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 medieval 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 Wên *Yuan Shuai*, Intendant of the Spiritual Officials 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 *Yuan 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 *Yuan 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-Naqqāsh 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

Glaubt ihr denn, daß die Wissenschaften entstanden und groß geworden wären, wenn ihnen nicht Zauberer, Alchimisten, Astrologen und Hexen vorangelaufen wären als die, welche erst Durst, Hunger und Wohlgeschmack an verborgenen und verbotenen Mächten schaffen mußten?

(Do you believe then that the sciences would ever have arisen and become great if there had not beforehand been magicians, alchemists, astrologers and wizards, who thirsted and hungered after abscondite and forbidden powers?)

FRIEDRICH NIETZSCHE
'Die fröhliche Wissenschaft', IV, 1886.

Occupé depuis longtemps de l'histoire de la chimie, nous voyons clairement aujourd'hui les difficultés auxquelles s'expose celui qui entreprendra de l'écrire. Une connaissance approfondie de la science sera loin de lui suffire, s'il n'a pas recours aux lumières de la littérature ancienne et de la littérature orientale.

(Having long been occupied with the history of chemistry, we can clearly see today what difficulties lie in the path of anybody who undertakes to write it. A deep knowledge of the science itself will not suffice unless he has recourse to the ancient, and to the oriental, literature.)

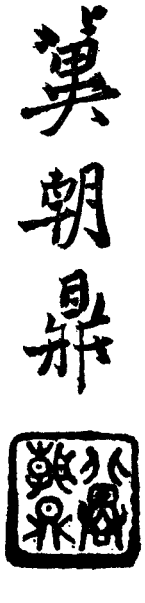
MICHEL EUGÈNE CHEVREUL (1786 to 1889)
reviewing Reinaud & Favé in
Journal des Savants, 1847, p. 219.

Seek for knowledge, even though it be as far away as China.

Veritable saying (*ḥadīth*) of the Prophet Muḥammad
(al-Suhrawardy, no. 273).

中國科學技術史

李約瑟著



SCIENCE AND CIVILISATION IN CHINA

BY

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

SOMETIME MASTER OF GONVILLE AND CAIUS COLLEGE, CAMBRIDGE,
DIRECTOR OF THE NEEDHAM RESEARCH INSTITUTE, CAMBRIDGE,
HONORARY PROFESSOR OF ACADEMIA SINICA

With the collaboration of

LU GWEI-DJEN, PH.D.

FELLOW OF ROBINSON COLLEGE, CAMBRIDGE, ASSOCIATE DIRECTOR OF
THE EAST ASIAN HISTORY OF SCIENCE LIBRARY

VOLUME 5

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PART II: SPAGYRICAL DISCOVERY AND INVENTION: MAGISTERIES OF GOLD AND IMMORTALITY

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To two comrades-in-arms in an age-long struggle,
The use of natural knowledge for peace and love,
Not in the service of hatred and war,

This volume is dedicated:

THANG PHEI-SUNG

Professor of Plant Biochemistry at Chhinghua University, Peking
author of *Green Thraldom*
proponent of food for the world,
—remembering the war-time laboratory among the hills of Tapuchi—

年 年 清 喜

and

J. DESMOND BERNAL

sometime Professor of Crystallography at Birkbeck College, London
author of *Science in History*
and the *Social Function of Science*

Of Loyolan subtlety in Ireland bred
Three enemies of man he re-interpreted;
Saw world, flesh, devil, black-rob'd walk their rounds
And love's two friends advance a banner red.

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LIST OF TABLES

LIST OF ABBREVIATIONS

The following abbreviations are used in the text and footnotes. For abbreviations used for journals and similar publications in the bibliographies, see pp. 306 ff.

B	Bretschneider, E. (1), *Botanicon Sinicum*.
CC	Chia Tsu-Chang & Chia Tsu-Shan (*1*), *Chung-Kuo Chih Wu Thu Chien* (Illustrated Dictionary of Chinese Flora), 1958.
CCIF	Sun Ssu-Mo, *Chhien Chin I Fang* (Supplement to the Thousand Golden Remedies), *c.* +660.
CHS	Pan Ku (and Pan Chao), *Chhien Han Shu* (History of the Former Han Dynasty), *c.* +100.
CLPT	Thang Shen-Wei *et al.* (ed.), *Chêng Lei Pên Tshao* (Reorganised Pharmacopoeia), ed. of +1249.
CSHK	Yen Kho-Chün (ed.), *Chhüan Shang-ku San-Tai Chhin Han San-Kuo Liu Chhao Wên* (Complete Collection of prose literature (including fragments) from remote antiquity through the Chhin and Han Dynasties, the Three Kingdoms, and the Six Dynasties), 1836.
CTPS	Fu Chin-Chhüan (ed.), *Chêng Tao Pi Shu Shih Chung* (Ten Types of Secret Books on the Verification of the Tao), early 19th cent.
HFT	Han Fei, *Han Fei Tzu* (Book of Master Han Fei), early –3rd cent.
HNT	Liu An *et al.*, *Huai Nan Tzu* (Book of the Prince of Huai-Nan), –120.
ICK	Taki Mototane, *I Chi Khao* (*Iseki-kō*) (Comprehensive Annotated Bibliography of Chinese Medical Literature [Lost or Still Existing]), finished *c.* 1825, pr. 1831; repr. Tokyo 1933, Shanghai 1936.
K	Karlgren, *Grammata Serica* (dictionary giving the ancient forms and phonetic values of Chinese characters).
KHTT	Chang Yü-Shu (ed.), *Khang-Hsi Tzu Tien* (Imperial Dictionary of the Khang-Hsi reign-period), +1716.
Kr	Kraus, P. *Le Corpus des Écrits Jābiriens* (*Mémoires de l'Institut d'Égypte* 1943, vol. 44, pp. 1–214).
LPC	Lung Po-Chien (*1*), *Hsien Tshun Pên Tshao Shu Lu* (Bibliographical Study of Extant Pharmacopoeias and Treatises on Natural History from all Periods).
MCPT	Shen Kua, *Mêng Chhi Pi Than* (Dream Pool Essays), +1089.
N	Nanjio, B., *A Catalogue of the Chinese Translations of the Buddhist Tripiṭaka*, with index by Ross (3).
PPT/NP	Ko Hung, *Pao Phu Tzu* (*Nei Phien*) (Book of the Preservation-of-Solidarity Master; Inner Chapters), *c.* +320.
PTKM	Li Shih-Chen, *Pên Tshao Kang Mu* (The Great Pharmacopoeia), +1596.

R Read, Bernard E. *et al.*, Indexes, translations and précis of certain chapters of the *Pên Tshao Kang Mu* of Li Shih-Chen. If the reference is to a plant see Read (1), if to a mammal, see Read (2); if to a bird see Read (3); if to a reptile see Read (4 or 5); if to a mollusc see Read (5); if to a fish see Read (6); if to an insect see Read (7).

RP Read & Pak (1), Index, translation and précis of the mineralogical chapters in the *Pên Tshao Kang Mu*.

SC Ssuma Chhien, *Shih Chi* (Historical Records), *c.* −90.

SF Thao Tsung-I (ed.), *Shuo Fu* (Florilegium of (Unofficial) Literature), *c.* +1368.

SHC *Shan Hai Ching* (Classic of the Mountains and Rivers), Chou and C/Han.

SIC Okanishi Tameto, *Sung I-Chhien I Chi Khao* (Comprehensive Annotated Bibliography of Chinese Medical Literature in and before the Sung Period). Jen-min Wei-shêng, Peking, 1958.

SKCS *Ssu Khu Chhüan Shu* (Complete Library of the Four Categories), +1782; here the reference is to the *tshung-shu* collection printed as a selection from one of the seven imperially commissioned MSS.

SNPTC *Shen Nung Pên Tshao Ching* (Classical Pharmacopoeia of the Heavenly Husbandman), C/Han.

SSIW Toktaga (Tho-Tho) *et al.*; Huang Yü-Chi *et al.* & Hsü Sung *et al.* *Sung Shih I Wên Chih, Pu, Fu Phien* (A Conflation of the Bibliography and Appended Supplementary Bibliographies of the History of the Sung Dynasty). Com. Press, Shanghai, 1957.

TKKW Sung Ying-Hsing, *Thien Kung Khai Wu* (The Exploitation of the Works of Nature), +1637.

TPHMF *Thai-Phing Hui Min Ho Chi Chü Fang* (Standard Formularies of the (Government) Great Peace People's Welfare Pharmacies), +1151.

TPYL Li Fang (ed.), *Thai-Phing Yü Lan* (the Thai-Phing reign-period (Sung) Imperial Encyclopaedia), +983.

TSCC Chhen Mêng-Lei *et al.* (ed.), *Thu Shu Chi Chhêng* (the Imperial Encyclopaedia of +1726). Index by Giles, L. (2).

TSCCIW Liu Hsü *et al.* & Ouyang Hsiu *et al.*; *Thang Shu Ching Chi I Wên Ho Chih*. A conflation of the Bibliographies of the *Chiu Thang Shu* by Liu Hsü (H/Chin, +945) and the *Hsin Thang Shu* by Ouyang Hsiu & Sung Chhi (Sung, +1061). Com. Press, Shanghai, 1956.

TT Wieger, L. (6), *Taoïsme*, vol. 1, Bibliographie Générale (catalogue of the works contained in the Taoist Patrology, *Tao Tsang*).

TTCY Ho Lung-Hsiang & Phêng Han-Jan (ed.). *Tao Tsang Chi Yao* (Essentials of the Taoist Patrology), pr. 1906.

TW Takakusu, J. & Watanabe, K., *Tables du Taishō Issaikyō* (nouvelle édition (Japonaise) du Canon bouddhique chinoise), Index-catalogue of the Tripiṭaka.

WCTY/CC Tsêng Kung-Liang (ed.), *Wu Ching Tsung Yao* (*Chhien Chi*), military encyclopaedia, first section, +1044.

YCCC Chang Chün-Fang (ed.), *Yün Chi Chhi Chhien* (Seven Bamboo Tablets of the Cloudy Satchel), Taoist collection, +1022.

YHL Thao Hung-Ching (attrib.), *Yao Hsing Lun* (Discourse on the Natures and Properties of Drugs).

YHSF Ma Kuo-Han (ed.), *Yü Han Shan Fang Chi I Shu* (Jade-Box Mountain Studio collection of (reconstituted and sometimes fragmentary) Lost Books), 1853.

ACKNOWLEDGEMENTS

List of those who have kindly read through Sections in Draft

The following list, which applies only to Vol. 5, pts 2–5, brings up to date those printed in Vol. 1, pp. 15ff., Vol. 2, p. xxiii, Vol. 3, pp. xxxixff., Vol. 4, pt. 1, p. xxi, Vol. 4, pt. 2, p. xli and Vol. 4, pt. 3, pp. xliiiff.

Prof. Derk Bodde (Philadelphia)	Introductions.
Mr J. Charles (Cambridge)	Metallurgical chemistry.
Prof. A. G. Debus (Chicago)	Modern chemistry (Mao Hua).
Prof. A. F. P. Hulsewé (Leiden)	Theories.
Dr Edith Jachimowicz (London)	Comparative (Arabic).
Mr S. W. K. Morgan (Bristol)	Metallurgy (zinc and brass).
Prof. Ladislao Reti (Milan)	Apparatus (alcohol).
Dr Kristofer M. Schipper (Paris)	Theories.
Prof. R. B. Serjeant (Cambridge)	Comparative (Arabic).
Mr H. J. Sheppard (Warwick)	Introductions.
Prof. Cyril Stanley Smith (Cambridge, Mass.)	Metallurgy, and Theories.
Mr Robert Somers (New Haven, Conn.)	Theories.
Dr Michel Strickmann (Kyoto)	Theories.
Dr Mikuláš Teich (Cambridge)	Introductions.
Mr R. G. Wasson (Danbury, Conn.)	Introduction (ethno-mycology).
Mr James Zimmerman (New Haven, Conn.)	Theories.

AUTHOR'S NOTE

IT is now nearly a dozen years since the preface for Vol. 4 of this series (Physics and Physical Technology) was written; since then much has been done towards the later volumes. We are now happy to be able to present a substantial part of Vol. 5 (Spagyrical Discovery and Invention), i.e. alchemy and early chemistry, which go together with the arts of peace and war, including military and textile technology, mining, metallurgy and ceramics. The point of this arrangement was explained in the preface of Vol. 4 (e.g. pt. 3, p. l). Exigences not of logic but of collaboration are making it obligatory that these other topics should follow rather than precede the central theme of chemistry, which here is published as Vol. 5, parts 2, 3, 4 and 5, leaving parts 1 and 6 to appear at a later date.

The number of physical volumes (parts) which we are now producing may give the impression that our work is enlarging according to some form of geometrical progression or along some exponential curve, but this would be largely an illusion, because in response to the reactions of many friends we are now making a real effort to publish in books of less thickness, more convenient for reading. At the same time it is true that over the years the space required for handling the history of the diverse sciences in Chinese culture has proved singularly unpredictable. One could (and did) at the outset arrange the sciences in a logical spectrum (mathematics—astronomy—geology and mineralogy —physics—chemistry—biology) leaving estimated room also for all the technologies associated with them; but to foresee exactly how much space each one would claim, that, in the words of the Jacobite blessing, was 'quite another thing'. We ourselves are aware that the disproportionate size of some of our Sections may give a mis-shapen impression to minds enamoured of classical uniformity, but our material is not easy to 'shape', perhaps not capable of it, and appropriately enough we are constrained to follow the Taoist natural irregularity and surprises of a romantic garden rather than to attempt any compression of our lush growths within the geometrical confines of a Cartesian parterre. The Taoists would have agreed with Richard Baxter that ''tis better to go to heaven disorderly than to be damned in due order'. By some strange chance our spectrum meant (though I thought at the time that the mathematics was particularly difficult) that the 'easier' sciences were going to come first, those where both the basic ideas and the available source-materials were relatively clear and precise. As we proceeded, two phenomena manifested themselves: first, the technological achievements and amplifications proved far more formidable than expected (as was the case in Vol. 4, pts. 2 and 3); and secondly, we found ourselves getting into ever deeper water, as the saying is, intellectually (as will fully appear in the Sections on medicine in Vol. 6).

Alchemy and early chemistry, the central subjects of the present volume, exemplified the second of these difficulties well enough, but they have had others of their own. At one time I almost despaired of ever finding our way successfully through the inchoate

mass of ideas, and the facts so hard to establish, relating to alchemy, chemistry, metallurgy and chemical industry in ancient, medieval and traditional China. The facts indeed were much more difficult to ascertain, and also more perplexing to interpret, than anything encountered in subjects such as astronomy or civil engineering. And in the end, one must say, we did not get through without cutting great swathes of briars and bracken, as it were, through the muddled thinking and confused terminology of the traditional history of alchemy and early chemistry in the West. Here it was indispensable to distinguish alchemy from proto-chemistry and to introduce words of art such as aurifiction, aurifaction and macrobiotics. It is also fair to say that the present subject has been far less well studied and understood either by Westerners or Chinese scholars themselves than fields like astronomy and mathematics, where already in the eighteenth century a Gaubil could do outstanding work, and nearer our own time a Chhen Tsun-Kuei, a de Saussure, and a Mikami Yoshio could set them largely in order. If the study of alchemy and early chemistry had advanced anything like so far, it would be much easier today than it actually is to differentiate with clarity between the many divergent schools of alchemists at the many periods, from the −3rd century to the +17th, with which we have to deal. More adequate understanding would also have been achieved with regard to that crucial Chinese distinction between inorganic laboratory alchemy and physiological alchemy, the former concerned with elixir preparations of mineral origin, the latter rather with operations within the adept's own body; a distinction hardly realised to the full in the West before the just passed decade. As we shall show in these volumes, there was a synthesis of these two age-old trends when in iatro-chemistry from the Sung onwards laboratory methods were applied to physiological substances, producing what we can only call a proto-biochemistry. But this will be read in its place.

Now a few words on our group of collaborators. Dr Ho Ping-Yü,[1] since 1961 Professor of Chinese at the University of Malaya, Kuala Lumpur, was introduced to readers in Vol. 4, pt. 3, p. lv; here he has been responsible for drafting the major part of the sub-section on the history of alchemy in China. Dr Lu Gwei-Djen,[2] my oldest collaborator, dating (in historian's terms) from 1937, has been involved at all stages of the present volumes, especially in that seemingly endless mental toil of ours which resulted in the introductory sub-sections on concepts, definitions and terminology, with all that that implies for theories of alchemy, ideas of immortality, and the physiological pathology of the elixir complex. But her particular domain has been that of physiological alchemy, and it was her discoveries, just at the right moment, of what was meant by the three primary vitalities, mutationist inversion, counter-current flow, and such abstruse matters, which alone permitted the unravelling, at least in the provisional form here presented (in the relevant sub-section *j*), of that strange and unfamiliar system, quasi-Yogistic perhaps, but full of interest for the pre-history of biochemical thought.[a] A third collaborator is now to be welcomed for the first time,

[a] Some of her findings have appeared separately (Lu Gwei-Djen, 2).

[1] 何丙郁 [2] 魯桂珍

Dr Nathan Sivin, Professor at the Massachusetts Institute of Technology, who has contributed the sub-section on the general theory of elixir alchemy.

Although Prof. Sivin has helped the whole group much by reading over and suggesting emendations for all the rest, it is needful to make at this point a proviso which has not been required in previous volumes. This is that my collaborators cannot take a collective responsibility for statements, translations or even general nuances, occurring in parts of the book other than that or those in which they each themselves directly collaborated. All incoherences and contradictions which remain after our long discussions must be laid at my door, in answer to which I can only say that the state of the art is as yet very imperfect, that it will certainly be improved by later scholars, and that in the meantime we have done the best we can. If fate had granted to the four of us the possibility of all working together in one place for half-a-dozen years, things could have been rather different, but in fact Prof. Ho and Prof. Sivin were never even in Cambridge at one and the same time. Thus these volumes have come into existence the hard way, drafted by different hands at fairly long intervals of time, and still no doubt containing traces of various levels of sophistication of understanding. Indeed it would have been reasonable to mark the elixir theory sub-section 'by Nathan Sivin', rather than 'with Nathan Sivin', if it had not been for the fact that some minor embroideries were offered by me, and that a certain part of it, not perhaps the least interesting, is a revised version of a memoir by Ho Ping-Yü and myself first published in 1959. Lacking the unities of time and place, complete credal unity, as it were, has been unattainable, but that does not mean that we are not broadly at one over the main facts and problems of the field as a whole; so that rightly we may be called co-workers.

Besides this I am eager to make certain further acknowledgements. During the second world war I was instrumental in securing for Cambridge copies of the *Tao Tsang* and the *Tao Tsang Chi Yao*. At a somewhat later time (1951–5) Dr Tshao Thien-Chhin,[1] then a Fellow of Caius, made a most valuable pioneer study of the alchemical books in the Taoist Patrology, using a microfilm set in our working collection (now the East Asian History of Science Library, an educational Trust). After his return to the Biochemical Institute of Academia Sinica, Shanghai, of which he has been in recent years Vice-Director, these notes were of great help to Dr Ho and myself, forming the ultimate basis for another sub-section, that on aqueous reactions. Secondly, when we were faced with the fascinating but difficult study of the evolution of chemical apparatus in East and West, Dr Dorothy Needham put in a considerable amount of work, including some drafting, in what happened to be a convenient interval in work on her own book on the history of muscle biochemistry, *Machina Carnis*. She has also read all our pages—perhaps the only person in the world who ever does so!

While readers of sub-sections in typescript and proof have not been as numerous, perhaps, as for previous volumes, a special debt of gratitude is due to Mr J. A. Charles of St John's College, chemist, metallurgist and archaeologist, whose advice to Prof. Ho and myself from the earliest days has been extremely precious. Valuable consultations

[1] 曹天欽

also took place with Mr H. J. Sheppard of Warwick, especially during his time in Cambridge as a Schoolmaster-Fellow of Churchill College. Few chemists in Cambridge, by some chance, happen to be interested at the present time in the history of their subject, but if Dr A. J. Berry and Prof. J. R. Partington had lived we could have profited greatly from their help. With the latter, indeed, we did have fruitful and most friendly contact, but it was in connection mainly with the gunpowder epic, Prof. Wang Ling[1] and I endeavouring, not unsuccessfully, to convince him of the real and major contribution of China in that field; those were days however before any word of the present volume had been written. In 1968, well after it had started, there was convened the First Conference of Taoist Studies at the Villa Serbelloni at Bellagio on Lake Como; Ho Ping-Yü, Nathan Sivin and myself were all of the party, and here much stimulus was obtained from that remarkable *Tao shih* Kristofer Schipper—hence the unexpected sub-section on liturgiology and alchemical origins in our introductory material. In addition to the invaluable advice of many other colleagues in special areas, Dr N. Sivin desires us to note the kindness of Prof. Cyril Stanley Smith in commenting upon the whole sub-section on the theory of elixir alchemy. He also expresses his gratitude to Prof. A. F. P. Hulsewé and his staff for the open-hearted hospitality which they gave him during the gestation of that study, carried out almost entirely at the Sinologisch Instituut, Leiden.

It is right to record that certain parts of these volumes have been given as lectures to bodies honouring us by such invitations. Thus various excerpts from the introductory sub-sections, on concepts, terminology and definitions, were given for the Rapkine Lecture at the Pasteur Institute in Paris (1970) and the Bernal Lecture at Birkbeck College in London in the following year. Portions of the historical sub-sections, especially that on the coming of modern chemistry, were used for the Ballard Matthews Lectures of the University of Wales at Bangor. A considerable part of the physiological alchemy material formed the basis of the Fremantle Lectures at Balliol College, Oxford,[a] and had been given more briefly as the Harvey Lecture to the Harveian Society of London the year before.

If there is one question more than any other raised by this present Section 33 on alchemy and early chemistry, now offered to the republic of learning in these volumes, it is that of human unity and continuity. In the light of what is here set forth, can we allow ourselves to visualise that some day before long we shall be able to write the history of man's enquiry into chemical phenomena as one single development throughout the Old World cultures? Granted that there were several different foci of ancient metallurgy and primitive chemical industry, how far was the gradual flowering of alchemy and chemistry a single endeavour, running contagiously from one civilisation to another?

It is a commonplace of thought that some forms of human experience seem to have progressed in a more obvious and palpable way than others. It might be difficult to

[a] The relevant volume is therefore offered to the Trustees of the late Sir Francis Fremantle's benefaction in discharge of the duty of publication of his Lectures (1971).

[1] 王鈴

say how Michael Angelo could be considered an improvement on Pheidias, or Dante on Homer, but it can hardly be questioned that Newton and Pasteur and Einstein did really know a great deal more about the natural universe than Aristotle or Chang Hêng. This must tell us something about the differences between art and religion on one side and science on the other, though no one seems able to explain quite what, but in any case within the field of natural knowledge we cannot but recognise an evolutionary development, a real progress, over the ages. The cultures might be many, the languages diverse, but they all partook of the same quest.

Throughout this series of volumes it has been assumed all along that there is only one unitary science of Nature, approached more or less closely, built up more or less successfully and continuously, by various groups of mankind from time to time. This means that one can expect to trace an absolute continuity between the first beginnings of astronomy and medicine in Ancient Babylonia, through the advancing natural knowledge of medieval China, India, Islam and the classical Western world, to the break-through of late Renaissance Europe when, as has been said, the most effective method of discovery was itself discovered. Many people probably share this point of view, but there is another one which I may associate with the name of Oswald Spengler, the German world-historian of the thirties whose works, especially *The Decline of the West* (1), achieved much popularity for a time. According to him, the sciences produced by different civilisations were like separate and irreconcilable works of art, valid only within their own frames of reference, and not subsumable into a single history and a single ever-growing structure.

Anyone who has felt the influence of Spengler retains, I think, some respect for the picture he drew of the rise and fall of particular civilisations and cultures, resembling the birth, flourishing and decay of individual biological organisms, in human or animal life-cycles. Certainly I could not refuse all sympathy for a point of view so like that of the Taoist philosophers, who always emphasised the cycles of life and death in Nature, a point of view that Chuang Chou himself might well have shared. Yet while one can easily see that artistic styles and expressions, religious ceremonies and doctrines, or different kinds of music, have tended to be incommensurable; for mathematics, science and technology the case is altered—man has always lived in an environment essentially constant in its properties, and his knowledge of it, if true, must therefore tend towards a constant structure.

This point would not perhaps need emphasis if certain scholars, in their anxiety to do justice to the differences between the ancient Egyptian or the medieval Chinese, Arabic or Indian world-views and our own, were not sometimes tempted to follow lines of thought which might lead to Spenglerian pessimism.[a] Pessimism I say, because

[a] Just recently a relevant polemical discussion has been going on among geologists. Harrington (1, 2), who had traced interesting geological insights in Herodotus and Isaiah, was taken to task by Gould (1), maintaining that 'science is no march to truth, but a series of conceptual schemes each adapted to a prevailing culture', and that progress consists in the mutation of these schemes, new concepts of creative thinkers resolving anomalies of old theories into new systems of belief. This was evidently a Kuhnian approach, but no such formulation will adequately account for the gradual percolation of true knowledge through the successive civilisations, and its general accumulation. Harrington himself, in his reply (3), maintained that 'there is a singular state of Nature towards which all estimates of reality

of course he did prophesy the decline and fall of modern scientific civilisation. For example, our own collaborator, Nathan Sivin, has often pointed out, quite rightly, that for medieval and traditional China 'biology' was not a separated and defined science. One gets its ideas and facts from philosophical writings, books on pharmaceutical natural history, treatises on agriculture and horticulture, monographs on groups of natural objects, miscellaneous memoranda and so on. He urged that to speak without reservations of 'Chinese biology' would be to imply a structure which historically did not exist, disregarding mental patterns which did exist. Taking such artificial rubrics too seriously would also imply the natural but perhaps erroneous assumption that medieval Chinese scientists were asking the same questions about the living world as their modern counterparts in the West, and merely chanced, through some quirk of national character, language, economics, scientific method or social structure, to find different answers. On this approach it would not occur to one to investigate what questions the ancient and medieval Chinese scientists themselves were under the impression that they were asking. A fruitful comparative history of science would have to be founded not on the counting up of isolated discoveries, insights or skills meaningful for us now, but upon 'the confrontation of integral complexes of ideas with their interrelations and articulations intact'. These complexes could be kept in one piece only if the problems which they were meant to solve were understood. Chinese science must, in other words, be seen as developing out of one state of theoretical understanding into another, rather than as any kind of abortive development towards modern science.

All this was well put; of course one must not see in traditional Chinese science simply a 'failed prototype' of modern science, but the formulation here has surely to be extremely careful. There is a danger to be guarded against, the danger of falling into the other extreme, and of denying the fundamental continuity and universality of all science. This could be to resurrect the Spenglerian conception of the natural sciences of the various dead (or even worse, the living) non-European civilisations as totally separate, immiscible thought-patterns, more like distinct works of art than anything else, a series of different views of the natural world irreconcilable and unconnected. Such a view might be used as the cloak of some historical racialist doctrine, the sciences of pre-modern times and the non-European cultures being thought of as wholly conditioned ethnically, and rigidly confined to their own spheres, not part of humanity's broad onward march. Moreover, it would leave little room for those actions and reactions that we are constantly encountering, deep-seated influences which one civilisation had upon another.

In a different place Nathan Sivin has written: 'The question of why China never spontaneously experienced the equivalent of our scientific revolution lies of course very close to the core of a comparative history of science. My point is that it is an utter

converge', and therefore that we can and should judge the insights of the ancients on the basis of our own knowledge of Nature, while at the same time making every effort to understand their intellectual framework. In illustration he took the medieval Chinese appreciation of the meaning of fossil remains (cf. Vol. 3, pp. 611 ff.). We are indebted to Prof. Claude Albritton of Texas for bringing this discussion to our notice.

waste of time, and distracting as well, to expect any answer until the Chinese tradition has been adequately comprehended from the inside.' The matter could not be better put; we must of course learn to see instinctively through the eyes of those who thought in terms of the Yin and Yang, the Five Elements, the symbolic correlations, and the trigrams and hexagrams of the *Book of Changes*. But here again this formulation might suggest a purely internalist or ideological explanation for the failure of modern natural science to arise in Chinese culture. I don't think that in the last resort we shall be able to appeal primarily to inhibiting factors inherent in the Chinese thought-world considered as an isolated Spenglerian cell. One must always expect that some of these intellectual limiting factors will be identifiable, but for my part I remain sceptical that there are many factors of this kind which could not have been overcome if the social and economic conditions had been favourable for the development of modern science in China. It may indeed be true that the modern forms of science which would then have developed would have been rather different from those which actually did develop in the West, or in a different order, that one cannot know. There was, for example, the lack of Euclidean geometry and Ptolemaic planetary astronomy in China, but China had done all the ground-work in the study of magnetic phenomena, an essential precursor of later electrical science;[a] and Chinese culture was permeated by conceptions much more organic, less mechanistic, than that of the West.[b] Moreover Chinese culture alone, as we shall see, perhaps, provided that materialist conception of the elixir of life which, passing to Europe through the Arabs, led to the macrobiotic optimism of Roger Bacon and the iatro-chemical revolution of Paracelsus, hardly less important in the origins of modern science than the work of Galileo and Newton. Whatever the ideological inhibiting factors in the Chinese thought-world may turn out to have been, the certainty always remains that the specific social and economic features of traditional China were connected with them. They were clearly part of that particular pattern, and in these matters one always has to think in terms of a 'package-deal'. In just the same way, of course, it is impossible to separate the scientific achievements of the ancient Greeks from the fact that they developed in mercantile, maritime, city-state democracies.

To sum it up, the failure of China to give rise to distinctively modern science while having been in many ways ahead of Europe for some fourteen previous centuries is going to take some explaining.[c] Internalist historiography is likely to encounter grave difficulties here, in my opinion, because the intellectual, philosophical, theological and cultural systems of ideas of the Asian civilisations are not going to be able to take the causal stress and strain required. Some of these idea-systems, in fact, such as Taoism and Neo-Confucianism, would seem to have been much more congruent with modern science than any of the European ones were, including Christian theology. Very likely the ultimate explanations will turn out to be highly paradoxical—aristocratic military feudalism seeming to be much stronger than bureaucratic feudalism but actually

[a] See our discussions in Vol. 3 and Vol. 4, pt. 1. [b] This was emphasised in Vol. 2, *passim*.
[c] We set forth in a preliminary way what is at issue here in Vol. 3, pp. 150ff. Some 'thinking aloud' done at various times has also been assembled in Needham (65).

weaker because less rational—the monotheism of a personal creator God being able to generate modern scientific thought (as the San Chiao could never do) but not to give it an inspiration enduring into modern times—and so on. We do not yet know.

A similar problem has of late been worrying Said Husain Nasr, the Persian scholar who is making valuable contributions to the history of science in Islam. He, for his part, faces the failure of Arabic civilisation to produce modern science. But far from regretting this he makes a positive virtue of it, rejecting belief in any integral, social-evolutionary development of science. Opening one of his recent books we read as follows:[a]

> The history of science is often regarded today as the progressive accumulation of techniques and the refinement of quantitative methods in the study of Nature. Such a point of view considers the present conception of science to be the only valid one; it therefore judges the sciences of other civilisations in the light of modern science, and evaluates them primarily with respect to their 'development' with the passage of time. Our aim in this work however, is not to examine the Islamic sciences from the point of view of modern science and of this 'evolutionist' conception of history; it is on the contrary to present certain aspects of the Islamic sciences as seen from the Islamic point of view.

Now Nasr considers that the Sufis and the universal philosophers of medieval Islam sought and found a kind of mystical *gnosis*, or cosmic *sapientia*, in which all the sciences 'knew their place', as it were (like servitors in some great house of old), and ministered to mystical theology as the highest form of human experience. In Islam, then, the philosophy of divinity was indeed the *regina scientiarum*. Anyone with some appreciation of theology as well as science cannot help sympathising to some extent with this point of view, but it does have two fatal drawbacks: it denies the equality of the forms of human experience, and it divorces Islamic natural science from the grand onward-going movement of the natural science of all humanity. Nasr objects to judging medieval science by its outward 'usefulness' alone. He writes:[b] 'However important its uses may have been in calendrical computation, in irrigation or in architecture, its ultimate aim always was to relate the corporeal world to its basic spiritual principle through the knowledge of those symbols which unite the various orders of reality. It can only be understood, and should only be judged, in terms of its own aims and its own perspectives.' I would demur. It was part, I should want to maintain, of all human scientific enterprise, in which there is neither Greek nor Jew, neither Hindu nor Han. 'Parthians, Medes and Elamites, and the dwellers in Mesopotamia, and in Judaea and Cappadocia, in Pontus and Asia. . . and the parts of Libya about Cyrene. . . we do hear them speak in our tongues the marvellous works of God.'[c]

The denial of the equality of the forms of human experience comes out clearly in another work of Said Husain Nasr (2). Perhaps rather under-estimating the traditional high valuation placed within Christendom upon Nature—'that universal and publick manuscript', as Sir Thomas Browne said,[d] 'which lies expans'd unto the eyes of all'—

[a] (1), p. 21.
[b] (1), pp. 39–40.
[c] Acts 2. 1.
[d] *Religio Medici* I, xvi. 'Thus there are two Books from whence I collect my Divinity; besides that written one of God, another of his servant Nature. . . .'

he sees in the scientific revolution at the Renaissance a fundamental desacralisation of Nature, and urges that only by re-consecrating it, as it were, in the interests of an essentially religious world-view, will mankind be enabled to save itself from otherwise inevitable doom. If the rise of modern science within the bosom of Christendom alone had any causal connections with Christian thought that would give it a bad mark in his view. 'The main reason why modern science never arose in China or Islam', he says,[a]

> is precisely because of the presence of a metaphysical doctrine and a traditional religious structure which refused to make a profane thing of Nature. . . . Neither in Islam, nor India nor the Far East, was the substance and the stuff of Nature so depleted of a sacramental and spiritual character, nor was the intellectual dimension of these traditions so enfeebled, as to enable a purely secular science of Nature and a secular philosophy to develop outside the matrix of the traditional intellectual orthodoxy. . . . The fact that modern science did not develop in Islam is not a sign of decadence [or incapacity] as some have claimed, but of the refusal of Islam to consider any form of knowledge as purely secular, and divorced from what it conceived to be the ultimate goal of human existence.

These are striking words,[b] but are they not tantamount to saying that only in Europe did the clear differentiation of the forms of experience arise? In other terms, Nasr looks for the synthesis of the forms of experience in the re-creation of a medieval world-view, dominated by religion,[c] not in the existential activity of individual human beings dominated by ethics. That would be going back, and there is no going back. The scientist must work *as if* Nature was 'profane'. As Giorgio di Santillana has said:[d]

> Copernicus and Kepler believed in cosmic vision as much as any Muslim ever did, but when they had to face the 'moment of truth' they chose a road which was apparently not that of *sapientia*; they felt they had to state what appeared to be the case, and that on the whole it would be more respectful of divine wisdom to act thus.

And perhaps it is a sign of the weakness of what can only be called so conservative a conception that Nasr is driven to reject the whole of evolutionary fact and theory, both cosmic, biological and sociological.

In meditating on the view of modern physical science as a 'desacralisation of Nature' many ideas and possibilities come to mind, but one very obvious cause for surprise is that it occurred in Christendom, the home of a religion in which an incarnation had sanctified the material world, while it did not occur in Islam, a culture which had never developed a soteriological doctrine.[e] This circumstance might offer an

[a] (2), p. 97.

[b] Views such as this are by no means restricted to Muslim scholars. From within the bosom of Christendom a very similar attitude is to be found in the book on alchemy by Titus Burckhardt (1), cf. esp. pp. 66, 203.

[c] It seems very strange to us that he should regard Chinese culture as having been dominated by religion at any time.

[d] In his preface to Said Husain Nasr (1), p. xii.

[e] This point was made by the Rev. D. Cupitt in discussion following a lecture for the Cambridge Divinity Faculty (1970) in which some of these paragraphs were used. It was afterwards published in part (Needham, 68). The contrast may be to some extent a matter of degree, since Islamic philosophy tended to recognise the material world as an emanation of the divine.

argument in favour of the primacy of social and economic factors in the break-through of the scientific revolution. It may be that while ideological, philosophical and theological differences are never to be undervalued, what mattered most of all were the facilitating pressures of the transition from feudalism to mercantile and then industrial capitalism, pressures which did not effectively operate in any culture other than that of Western, Frankish, Europe.

In another place Nasr wonders what Ibn al-Haitham or al-Bīrūnī or al-Khāzinī would have thought about modern science. He concludes that they would be amazed at the position which exact quantitative knowledge has come to occupy today. They would not understand it because for them all *scientia* was subordinated to *sapientia*. Their quantitative science was only one interpretation of a segment of Nature, not the means of understanding all of it. '"Progressive" science', he says,[a] 'which in the Islamic world always remained secondary, has now in the West become nearly everything, while the immutable and "non-progressive" science or wisdom which was then primary, has now been reduced to almost nothing.' It happened that I read these words at a terrible moment in history. If there were any weight in the criticism of the modern scientific world-view from the standpoint of Nasr's perennial Muslim *sapientia* it would surely be that modern science and the technology which it has generated have far outstripped morality in the Western and modern world, and we shudder to think that man may not be able to control it. Probably none of the human societies of the past ever were able to control technology, but they were not faced by the devastating possibilities of today, and the moment I read Nasr's words was just after the Jordanian civil war of September 1970, that dreadful fratricidal catastrophe within the bosom of Islam itself. Since then we have had the further shocking example of Bengali Muslims being massacred by their brothers in religion from the Indus Valley. *Sapientia* did not prevent these things, nor would it seem, from the historical point of view, that wars and cruelties of all kinds have been much less within the realms of Islam or of East Asia than that of Christendom. Modern science, at all events, is not guilty as such of worsening men's lot, on the contrary it has immensely ameliorated it, and everything depends on what use humanity will make of these unimaginable powers for good or evil. Something new is needed to make the world safe for mankind; and I believe that it can and will be found.

In later discussions Nathan Sivin has made it clear that he is just as committed to a universal comparative history of science as any of the rest of us. That would be the ultimate justification of all our work. His point is not that the Chinese (or Indian, or Arabic) tradition should be evaluated only in the light of its own world-view, then being left as a kind of museum set-piece, but that it must be understood as fully as possible in the light of this as a prelude to the making of wide-ranging comparisons. The really informative contrasts, he suggests, are not those between isolated discoveries, but between those whole systems of thought which have served as the matrices of discovery.[b] One might therefore agree that not only particular individual anticipations of modern scientific discoveries are of interest as showing the slow

[a] (1), p. 145.

[b] Cf. Sivin (10).

development of human natural knowledge, but also that we need to work out exactly how the world-views and scientific philosophies of medieval China, Islam or India differed from those of modern science, and from each other. Each traditional system is clearly of great interest not only in itself but in relation to our present-day patterns of ideas. In this way we would not only salute the Chinese recording of sun-spots from the − 1st century,[a] or the earliest mention of the flame test for potassium salts by Thao Hung-Ching in the + 5th century, or the first correct explanation of the optics of the rainbow by Quṭb al-Dīn al-Shīrāzī in + 1300,[b] as distinct steps on the way to modern science, but also take care to examine the integral systems of thought and practice which generated these innovations. Modern science was their common end, but their evolution can only be explained (that is to say, causally accounted for) in the context of the various possibilities opened and closed by the totality of ideas, values and social attitudes of their time.

Section 33(*h*), on the theoretical background of proto-chemical alchemy, may be taken as an exemplification and a test of this way of looking at early science.[c] Nathan Sivin's contribution deals with an abstract approach to Nature which has little to do with post-Galilean physical thought. Looking at the aims of the theoretically-minded alchemists as expressed in their own words, they turn out to be concerned with the design and construction of elaborate chemical models of the cyclic Tao of the cosmos which governs all natural change. A multitude of correspondences and resonances inspire the design of these models. One can distinguish as elements in their rationale the archaic belief in the maturation of minerals within the earth, the complex role of time, and the subtle interplay of quantity and numerology in ensuring that the elaboratory would be a microcosmos. Once we have reached at least a rough comprehension of the system which unites these elements, we can apprehend the remarkable culmination envisaged by the Chinese alchemists: to telescope time by reducing the grand overriding cycles of the universe to a compass which would allow of their contemplation by the adept—leading, as we have phrased it, to perfect freedom in perfect fusion with the cosmic order. But in the course of our reconnaissance we gather a rich harvest of ideas worth exploring and comparing with those of other cultures, including those of the modern world—for instance, the notion of alchemy as a quintessentially temporal science, springing from a unique concept of material immortality, a sublime conviction of the possibility of the control of change and decay. And we make a beginning towards understanding how the alchemist's concepts determined the details—the symmetries and innovations of materials, apparatus, and exquisitely phased combustions—of his Work, and how new results were reflected in new theoretical refinements as the centuries passed.

It is no less important to be aware that every anticipatory feature of a pre-modern system of science had its Yin as well as its Yang side, disadvantages as well as advantages. Thus the polar-equatorial system of Chinese astronomy delayed Yü Hsi's recognition of the precession of the equinoxes by six centuries after Hipparchus, but

[a] Cf. Vol. 3, p. 435. [b] Cf. Vol. 3, p. 474.
[c] Another attempt at this approach, applied to mathematical astronomy, will be found in Sivin (9).