late imperial discovery-barrier problem remains as elusive as it is important.

[31] Huff (1993), p. 288; see also p. 278. [32] Goodman & Russell (1991), p. 12.
[33] For a summary of the debate between the present author and Professor Makeham on this see Elvin (1996), pp. 276–9. Also Elvin (1990).
[34] Chemla (1997–8).
[35] See the revised edition of Blunden & Elvin (1998), 'Principles of Mathematics', pp. 194–7, for a sketch of these and other topics. (The original English-language edition of 1983 contains misprints in this section.) See also *SCC*, vol. 3.