THE SHORTER SCIENCE & CIVILISATION IN CHINA: 1

An abridgement by Colin A. Ronan of
Joseph Needham's original text

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The Shorter Science and Civilisation in China

AN ABRIDGEMENT OF
JOSEPH NEEDHAM'S ORIGINAL TEXT

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1

Introduction

Today the history of science is becoming recognised as an integral part of the whole history of human civilisation; an essential ingredient in the development of human culture. Tracing its growth has occupied a host of scholars who, almost without exception, have worked backward from the science and technology of today to its cradle in the thought and practice of Mediterranean antiquity. They have uncovered an evolution starting from the Sumerians, Babylonians and Egyptians, an evolution that led to the growth of scientific thought and observation of the natural world among the Greeks and in the Roman Empire. From here they have tracked its transmission to mediaeval Europe by way of Islam, and seen how its arrival led to the revolutionary changes that occurred in the wake of the Renaissance.

To a great extent, all this is something new. A century and a half ago, the scientific contributions of the Sumerians and Babylonians, for instance, were quite unsuspected. In 1837, when William Whewell wrote his memorable *History of the Inductive Sciences*, he could display a bland unconsciousness of any contributions by other civilisations to the scientific culture of the modern West, and do so without criticism. Yet now the situation is somewhat different; not only are the Babylonians and Sumerians recognised, but there is also some appreciation of the legacy we owe to India. All the same, there is still one vast gap in our understanding of our debts to other civilisations – the contribution from Asia, and especially the northernmost of its two oldest civilisations, the Chinese. This scientific heritage is the theme of this book.

Precisely what the Chinese contributed to science and technology as well as to scientific thought depended, as will become clear, on the historical period being considered. In ancient and mediaeval times it was of immense importance, but its character changed after the visit of Jesuit missionaries to Peking early in the seventeenth century, and it gradually fused into the universal science that has continuously

developed over the last three hundred years. Before the Jesuit arrival Chinese science was quasi-empirical – based on observation and experience, with theory in a comparatively undeveloped state. Yet, even so, the Chinese succeeded in anticipating many scientific and technical discoveries of the Greeks; they managed to keep pace with the Arabs who had all Greek knowledge at their disposal; and between the first and thirteenth centuries A.D. reached a level of scientific knowledge unapproached in the West.

To those of us brought up in a culture which has the classical world as its foundation, the Chinese achievement may well seem nothing less than astonishing. Certainly there was no rise of modern science in sixteenth-century China as occurred in Europe from this time onwards, while it is also true that the Chinese suffered from a weakness in theoretical ideas and a lack of deductive geometry – the very essence of precision in Greek science. Yet in spite of all this we see in ancient China a society more amenable to the application of science than was the case in Greece, in Rome, or even in mediaeval Europe. What is more, in China there developed an organic philosophy of Nature that closely resembles that which modern science has been obliged to adopt after three centuries of scientific materialism. How this could be under the circumstances is one of the questions that will be discussed.

To appreciate what the Chinese accomplished can be difficult, even today, because unfortunately many misconceptions about Chinese discoveries and scientific development still exist. The old legendary chronology relayed by the seventeenth-century Jesuits lives on, with the result that either too much or too little is ascribed to East Asian origin, and Chinese as well as Western scholars have sometimes been known to ignore, or at least pay scant attention to, achievements made early on in China. Frequently, too, legends themselves are unrecognised as such, with the result that worthwhile evidence is glossed over. Nevertheless, most Europeans are at least dimly aware of a vast and complex civilisation no less intricate and rich than their own, at the other end of the huge Euro-Asian land mass. The main barrier to a more intimate understanding, especially when it comes to Chinese science and technology, has been the Chinese use of ideographic characters. Inevitably most sinologists have been of literary tastes and training and, in consequence, there is a vast amount of scattered literature that has hardly been surveyed, let alone studied in detail.

In one sense, then, this book can be no more than a reconnaissance, and a brief reconnaissance at that, but at least it is based on a detailed approach to some sources made by Joseph Needham and his collaborators. Uniquely qualified as a research scientist and historian of science familiar with the country and its language, and in contact with many

Chinese scientists and scholars, he has been able to study the original Chinese texts from which translations have been made as well as those for which no translations have so far been available. This has enabled him to correct mis-translations and misconceptions. For example, in the only complete translation of the important *Mo Tzu* (Book of Master Mo Ti) from the fourth century B.C., there is a reference to textile manufacture. The accepted translation runs: 'Women work at variegated embroidery: men work at the weaving of stuffs with inserted patterns.' Taken at its face value this looks like a reference to the drawloom; only a careful study of the text shows that nothing is said of inwoven figured patterns. The author is, in fact, referring to 'cut and engraved' work; in other words to a kind of brocade made by stitching coloured threads into an already woven fabric. Thus the drawloom is not concerned and one cannot, therefore, claim evidence for its invention in the fourth century B.C. on this ground. But other evidence does date back some form of it to that time. Plenty of other examples could be quoted but this alone may serve to underline the dangers that face anyone unfamiliar either with the language or with the techniques involved.

Here it should be emphasised that although ninety per cent of the work as published has been written by Joseph Needham, the project, he tells me, would have been absolutely impossible without the partnership of a number of colleagues. From 1948 to 1958 his chief collaborator was Wang Ching-Ning (Wang Ling), now professor at Canberra in Australia, a historian and mathematician; and since 1958 an even older friend, Lu Gwei-Djen, a specialist on the history of medicine and biology. Several other Chinese scholars have also collaborated, notably Ho Ping-Yü of Brisbane, historian of astronomy, alchemy and early chemistry, Lo Jung-Pang in California who contributes, for instance, the chapter on the salt industry and the epic of deep borehole drilling, Chhien Tshun-Hsün at Chicago, one of the best authorities in the world on the history of paper and printing, and Li Li-Shêng, studying the traditional chemical industries. As time has gone on it has been necessary to enlarge more and more the circle, so that textile technology, for example, is now in the charge of Ohta Eizō in Kyoto, and ceramics undertaken by Chhü Chih-Jen in Hong Kong. Western collaborators have also participated in the project, notably Kenneth Robinson, who drafted the physical acoustics section, Derk Bodde, who is surveying the world-outlook of the traditional Chinese literati, and Janusz Chmielewski who is writing the important study of Chinese logic. This is by no means a full list of all collaborators and participators, but it may give some idea of the scope of the team-work that has been involved.

Like the full seven-volume study in perhaps twenty separate parts that

Needham and his collaborators are writing and of which ten parts have now appeared, this abridgement may be, it is hoped, a contribution to international understanding. The genius of the Chinese people has so often been represented to the West as primarily artistic and agricultural: the long succession of technical discoveries taken over from China during the first thirteen centuries of our era has been almost entirely overlooked. How much this genius may have influenced the seventeenth-century scientific revolution in the West has yet to be fully assessed. Even so, one must recognise that all the foundations of our knowledge of electromagnetics were laid in China, and Europe at the turning-point was greatly affected by the Chinese conviction of the infinity of the universe. Whatever the final answer may be, a knowledge and appreciation of the achievements of the scholars and craftsmen of other cultures can only lead to a growth of mutual comprehension. After all, we must be on our guard against the temptation of thinking that the whole of modern civilisation began with Renaissance figures like Galileo and Vesalius in the sixteenth and seventeenth centuries, and the conclusion that 'Wisdom was born with us'. There was a Chinese contribution to Man's understanding of Nature and his control over it, and it was a great one. No single people or group of peoples has had a monopoly in contributing to the development of science. All achievements should be recognised, and celebrated, if we are to move on our way to a universal brotherhood of Man.

2

The Chinese language

Before describing any of the achievements of Chinese science and technology, it is necessary to have some kind of cultural background against which they can be set. That is the purpose of this volume – to provide a backcloth for the scientific details that the remaining volumes will contain. To form this background it will be best if we glance first at the geography of China, then at its history, and next consider what opportunities there were for an interchange of ideas between Eastern Asia and the West. We shall then be in a position to trace the origin and development of scientific thought in Chinese philosophy – something that is vital if we are to see the inventive genius of China in anything like a proper perspective.

Throughout this volume we shall, of course, have occasion to use Chinese names and refer to Chinese words, so as a preliminary to our background reconnaissance, it is desirable to spend a few moments on the Chinese language itself. To begin with we shall need to be able to transform Chinese words into our own romanised script so that we can write them and, at the same time, get some idea of their pronunciation. Since Chinese is a tonal language where the tone can give different meanings to a single word, any system we adopt is bound to be at best only approximate, and there has been, and still is, controversy about how romanisation should be done. A large number of competing systems grew up, some stemming from a romanisation of the Cantonese dialect once used by the Chinese Post Office, others based on phonetic and linguistic studies. Sir Thomas Wade in 1867 tried to formulate an internationally acceptable system, but French and German sinologists evolved methods based on their own way of pronouncing the Latin alphabet. Nevertheless the Wade–Giles system, so called because it was modified and adopted by H. A. Giles in the 1890s, is that most widely used in the Western world today. Its chief rival perhaps is the Phin-yin system, an alternative introduced officially by the Chinese Government

in 1962. In the previous table both systems are given, together with the scheme adopted by Joseph Needham and collaborators, which is the one in these volumes. It avoids the apostrophes that Wade and Giles used for aspiration, and replaces them by *h*, thus permitting direct comparison with the sounds of Indian languages where, for instance, 'Buddha' and 'Buddhism' are common romanisations.

As a language Chinese is unique: it is the main one which has remained faithful to the ideographic form of writing. Why it has done so is uncertain; perhaps it refused to move to an alphabetical system because it may originally have been monosyllabic. Whatever the reason, it has retained the ideographic script, unlike what happened, for instance, in ancient Egypt and Sumeria.

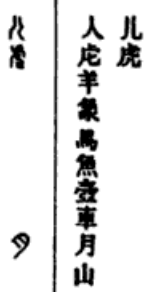
The most primitive elements of Chinese are pictographs – drawings reduced to the bare essentials, conventionalised and, in due course, highly stylised. Natural objects, such as celestial bodies, animals, plants, tools and implements, lend themselves most easily to such drawings, and a number of them are shown in Table 2. The ancient forms of characters are often of considerable interest from the standpoint of Chinese science and technology, as will become evident in later volumes. As the language developed, other written characters were adopted. *Indirect symbols* were introduced, being derived by using gestures for actions, effects for causes and so on. Thus, as Table 2 shows, *chih*, to mount, originated from a picture of two footprints pointing upwards, and *fu*, meaning full or blest, is derived from an ancient picture of a jar. There were also *associative compounds*: *fu*, father, consists of ancient signs for hand and stick; *fu*, wife, signs for woman and broom, while the ideograph *nan*, for male or man, comes from the radicals for plough (or strength) and field.

Besides indirect symbols and associative compounds, some sinologists recognise what may be called *mutually interpretative compounds*. Here one sign is derived from another, although originally they both meant the same thing; only later becoming interpreted differently. For instance, *khao*, meaning examination, is said to be derived from *lao*, old, because it is the old who examine the young, yet originally the two characters meant the same.

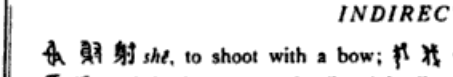
At the present time there are about 2000 pictographs, indirect symbols, associative compounds and mutually interpretative compounds. Yet these do not exhaust the Chinese characters that may be used. Chinese is also very rich in homophones – words having different meanings but sounding the same (like the English words sew, sow, so). Because of this there was always a tendency to use one ideograph with the sense that properly belonged to another that looked different but sounded the

Table 2. *The development of Chinese script*

PICTOGRAPHS

Archaic script	Small seal	Modern script	Forms in writing	Meaning	Rad. no.
		人 *jên*, man 虎 *hu*, tiger 羊 *yang*, sheep 象 *hsiang*, elephant 鳥 *niao*, bird 魚 *yü*, fish 壺 *hu*, wine-vessel 車 *chhê*, chariot, car 月 *yüeh*, moon 山 *shan*, mountain			9 141 123 — 196 195 — 159 74 46

INDIRECT SYMBOLS



射 *shê*, to shoot with a bow; 伐 *fa*, to attack (man being decapitated); 爲 *wei*, lead, manage, do (hand leading an elephant by the trunk); 立 *li*, to stand (a man standing); 降 *chiang*, descend (hill and two footprints pointing downwards); 陟 *chih*, to mount (footprints upwards); 至 *chih*, arrive at (arrow hitting target); 回 *hui*, revolve (meander); 曰 *yüeh*, speak (mouth and breath); 甘 *kan*, sweet (mouth and something in it); 高 *kao*, high (picture of a high building); 長 *chang*, senior, grown up, *chhang*, extended (long-haired man walking on stick); 力 *li*, strength(ard or plough); 畐 *fu*, blest (picture of a jar); 酉 *yu*, wine-must (jar and liquid inside).

ASSOCIATIVE COMPOUNDS

父 *fu*, father (hand and stick); 婦 *fu*, wife (女 woman and 帚 broom); 好 *hao*, to love, *hao*, good (woman and 子 child); 妧 *wan*, to quarrel (two women); 林 *lin*, forest (two 木 trees); 森 *sên*, umbrageous (three trees); 析 *hsi*, split (tree and 斤 axe); 牧 *mu*, tend cattle (ox and hand wielding whip); 鳴 *ming*, sing (鳥 bird and 口 mouth); 男 *nan*, male, man (employ 力 strength in the 田 fields).

DETERMINATIVE-PHONETIC CHARACTERS

耳 êrh, ear, is PHONETIC in: 珥 *êrh*, ear-pendant (determinative 玉 jade, precious stone; word cognate to 耳); 餌 *êrh*, cake (det. 食 food or 鬻 cauldron); 毸 *êrh*, plume (det. 毛 hair); 佴 *êrh*, assistant (det. 亻人 man); 鉺 *êrh*, bait (det. 虫 worm); 衈 *êrh*, a sacrifice (det. 血 blood; 恥 *chhih*, shame (det. 心 heart); 弭 *mi*, repress, ends of a bow (det. 弓 bow); DETERMINATIVE in: 聞 *wên*, to hear (phonetic 門 *mên*); 聆 *ling*, listen to, apprehend (phon. 令 *ling*); 聾 *lung*, deaf (phon. 龍 *lung*); 聰 *tshung*, acute of hearing, clever (phon. 悤 *tshung*); 慫 *sung*, alarm, excite (phon. 從 *tshung*).

立 li, to stand, is PHONETIC in: 笠 *li*, conical hat (det. 竹 bamboo); 粒 *li*, grain of rice (det. 米 rice or 食 food); 苙 *li*, pen for animals, *chi*, hyacinth (det. 艸 herb, plant); 拉 *chhi*, to weep (det. 氵水 water); 拉 *la*, to pull, break (det. 扌手 hand); 翍 *la*, to fly (det. 羽 wings); 霖 *li*, *chhih*, heavy rain (det. 雨 rain); 颯 *sa*, storm (det. 風 wind); DETERMINATIVE in: 站 *chan*, to stop (phon. 占 *chan*); 竚 *chu*, to wait for (phon. 宁 *chu*); 竣 *chün*, *tsun*, stop work (phon. 夋 *chün*); 靖 *ching*, quiet (phon. 青 *chhing*); 端 *tuan*, extremity, origin, end, principle (phon. 耑 *chuan*); 竭 *chieh*, exhausted (phon. 曷 *ho*).

Reproduced from G. Haloun, 'Chinese Script', *World Review* (Sept. 1942), by permission; with some modifications.

same. Due to a strong inclination of the Chinese to pun, it led some characters which had ceased to have their original function being used for other purposes. Thus *lai*, meaning to come (來), originally meant a cereal plant, as its ancient ideograph () shows, and *wan*, ten thousand (萬), was originally a scorpion (). The changes happened because the words are homophones, and the new phonetic characters are called *loan characters*.

The greatest invention in the development of Chinese was that of the *determinative-phonetic* characters. A determinative is a basic element (a radical) that is added to a phonetic word to indicate the category in which the meaning of the word is to be sought. Thus a whole series of words with the same, or approximately the same, sound can be written down without any possibility of confusion. Some examples will make this clear. The word *thung*, a phonetic meaning with, together, is combined with various radicals to provide a new series of words:

chin (金) (metal)+*thung* (同) = *thung* (銅) copper, bronze.
chu (竹) (bamboo)+*thung* (同) = *thung* (筒) pipe, flute.
hsing (行) (to go)+*thung* (同) = *thung* (衕) side street.

On the other hand the radical *shui*, water, can be used in combination with another word to show that the word in question has something to do with water. Thus:

shui (水) (water)+*mo* (末) (branches) = *mo* (沫) (froth, foam).
shui (水) (water)+*chha* (叉) (fork) = *chha* (汊) (branching streams).
shui (水) (water)+*mei* (每) (each, every) = *mei* (海) (the sea).

How far combinations like these were the result of ingenuity by scribes in the tenth to seventh centuries B.C. we cannot tell, but many certainly reveal appropriate, even poetical, contexts of thought. Some ideographs can be both phonetic and radical-determinative, like *erh* (ear) (耳) and *li* (to stand up) (竹), as can be seen in Table 2.

Any one of the pictographs or symbols of the classes mentioned could be used as a phonetic, and so render words that sounded the same or, at least, closely similar. But the number of determinatives was not unlimited, since the number of categories required in the primitive stages of a civilisation was not great. As a result the radical-determinative came to be adopted as a convenient way of forming characters; it was already in full use in the ninth century B.C., and codified in 213 B.C. The first great dictionary appeared in A.D. 121, containing 541 radicals. This large number remained in use for some 1200 years, then it was reduced to 360 and finally to 214, the figure in use today.

To anyone with scientific interests approaching Chinese, a helpful analogy is possible if we consider Chinese characters as molecules

Fig. 2. A sound-table from the *Thung Chih Lüeh* of Chêng Chhiao (*c.* A.D. 1150). The words are located on a co-ordinate system, the longitudinal axis of which (reading from right to left) is 'graduated' with initial consonants, while the vertical axis (reading from above downwards) is 'graduated' with vowels and terminal sounds. The longitudinal axis serves also for classification according to musical notes (third row from the top), while the places on the vertical axis are arranged according to the four tones of speech.

composed of permutations and combinations of a set of 214 atoms. There may be up to seven atoms in one molecule, and the atoms may repeat – rather as they do in a crystal – with up to three identical ones in a character as, for instance, in *sên* (undergrowth), where the wood radical appears three times (森). Admittedly, breaking down phonetics into their basic radicals is an artificial and somewhat late process. Originally some phonetics had no connection with the radicals to which they have become attached by convention and stylisation, so in these cases it is very difficult to know where in a dictionary certain characters should be placed. For this reason, lists of characters 'the radical of which is not obvious' are sometimes given as a separate list. Again, there are some very complex characters that completely defy dissection simply because they are ancient pictographs that have become stylised and now belong to the complex seventeen-stroke end of the list of Chinese characters. *Kuei* (龜) (tortoise) is one of these. Nevertheless the atom-molecule analogy is useful for a great number of characters, and the significance of an analysis of written signs will become evident later when studying Chinese scientific terms.

The six classes of characters described were distinguished first by Liu Hsin and Hsü Shen in the first and second centuries A.D., and have been under discussion ever since. Called the *liu shu* (the six writings), they are:

1 *Hsiang hsing* (images, shapes) = pictographs.
2 *Chih shih* (pointing to situations) = indirect symbols.
3 *Hui i* (meeting of ideas) = associative compounds.
4 *Chuan chu* (transferable meaning) = mutually interpretative symbols.
5 *Chia chieh* (borrowing) = loan characters.
6 *Hsing shêng* (picture and sound) = determinative-phonetics.

The last, determinative-phonetics, form the greatest majority of characters. In the great eighteenth-century dictionary *Khang-Hsi Tzu Tien* only five per cent are pictographs or symbols, the remaining ninety-five per cent being determinative-phonetics.

Throughout Chinese history there has been a continual pruning and simplification, and archaic Chinese contained many more sounds than modern, or even mediaeval, Chinese. Changes in sounds have also occurred in other Asiatic languages and a study of all these gives helpful evidence for the way in which news of natural products, ideas and techniques was disseminated in the past. In Chinese the changes also had other significance. For instance, by the eleventh century A.D., changes had reached such a stage that Ssuma Kuang produced a new systematic key to sounds in a series of what came to be known as 'rhyme-tables'. These were found of considerable use and were soon copied (Fig. 2). Incidentally, such tables have a scientific as well as

3

The geography of China

The geographical background of China – the stage on which the drama of the development of Chinese civilisation was played – took more than a passive role in determining the differences between the cultures of Europe and China, as will become clear later.

At a first glance, China can be said to be divided laterally by its two main rivers, the Yellow River and the Yangtze (see Fig. 1). This is an oversimplification, but in a country both mountainous and plain with vast deserts and fertile areas, the rivers form a useful network with which to begin a brief physical description. We may conveniently look first to the north-east and the Pei-chih-li gulf. Into its north-eastern shores flows the Liao River which has come down from Manchuria, and opposite, on its south-western shore, is the mouth of the vast Yellow River. Following the Yellow River upstream, on the left is the sacred mountain Thai Shan, once venerated for its rain-giving dragons, and the whole mountainous peninsula of Shantung; on the right is the North China plain. The river now runs through mountainous country, and we turn northwards and then westwards, with the Gobi desert to the north. Next we sail south-westwards to the great city of Lanchow, and to where the river comes down from its source in the Tibetan massif. Rather more than half the area inside this vast curve of the Yellow River is fertile, separated from the Ordos desert approximately by the line of the Great Wall and the romantic city of Yulin, where the sand blows up in drifts as high as the walls and the triumphal gateways.

The Yellow River is not alone – other rivers flow into it: the Chhin, the Lo on the shores of which stood the one time capital Loyang, another river also called the Lo, and the river Wei. The whole south slope of the Wei River valley is a sharp escarpment, but the northern slopes are gentler since the ancient rock formations are covered to a depth of thirty metres or more by yellow loess – a compacted dust blown for long ages southwards from the northern deserts. Along these slopes are

the tumulus graves of former emperors, and the whole region is saturated with history; it saw the earliest Chinese civilisation, the rise of the feudal state of Chhin and the successive glories of the Han and Thang capitals at Chhang-an (Sian). This region – the eastern part of Kansu province, the south-eastern part of Ninghsia, and the centre of Shensi – forms a distinct natural province, for in spite of the mountain passes in the west, south and south-east, it is self-contained in a way frequently to be found in Chinese geography.

The Yangtze River, more navigable than the Yellow River, flows into the Pacific north-west of Shanghai. Again, if one travels upstream, one soon reaches a relatively flat country with three lakes, the Thai Hu (Hu = Lake), Poyang Hu, and Tung-thing Hu, the provinces Hupei (north of the lake) and Hunan (south of the lake) deriving their names from the latter. Hopei and Honan similarly mean north and south of the (Yellow) River. At Hankow, between the two western lakes, the Yangtze is joined by the Han River, which flows south, and then the Yangtze itself comes down from Szechuan province through a series of mighty gorges comparable with the Grand Canyon and the African Great Rift valley. On reaching the brick-red sandstone soil of the Szechuan plateau-basin with the Tibetan mountain block to the west, we come upon another self-enclosed natural province which, in World War II, proved an impregnable fortress against the Japanese. Again these central regions were isolated from the south-eastern and southern coasts, which stretch in a huge arc from Hangchow to the Indo-Chinese border. Only comparatively recently have there been good communications in and between them.

The mountains in China seem to be nothing less than a vast jumble of ranges, but in fact they may be broken down into three main groups – north-east/south-west folds, a series of east/west ranges, and a host of lesser folds. The great belt of the north-east/south-west folds is like a series of gigantic steps up to the Tibetan massif (Fig. 3), and they encompass between them most north-eastern and east-central key economic areas. As far as the east/west ranges are concerned, the four main ones effectively divide up the country into four domains – the Shensi basin (west of Loyang), the red plateau-basin of Szechuan, the Kweichow plateau (west of Honan), and the southern maritime area, especially around Canton. The other folds contain the so-called 'Yunnan arc' which the upper Yangtze follows as it comes down from the Tibetan massif.

Essentially, then, China – and Central Asia too, for that matter – are distinguished from most other regions by having a complex network of high mountain ranges separating a number of flatter areas. The

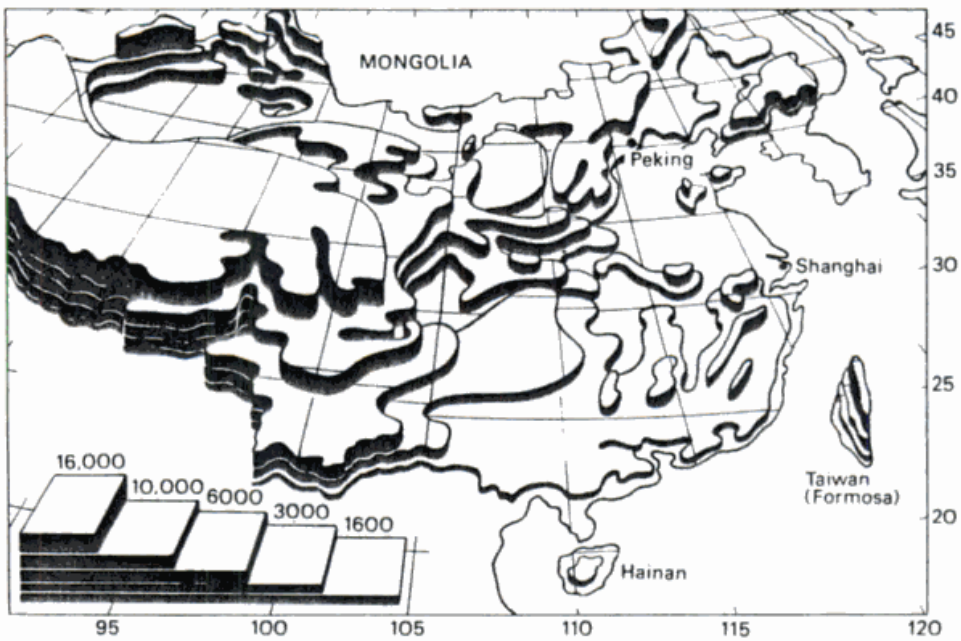


Fig. 3. The eastward staircase of the Chinese subcontinent. Based upon Lo Kai-Fu, 'The Basic Geography of China', *China Reconstructs*, 1956, 5 (no. 12), 18.

significance of this is that, compared with Europe, China is far more cut up by mountain ranges into isolated regions not accessible by inland seas, or even by simple roads. It was, then, an immense task to try to unify Chinese culture and stabilise a common language.

Besides a geography of wide contrasts, China is also subject to a great range of climatic conditions. In the west, the Tibetan massif is mostly an inhospitable waste of high frozen desert with mainly nomadic inhabitants tending yak and goats. The Tarim basin and Mongolian steppe to the north are a mixture of arid grassland and true desert, beautiful but sparsely inhabited. Life here is also traditionally nomadic and never coalesced with the mainstream of Chinese civilisation until our own time. The grassy steppes of the Manchurian plain, in spite of being frost-free for only five months of the year, are now well developed agriculturally, although of minor importance historically.

Moving down from the arid Shantung mountains in the east, however, we at last enter historic ground – part of the ancient feudal state of Chhi – where, in spite of severe winters, it is possible to grow some staple crops and produce a kind of wild silk based on the oak, not the mulberry. The adjoining North China plain to the south-west is a great area of alluvial soil, fertile given intense manuring (including human excreta). Composed of silt carried down by the Yellow River, it teems

with life in spite of periodical floodings, and many crops are cultivated; the chief is wheat but there are also millet, beans, cotton and hemp.

To the north and north-east, the Shansi, Shensi and Kansu provinces show a totally different picture. Covered with loess giving an unleached soil of exceptional richness, crops can be raised year after year without fertilisation and the ability of the soil to hold moisture allows good harvests in spite of limited rainfall. Here, in an area particularly favourable to fruit-growing, was the oldest focus of ancient Chinese agriculture. Different again is the Lower Yangtze valley to the east. With a network of canals and rivers, no land is unused in what is the heart of rice-growing country. Rice, too, is cultivated south of the southern borders of the Shantung, Honan and Shensi provinces, that is in the south-eastern maritime provinces. But here the main activities are lumber and fishing; Chinese sailors are traditionally Fukinese and Cantonese. The climate is warm and wet, and the language composed of mutually incomprehensible dialects, a result of the area's historic isolation from the interior.

In the west lies the red basin of Szechuan, one of China's most densely populated, attractive, and fruitful regions. Rice is the main crop, but there are many others, including cotton, sugar-cane, oranges and tobacco, and winter crops as well, some farmers harvesting no less than three crops a year. South of the area are the Kweichow and Yunnan highland plateaux and mountain blocks. Here only some five to ten per cent of the region has flat ground, but the climate has the moderate and agreeable character typical of places at high altitudes in tropical and subtropical latitudes, and where flat ground does exist, it is intensely cultivated.

Lastly, to complete this brief impression of China's wide-ranging geographical conditions, there are the seaward-looking valleys of Kuangtung and the plateau of Kuangsi. Both Kuangs are subtropical with long hot summers of high humidity, and rather cool winters that are followed by two transitional months of mist and fog. Farming is predominantly centred on rice cultivation, but there are also crops of sugar-cane, tobacco and oranges, as in Szechuan. Three crops a year are common, and much silk is also made in the region.

4

Chinese history: (i) The pre-Imperial Ages

China is better provided with original source-material about its past than any other Eastern, and indeed most Western, countries. Unlike, for example, India, where chronology is still very uncertain, with China it is often possible to be certain not only of the year, but even of the month and day as well. A great number of official histories and annals have survived, all written with remarkable lack of bias, but it is an unfortunate fact that only very small parts of them have been translated into European languages. They are very valuable from an economic, political and social point of view, but generally speaking of relatively little use for the history of science. They do indeed provide much astronomical and meteorological information because the heavens were the fundamental basis for computing calendars, and events in them, as well as the weather, were used to foretell the future. But Chinese literary culture was on the whole uninterested in science, and by and large the historian of science has to look elsewhere for his evidence. Happily a vast amount of information is available: it is to be found in what the Confucian scholars classified as 'Miscellaneous' writings, and though few have been translated, Joseph Needham and his collaborators have been in a position to draw on them extensively.

We shall, of course, need a framework of historical dates against which scientific discoveries may be set, and to do this means compiling a list of dynasties, since the Chinese, like the mediaeval European, counted time from the accessions of kings or emperors. Chinese dynasties, however, do not follow a completely consecutive course, but Table 4 should orientate us into their long time-scale of close on four thousand years. Admittedly, there is some uncertainty when it comes to dates prior to 841 B.C., but after that there is general agreement and, fortunately for us, the history of science is concerned primarily with the later period.

Table 5. *Some historical chronology*

Dates	Mediterranean	Egypt	Palestine	Mesopotamia	India	China
B.C.						
3500				Beginning of the city of Ur		
		Old Kingdom (2600 B.C.)				
	Early Minoan (*c.* 2600 B.C.)	Pyramid building (2700–2500 B.C.)			Indus valley civilisation	Yangshao civilisation
2500		Middle Kingdom (2100 B.C.)		Gudea of Lagash (2100 B.C.)		
2000			Abraham (?)			
	Middle Minoan (*c.* 1800 B.C.)					Lung Shan civilisation (1600 B.C.)
1500		New Kingdom				Shang dynasty
			Moses (*c.* 1300 B.C.)			
		Tutankhamen (1361–1352 B.C.)				
						Chou conquer Shang (1027 B.C.)
1000			David (*c.* 1000 B.C.)			
			Solomon (*c.* 950 B.C)			
				Zoroaster (in Iran) (*c.* 600 B.C.)	Guatama (Buddhism) (*c.* 560 B.C.)	Confucius (*c.* 550 B.C.)
				Nineveh destroyed (*c.* 600 B.C.)	Mahāvīra (Jainism) (*c.* 560 B.C.)	
				Fall of Babylon to Cyrus (538 B.C.)		
			Destruction of temple at Jerusalem		Invasion of Punjab by Darius (512 B.C.)	

500					Warring States (480 B.C.)
	Erection of Parthenon at Athens (450 B.C.)				
	Plato (428–348 B.C.)				
400	Aristotle (384–322 B.C.)				
		Conquests of Alexander the Great (*c.* 327 B.C.)			
300				Reign of Asoka (300–274 B.C.)	
	Punic Wars in the Mediterranean (250–150 B.C.)				Supremacy of the Chhin (212 B.C.)
200					Han dynasty (202 B.C.)
100					
	Beginning of Roman Empire (31 B.C.)	Cleopatra (69–30 B.C.)	Roman capture of Jerusalem (63 B.C.)		
A.D.					
0					
100			Destruction of Jerusalem (A.D. 70)		
200					End of Han (A.D. 220)

Fig. 4. A Shang dynasty *li* (see p. 21). This example dates from the seventeenth to sixteenth centuries B.C.; its height is 16.5 cm. Photo © Times Newspapers Ltd., by permission of Robert Harding Associates.

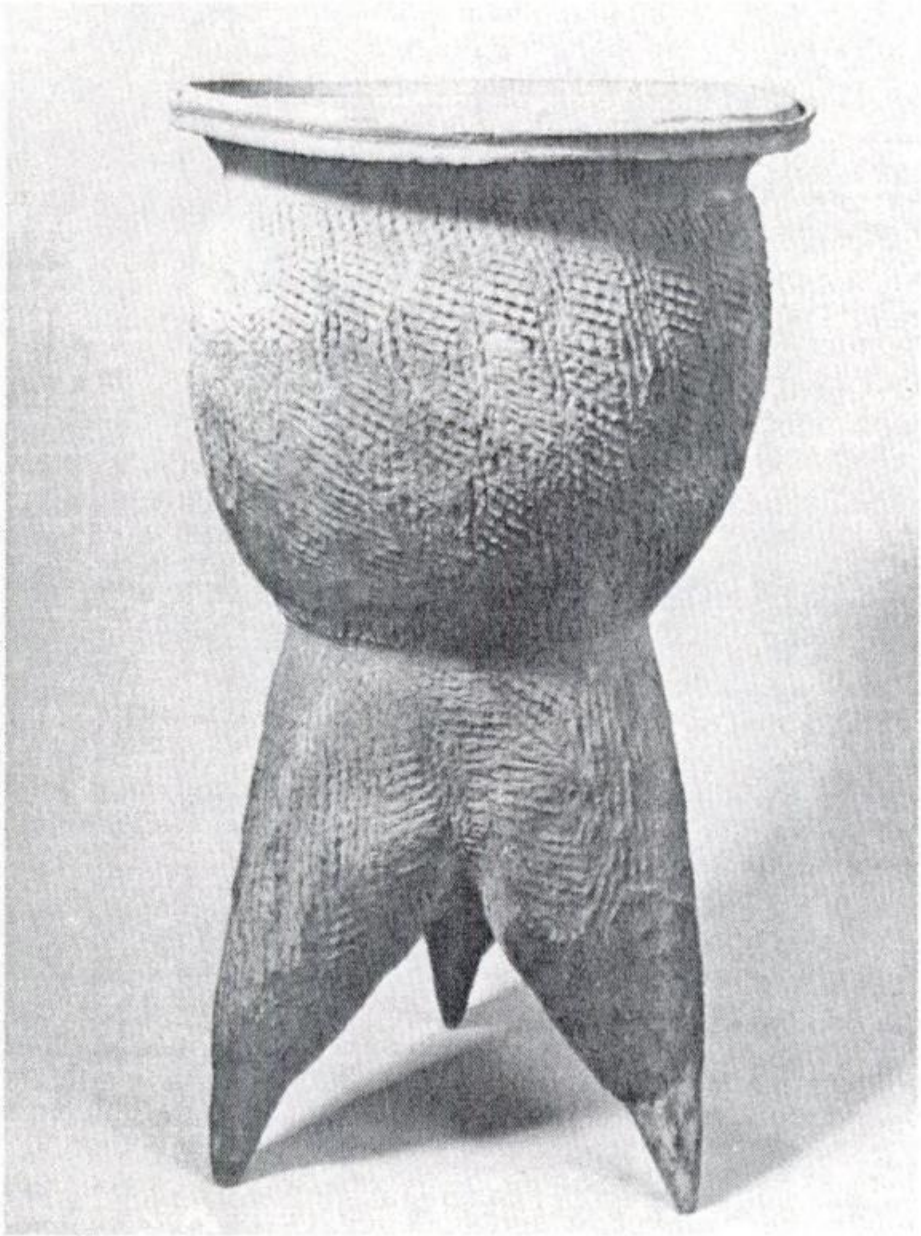


Fig. 5. A *hsien* of the Shang dynasty. This is a pottery version of the combination steam cookery vessel (see p. 26), and was excavated in 1953 at Chêng-chou in Honan. Standing 40 cm high, it is of similar age to the *li* shown in Fig. 4. By permission of Robert Harding Associates.

on top of a *li*, thus making an efficient steam cooking combination, which also had the advantage of allowing more than one foodstuff to be cooked at the same time. When the two were combined into a single form, often with a removable grating, it was called a ***hsien*** and became more preponderant when bronze replaced pottery (Fig. 5). We now know that this led directly later on to the characteristic East Asian apparatus for distillation.

The Yangshao was followed in Honan and Shansi, by a later Neolithic culture, the Chhêng-Tzu-Yai or Lung-Shan (archaeological site names). Although still without metal, the people of this culture used a smooth black earthenware of fine texture and high finish, while those of Lung-Shan had domesticated all the animals of the Yangshao including, probably, the horse. There is a possibility, too, that the Lung-Shan knew of wheeled vehicles, although the evidence for this is uncertain. This was also the time at which various inventions appeared, inventions such as the potter's wheel and the use of tamped earth for buildings, long known in the Middle East but new to China.

With the Lung-Shan we reach 1600 B.C. and then, within a century, we come quite suddenly to a mature bronze-age culture, the Shang dynasty (Fig. 6). Most of our knowledge comes from excavations at the capital, Anyang, now in Honan province, and the discovery of the very existence of this dynasty is one of the most romantic in all archaeology. It all began in the late nineteenth century when farmers tilling their fields near Anyang kept turning up curious pieces of bone. Bought up by someone in the village, they were sold to drugstores as 'dragon-bones' for medicine, but not for long as in 1899 some Chinese scholars came across them and realised, with surprise, that the bones were inscribed with very ancient writing; by 1902 their full significance was appreciated. They were nothing less than inscribed oracle-bones, and provided evidence that no one had possessed since the early days of the Han dynasty (Fig. 7). At one stroke they pushed back the philology, linguistics and history of China by almost a thousand years, and have made it clear that much of China's hitherto legendary history – the rule of the Yellow Emperor, the work of the Great Engineer Yü, and a host of others – was a reflection of events and practices of times that had been in fact historic. One aspect of this is the question of what script preceded the well-developed writing on the oracle-bones. Recently many signs have been recorded from Neolithic pottery, and these may have been the earliest forms of what afterwards developed into the Chinese characters.

The oracle-bones were used for scapulimancy, a divination technique that involved heating the shoulder-blades of mammals or the shells of turtles with a red-hot poker and discerning the reply of the gods from

kept records of their results, possibly as secret dossiers; it is a collection of such records that the Anyang finds have brought to light.

The use of bronze during the Shang dynasty was outstanding. It was employed in all kinds of ways, especially for ritual, military and luxury purposes, for the metal parts of wheeled vehicles, but, interestingly enough, seldom for tools and implements. The high artistic quality and workmanship of Shang bronze ritual vessels is breathtaking and surpasses all later work. Yet the Shang ruled over only a restricted area, perhaps spreading no more than 300 km in any direction from Anyang. Theirs was a feudal society in which matriarchal traces had given place to patriarchal control, where there was family or ancestor worship, and human sacrifice. Slaves were immolated at royal burials, a practice that persisted well into Chou times.

Two other features of the Shang Age are worth noting here. One is the extensive use of bamboo, not least made up into books for writing. Probably similar to the Han books that still survive, bamboo strips were taken and held together by two lines of cords, and it is from these that the character *tshê* (冊), depicting a written book, was derived. Incidentally, it was during Shang times that the Chinese writing brush was introduced, and that pictographs began to be replaced by written characters. The second feature is the use of cowrie shells as a form of currency, an innovation that gave many words expressing 'value' the radical *pei*, which originally meant cowrie shell. Where the cowries came from is still uncertain: the Pacific coast south of the Yangtze estuary seems probable, but their journey to the centre of the Shang civilisation would present a remarkable feat.

The Chou period, the Warring States and the first unification

We turn now to the Chou people who came from the western regions (the present provinces of Kansu and Shensi). Less advanced than the Shang, whom they admired, the Chou conquered the Shang area about 1027 B.C., encouraged the bronze-working, pottery and textile-making they found there, and developed the written language.

Though probably of pastoral antecedents, the Chou soon adopted the thorough-going agricultural character of the unfolding Chinese civilisation. In addition they systematised the incipient feudal system of the Shang until it became almost as developed as it was to become two millennia later in Europe, basing their economy on the work of peasant-farmers who all had to do their quota of unpaid labour on the land of the local nobility. The empire, as it had now become, was divided in fiefs, held by a new aristocratic class, and much of the Shang population was deported to the dukedoms of Lu and Chhi.

In spite of its apparently overriding control, Chou society began to manifest an increasing instability which, in the eighth century B.C., led to the collapse of the myth that it was a tightly knit feudal empire. In 771 B.C. the Emperor Lu was killed by an army of one of the smaller states which had allied itself with 'barbarians', and his successor was forced to move the state capital from near Sian eastwards to Loyang and vacate the fertile loess region to the west. During the next few centuries some twenty-five feudal states, paying only lip-service to Loyang, vied with one another in attempts to gain independence. The first to achieve it was the state of Chhi in Shantung, a state which had two peculiar qualities of its own: it was the main source of salt (obtained by evaporation of sea-water) and a leader in the working of iron. Iron had become known in China by 500 B.C. and the Chhi possessed an enviable iron-working technology that the Chou did not, a factor that may well have been significant in their bid for power. Later, independence also passed to the states of Sung, Chin, Chhin and Chhu.

By the sixth century B.C. not only do we see far-reaching political changes, but we also enter the greatest period of intellectual development in ancient China. The 'hundred schools' of philosophers were at their height between 500 and 250 B.C., with scholars travelling with their disciples from capital to capital to act as advisers to the feudal lords, whose realms were beset by conflicts with barbarians, unrest within and vast technological changes due to the increasing use of iron. During this period academies of scholars were set up, the most famous being the Academy of the Gate of Chi (Chi-Hsia) at the Chhi capital, founded in 318 B.C. by Prince Hsüan. Here scholars were welcomed from other states besides Chhi, and all were provided with quarters and maintenance. Established not long after Plato's Academy in far-off Athens, it attracted a great number of superb scholars, some of whom we shall meet later.

Side by side with these intellectual developments went a host of other advances, so this has always been looked on as China's 'classical' period. There were developments in craftsmanship, in methods of production, and in irrigation: the animal-drawn plough appeared, there was a multiplication of market-places and an intensification of a money economy which tended to replace the ownership of land and of unpaid labour duty as a source of wealth. In military techniques iron came to be widely used, and the cross-bow, invented earlier in China than elsewhere, brought to a state bordering on perfection.

During the time of the Warring States, industrial concentration and the control of hydraulic engineering systems played a great part in what was a general consolidation, with the smaller states being absorbed by

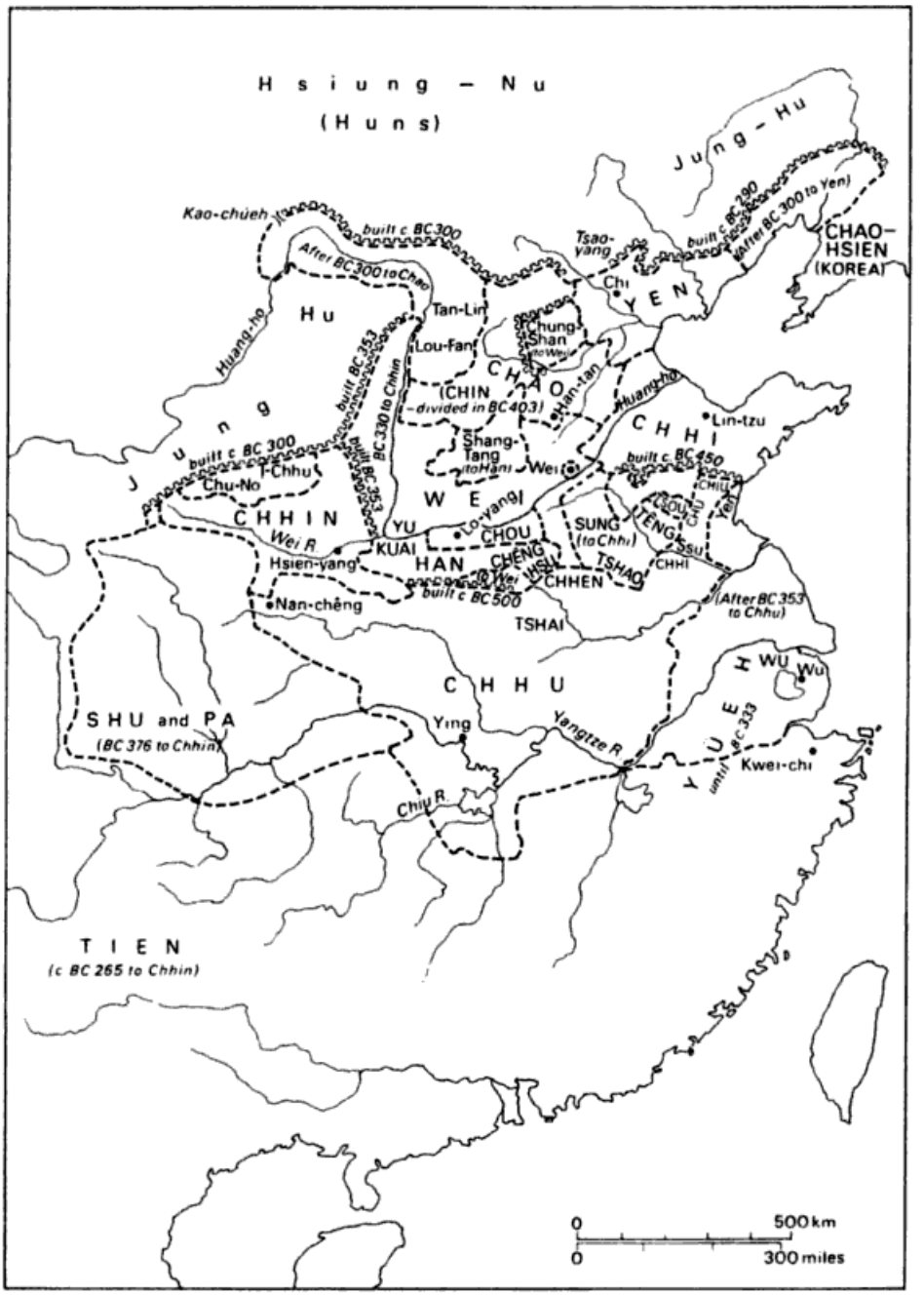


Fig. 8. Approximate boundaries of the Feudal States about the beginning of the third century B.C. Based upon A. Herrmann, *Atlas of China*, Harvard University Press, Cambridge, Mass., 1935, by permission.

the larger. Feudalism was replaced by bureaucratism, first in the state of Chhin and then elsewhere. The population became increasingly militarised, a police and passport system was introduced, and general coercion exercised by the use of drastically severe punishments. The power of Chhin continued to grow and was viewed with alarm by other states, which made alliances in self-defence and adopted other expedients to try to increase their security. Yet try as they would, they were unsuccessful, as for instance when a number banded together and approached the Chhin with proposals for a vast inland navigation system. The idea was to build a canal connecting the Ching and Lo rivers that lay to the north of Sian, in the belief that constructing the canal would keep the population occupied and reduce Chhin military strength. The result was just the opposite; a vast area became irrigated, additional grain was grown, with the Chhin realising that they now had the wherewithal to build up a greater army and become strategically stronger. Indeed the Chhin found the scheme so satisfactory that the construction of large water-works became a settled policy of their administration, and in 316 B.C. they undertook the magnificent project of irrigating the Chhêngtu plain, a project that still flourishes today.

For almost a century, from 318 to 222 B.C., the Chhin adopted a policy of conquest until, at last, they ruled a united China, and Prince Chêng adopted the title Chhin Shih Huang Ti, the First Emperor of a united China (Fig. 8). Yet this triumph of the Chhin was short-lived, and to its demise and the rise of its successor, the Han dynasty, we now turn.

5

Chinese history: (ii) The Empire of All Under Heaven

The dynasty of Chhin

As soon as their new unified empire was established, the Chhin created a type of bureaucratic government that was to form the pattern for all subsequent Chinese history. The large feudal estates were expropriated and managed by government officials, such nobles as remained being forced to reside at the capital; farmers were granted more rights over their lands than ever before, but they were made subject to taxes. Administratively the country was divided up into provinces, each with a military governor and a body of civil officials, and there was wide-scale standardisation, ranging from weights and measures to the gauge of carts and chariots. Tree-lined roads, already begun in some provinces, were extended into a network, and, in the north, joined together to form a supply route to the immense defence structure of the Great Wall, the dividing line between the steppe and the cultivated land. A military device to prevent incursions from the nomadic tribes, it could only be breached either through one of its heavily defended gates or by building ramps to permit the wall itself to be scaled; in either case there would be a long enough delay for reinforcements to arrive. Yet the purpose of the Great Wall was not only to keep out barbarians from the north; it was also designed to act as a barrier to migration from China itself, to stop any movement out to the north and the formation of mixed agricultural and pastoral economies (Fig. 9).

The Chhin retained a large standing army which had, of course, to be kept busy; an aim which the Emperor Chhin Shih Huang Ti achieved by a series of campaigns to extend the borders of his empire further south. These campaigns were remarkable in their extent, covering the coastal province of Fukien, the two Kuang provinces, and even penetrating as far as Tongking in what is now North Vietnam. One of these, consisting of 3000 likely young men, artisans, and useful girls, was headed by Hsü Fu, whose tomb can still today be seen at Shingū

method that gave the Confucians (to be discussed later, Chapter 7) a hold on Chinese society that was to become permanent. The Confucians were able to achieve this power partly because of the unpopularity of the previous advisers, the Legalists, whose measures were now considered to have been too rigorous, and they confirmed themselves on a sound footing by introducing simpler laws and less severe punishments. Indeed, during Han times the Confucian bureaucracy turned into a highly developed form of civil government. Assemblies of scholars were held to determine a kind of case law and decide on precedents based on ancient writings, the first such assembly, held in 51 B.C. in the Shih-Chhü (Stone Canal) Pavilion of the Palace, having an importance in Chinese history on a par with the Council of Nicaea (A.D. 325) in Western Christendom.

It was during Han times that eunuchs began to exert an increasing power at court. Although condemned by the scholar-gentry of the civil service, they always managed to reassert their influence after every setback, due partly to the fact that no ruler need fear a eunuch establishing a dynasty of his own. This was a valuable asset in a bureaucracy where it was customary to try to make offices hereditary and where nepotism often led to bloody revolutions every time there was a change of reign. The power of the eunuchs reached one of its peaks at the time of the great Han Emperor Wu Ti because, unlike his predecessors, he was unwilling to leave his ministers to govern, and took things into his own hands. As a result the bureaucrats lost their position as intermediaries between emperor and people, and in the end it was only the eunuchs who exercised any power, since it was they and they alone who had access to the private apartments and could there gain the emperor's ear.

Han Wu Ti's reign (from 140 to 87 B.C.) was one of the most important epochs of Chinese history, for it brought stability and a well-administered state with an enlightened foreign policy. Yet there were economic difficulties to begin with; previous anti-mercantile edicts had driven the merchants to wild speculation and sent prices so high that additional currency had been required. Wu's counter-measures were simple and effective: he persuaded the most capable merchants to enter the administration, and conducted currency experiments, trying out the first 'paper' money, which, made from the skin of white deer to be found only in the royal hunting reserves, was used in specific cases of compulsory purchase by the state. As an additional stabilising force, the conception of the 'ever normal granary' was introduced: here the government purchased grain when prices were low and sold it when prices rose. Nevertheless continuing struggles against the Huns north of the Great Wall kept what were still high taxes on the increase.

Han contacts with other countries led to several maritime visits from Romans and Roman Syrians, but is perhaps best exemplified by the extraordinary diplomatic mission of Chang Chhien. A yeoman, he was sent westwards some 5000 km to the Yüeh-chih in Bactria (now an area of North Afghanistan and parts of Tadzhikistan and Uzbekistan in the south of the U.S.S.R.). The purpose of his mission was to get the Yüeh-chih to ally themselves against the Huns, the emperor believing there was a good chance of success because the Huns had killed their king and further insulted the Yüeh-chih by using his skull as a drinking vessel. Unfortunately Chang Chhien was captured by the Huns both on his outward journey and his return, and detained by them for some ten years. Yet the fact that he was able to undertake the mission at all and return safely with a valuable collection of plants and natural products, after twice using a route that took him through enemy territory, is nothing less than remarkable. However, it had more importance than an epic adventure, for Chang Chhien's visit to Bactria led to the later expansion westwards of the Chinese Empire, with the foundation of the famous trade-route that linked the culture-areas of China and Iran, known as the Old Silk Road. Above all, it was the discovery of Europe by China, not the reverse, for Bactria had been Greek since Alexander's time.

The Han emperors, and Wu Ti in particular, are sometimes criticised for 'superstitious practices'. Certainly Wu extended sacrifices and magico-religious rites and spent considerable time in trying to cultivate relationships with spiritual beings, but he was too acute to be fooled by false manifestations even if he could not bring himself to believe that everything his magicians did was fraudulent. It may well be that he was not far wrong in his assessment of them for we know that in earlier ages there were intimate connections between magic and science, and it is highly probable that the Han magicians did make some worthwhile new observations in alchemy, magnetism, the use of medicinal herbs, and so on. Indeed this, the second century B.C., was the time when the greatest classics of Chinese medicine were compiled, especially the *Huang Ti Nei Ching* (The Yellow Emperor's Compendium of Corporeal Healing). This corresponds in large measure to the slightly earlier Hippocratic Corpus of the Greeks, and has been the foundation of Chinese medical thought during the subsequent 2000 years. Among other things it contains the first systematisation of the acupuncture technique.

Emperor Wu, like Huang Ti before him, sent maritime expeditions into the Eastern Ocean, in the belief that spiritual beings dwelt on some of the Pacific Islands. He and his successors also mounted more warlike excursions to the south, and to Korea in the north-east where a colonial

government was set up, a government which, in its turn, exerted a great influence on the slowly developing culture of Japan.

From A.D. 9 to 23 the Han dynasty suffered an interregnum, the Regent Wang Mang outmanoeuvring the members of the Han family and establishing himself as the first (and last) Hsin emperor. Wang's rule may have been brief, but it was marked by a series of fundamental reforms that seem to have been aimed at strengthening the bureaucratic state. All land was declared state property, large holdings were distributed among peasant-farmers, and a tax imposed on all uncultivated fields. A law freeing male slaves was also promulgated, but it proved impossible to enforce, and a heavy tax was placed on all slave-owners instead. All gold coins were called in and replaced by bronze, a move that brought immense wealth to the Treasury, which gradually accumulated more gold than was ever to be available in mediaeval Europe. The ever-normal granary system was tried again but like the rest of the reforms it did not work well. Perhaps an honest civil service might have made a success of the new system, but the Wang administration suffered from corrupt officials, drove merchants and financiers to desperation, and made the population restive. Finally, aided by the 'Red Eyebrows' – a secret society typical of those that were so often to play a great role in Chinese society – there was a popular revolt; Wang Mang's power collapsed and he was assassinated.

Wang Mang's reign was not as much a complete fiasco as this brief sketch might seem to imply, because he encouraged the development of the science and technology of his day and, as we shall see in a later volume, may have been intimately concerned with the origin of the magnetic compass. It was Wang, too, who in A.D. 4 convened the first assembly of scientific experts in Chinese history: though unfortunately no record of their deliberations has reached us. Again, fifteen years later, when one man in thirty of the population had been conscripted to fight the Huns, he enlisted experts who claimed to be able to provide scientific and technical assistance to the army. The fact that Wang's tests proved that none of their schemes were practicable is beside the point: it was his attempt to apply such methods that matters.

A short period of confusion followed Wang Mang's assassination, then Liu Hsiu, a cousin of the former Han emperors, emerged triumphant. Forming the Later or Eastern Han dynasty in A.D. 25, he moved the capital eastwards to Loyang and consolidated Han practices and policies. Wars with the Huns continued, but by 80 Pan Chhao, the Han governor-general in Central Asia, had quelled the whole Tarim basin (modern Sinkiang province), and made Chinese influence felt as far west as the Caspian Sea. Only Parthia (modern north Iran), through which the silk

route ran, separated the Chinese and Roman empires. After 120, further mercantile contacts were made, mainly with Arabia and Syria by way of the Persian Gulf.

The time of the Han dynasty, especially the Later Han, was one of the relatively important scientific periods in Chinese history. There were great advances in astronomy, improvements in the calendar, an outstanding development in the earth sciences, and foundations laid for methods of classifying plants and animals; alchemy flourished, and the first book ever written on the subject appeared (A.D. 142). A sceptical and rationalist way of thinking developed, particularly about A.D. 80 in the hands of Wang Chhung (see p. 203), while there were two Han princes who also took part in this active intellectual life. One, Tê of Ho-Chien, was a scholar and bibliophile who preserved the important 'Artificer's Record' section of the *Chou Li* (Records of the Rites of Chou), the other was the almost legendary Liu An of Huai-Nan, who gave his name to the *Huai Nan Tzu*, a compendium on all the science of the day and one of the most important monuments of ancient Chinese scientific thought. Indeed, bibliography as a whole received great stimulus, for the Han period marked the first systematic development of book lists; compiled by experts in astronomy, medicine, military science, history, magic and divination, these were incorporated in the Han histories and list some 700 works written on wooden or bamboo tablets, and on silk. Buddhism also entered China in Later Han times and the first sutras were translated into Chinese at the capital, Loyang.

In technology the Han age was marked by the invention and spread of the use of paper, by numerous developments in ceramics such as the first glazes and the introduction of a material that was the forerunner of porcelain, by advances in architectural techniques such as making decorated bricks and tiles, and by raising the level of textile technology to a stage not approached by Iran or Europe until centuries later. A large number of natural products new to China were also imported: alfalfa and the grape-vine from the west, oranges, lemons, betel nuts and lychees from the south and south-west. From the west also came improved breeds of horses, and from Khotan, possibly from Burma too, jade arrived in large quantities. Perhaps the greatest achievement of the Han people in nautical technology was the cardinal invention of the axial rudder at least as early as the first century A.D.

Towards the end of Later Han times, palace revolutions became increasingly frequent, and in 184 a farming crisis led to a peasant revolt guided, in this case, by the 'Yellow Turban' secret society. Although the revolt was suppressed, it left some of the army generals in positions

of great power, and by 220 the central government found itself ineffective. The country became divided, and for the next half century remained fragmented into three independent kingdoms in a state of permanent mutual hostility.

The San Kuo (Three Kingdoms)

The three kingdoms were the Wei, the Wu and the Shu. The Wei controlled the north and north-west, being based essentially on the Yellow River valley with their capital at Loyang; the Wu in the south and south-east ruled the Yangtze valley and the two Kuang provinces, while the Shu were based on the Szechuan basin in the east, but also commanded the hills of Kweichow and part of Yunnan (Fig. 10).

The battles and manoeuvres of the Three Kingdoms have become legendary, inspiring one of China's most famous novels as well as many plays, with the Wei leader Tshao Tshao as the model of a brave but cunning and ruthless prince. More important from our point of view, however, is the fact that the Three Kingdom division was essentially an economic one, each kingdom covering a key economic area. This was significant, for in a civilisation based on intensive agriculture, the accumulation of grain at the centre of power was vital, and in third-century China this depended on efficient hydraulic engineering, both for irrigation and transport: political power was therefore closely connected with technology and efficient administration. Regional geography also played a part, but as the three economic regions were essentially equal in their natural resources, hydraulic engineering became the main factor in the power struggle. The Wu completed an important canal and made an artificial lake for irrigation at Tan-yang (close to modern Nanking), the Shu carried out some works in the upper Wei valley, but it was the Wei themselves who paid the greatest attention to hydraulic projects. Between 204 and 233 they constructed three large reservoirs, two trunk canals, and six other important canals, and it was they who were eventually victors due partly to their policy of developing military agricultural colonies, partly to their policy of starving out their enemies rather than fighting them, but also not a little to their efficient hydraulic engineering.

During the destruction and devastation caused by the struggles of the Three Kingdoms, it was natural that people should turn to an otherworldly religion as a refuge. Buddhism was already there to fulfil the need, but about the same time the Taoist philosophy (see pp. 110 onwards) united with the magical scientific elements in primitive North Asian religion to produce an alternative and indigenous church. However, Buddhism became very popular, especially in later centuries, and

during the more settled times of the fourth and fifth centuries gave rise to a flowering of religious art, evidence of which is still to be seen in the famous carvings in the Yünkang caves in the east and the frescoes in the caves of the Thousand Buddhas at Tunhuang.

How imperishable the struggles of the Three Kingdoms became can be seen in the following story. Joseph Needham tells me that in 1943 he was sitting talking about the war with the peasant-farmers in a teahouse in Szechuan, and they said: 'You'll see, it will happen again as it did before, the North will win!' The Japanese ally Wang Ching-Wei was sitting in Nanking in the south like Sun Chhüan, ruler of Wu; the Generalissimo Chiang Kai-Shek corresponded to Chuko Liang in Chungking in Shu in the west; and far to the north Mao Tsê-Tung was the leader who represented Tshao Tshao of Wei. It was with some slight sense of shock that Needham and his companions realised the farmers were talking about the third century A.D. almost as if it was a few years ago.

The dynasty of Chin and its successors

Although the Wei gained control of the Three Kingdoms in 265, it was the Chin dynasty, founded the same year by Ssuma Yen, one of their generals, that ruled the newly unified state. Yet this did not mean peace for China, since almost at once the northern economic area came under pressure from the semi-barbarian peoples of the north, some of whom had already gained influence in China by becoming involved in its internal power struggles as allies. Within virtually the next half century, the Chin were driven south of the Yangtze and had to establish a new capital at Nanking. Yet in spite of their conquest, the northerners were never at peace among themselves, and for more than two centuries, between 304 and 535, no less than seventeen dynasties vied with one another for power. The Northern Wei was the longest surviving of these dynasties, eventually controlling the whole of the north, with the exception of Shantung in the north-east (Fig. 11). However, even though the north suffered continuously troubled times, it exerted its own influence on the invaders, who became increasingly sinified. Indeed, then, as at other times, Chinese culture displayed an astonishing integrative and absorptive power which no invader before the modern period could withstand.

As early as the latter half of the third century, at the beginning of the Chin, increasing foreign contacts stimulated the science of geography, especially under the great cartographer Phei Hsiu, and brought about the introduction of some new customs, among them the drinking of tea. All the same, the depopulation that had occurred due to the

continual wars and skirmishes had its effect, and was probably the reason for the introduction of labour-saving devices like the wheelbarrow and the water-mill, and later, in the fourth and fifth centuries, for a developing military technology. One of the results of this technology was that military rather than administrative talents were sought after, with the result that those who did not have this flair began to turn more and more to speculation which, in its turn, led to a growth of theoretical science. Thus it was that in the fourth century the Taoists produced Pao Phu Tzu, one of their greatest naturalists and alchemists, while mathematics also flourished, and a new genre of writing, the gazetteers, appeared. Concerned ostensibly with local topography and records, they proved to be works of astonishing comprehensiveness, as the first, produced in 347, shows already clearly. Compiled by Chhang Chhü, and known as the *Hua Yang Kuo Chih* (Record of the Country South of Mount Hua), this gave details of the country south of Shensi and north Szechuan, described the building of the Shu capital, and then gave biographies of local notables. Yet these were only part of its contents; it also gave accounts of local monuments, described local customs, plants, birds and other animals, and provided information about the commodities available such as copper, iron, salt, honey, drugs, bamboo, and so on. Such books became widely popular and 6500 of them are known, although only comparatively few of these were written before the seventh century.

Political instability returned in the sixth century when the Northern Wei split into an eastern and western portion and then when both these were taken over in 550 by Chinese successor states, the Northern Chhi and Northern Chou. In the previous century there had been power struggles in the south also; the Chin had been replaced by the Liu Sung, which had itself given way to three other short-lived dynasties. Unification of both north and south did not come again until the 580s with Yang Chien and the Sui dynasty, which by 610 controlled the entire continent in a broad sweep taking in Annam and Formosa in the south to Tashkent and Sinkiang in Central Asia.

The dynasty of Sui

China had been divided for some 330 years, 60 under the Three Kingdoms and 270 under the 'Northern and Southern Empires'. The new unification, as might be expected, brought about improved connections between the northern and southern economic areas, the first Sui Emperor Wên Ti effecting some developments, and his successor, Yang Ti, overhauling the fragmentary water transport system between the Yellow River and the Yangtze, and building the main links in the first

form of the Grand Canal. These new waterways passed right across the traditional battlefields between north and south, and formed a grandiose communication network that proved a blessing to later generations, yet they were only obtained at a great cost in human suffering. Some 5½ million people, including in some areas all commoners between the ages of 15 and 55, worked under the supervision of 50000 police, and those who could not or would not fulfil the demands made on them were punished by flogging and neck-weights. Every fifth family was also required to contribute one person to supply and prepare food and, in the end, the harsh conditions took their toll, and something of the order of two million men were said to have been 'lost'.

The Sui dynasty was too short-lived to have much effect on cultural matters. The cost of its public works and its extravagant military expeditions to Korea and Central Asia depleted the exchequer, and, coupled with other causes for complaint, brought public unrest that escalated into revolution when the emperor was surrounded by Turkic tribes at Yenmên and his power was obviously crumbling. Finally, in 617, power was seized by the official Li Yuan and his ambitious second son Li Shih-Min, who took the capital Chhang-an, and the next year proclaimed the Thang dynasty.

The dynasty of Thang

Building on the foundations laid by the Sui, the Thang emperors, whose reign was to last almost three hundred years, were able to enlarge China's boundaries and influence to an extent not reached since Han times, four centuries and more before. They repulsed attacks from Turkic tribes, taking the war into the nomadic lands where, thirty years later, the sovereignty of the Chinese 'khan' was finally accepted. They penetrated Tibet, whose king welcomed a Chinese wife and many civilising influences including technological developments like water mills and iron-chain suspension bridges, and by 660 they also ruled practically the whole of Manchuria and Korea, as well as Sinkiang. Maximum expansion occurred about 750, but after this there was a slow decline, triggered off by unfortunate diplomatic incidents in Tashkent, incidents that led in 751 to a clash between Chinese and Muslim armies at the Battle of the Talas River, and a resounding defeat for the Chinese. But the victory was a Pyrrhic one for although it resulted in the loss of Western Turkestan (part of modern Sinkiang), it also marked the end of Islam's expansion towards the east and was truly one of the decisive battles of world history.

The defeat of the Thang gave a signal to some countries within the vast Chinese Empire to seek their own independence: Mongolia was

first, then the Thai principalities in the south-west, including Yunnan, rebelled and formed a separate dynasty, while in the north-east the Tartars set up strong bases in Manchuria, and south of them Korea absorbed the Chinese protectorates on its soil. What is more, good relationships with the Tibetans deteriorated until, in the end, they became such a menace to China and to the Muslim possessions in Central Asia that an Arab–Chinese alliance was formed between the Thang emperor and Hārūn al Rashīd, the famous Caliph immortalised in the *Arabian Nights*. After this a less unsettled period followed and the unification of the Thang continued for well over a century more.

Among the alternating periods of reception and rejection of foreigners that have characterised Chinese, as well as English history, the Thang was one when strangers were very welcome. The capital Chhang-an became an international meeting place; Arabs, Persians, Syrians came there to meet a diversity of other peoples, to discuss all manner of subjects with Chinese scholars in the elegant pavilions of the city in the Wei valley; and it became commonplace for wealthy Chinese to employ Central Asians as grooms and camel-drivers, Indians as jugglers, and Bactrians and Syrians as actors and singers. New foreign religions were imported: Zoroastrianism early in the sixth century, Christianity from Syria about 600, and Manichaeism from Persia at the close of the seventh century. As in Han times the Chinese themselves also journeyed far, the classic example being the Buddhist monk who went to India for 16 years, travelling the length and breadth of the subcontinent to gather religious writings. Buddhism, indeed, saw a period of great expansion and stimulated some of the finest artists of the period: the cave frescoes of Tunhuang are mostly from this time and reflect the general cosmopolitan attitude by showing monks and laity sometimes with brown or even red hair, blue or green eyes and even European features (Figs. 12 and 13). In the end, however, the Buddhist expansion, the proliferation of temples, the vast numbers who became monks or nuns, all began to seem like a state within the state challenging the accepted foundations of Chinese society. The administration became increasingly alarmed at this, and in 845 there was a vast purge; upwards of 4600 temples were destroyed and 40000 shrines abolished, some 260000 monks and nuns were secularised, 150000 slaves emancipated, and millions of hectares of arable land confiscated.

Yet if Buddhism appeared to present political dangers, one fruitful effect of its expansion was the stimulus it gave to the invention of printing. Buddhists required sacred pictures, repetitions of sacred names, and other similar items whose demand could best be met by block-printing. When this demand was coupled with the administra-

Joseph Needham's *Science and Civilisation in China* is a monumental piece of scholarship which breaks new ground in presenting to the Western reader a detailed and coherent account of the development of science, technology and medicine in China from the earliest times until the advent of the Jesuits and the beginnings of modern science in the late seventeenth century. It is a vast work, necessarily more suited to the scholar and research worker than the general reader. This paperback version, abridged and re-written by Colin Ronan, makes this extremely important study accessible to a wider public.

The present book covers the material treated in volumes I and II of Dr Needham's original work. The reader is introduced to the country of China, its history, geography and language, and an account is given of how scientific knowledge travelled between China and Europe. The major part of the book is then devoted to the history of scientific thought in China itself. Beginning with ancient times, it describes the milieu in which arose the schools of the Confucians, Taoists, Mohists, Logicians and Legalists. We are thus brought on to the fundamental ideas which dominated scientific thinking in the Chinese middle ages, to the doctrines of the Two Forces (Yin and Yang) and the Five Elements (*wu hsing*), to the impact of the sceptical tradition and Buddhist and Neo-Confucian thought.

The cover shows part of a painted temple scroll depicting four Taoist genii. Top left is Liu *Thien Chün*, Comptroller-General of Crops and Weather; top right is Wên *Yuan Shuai*, Intendant of the Spiritual Officials of the Sacred Mountain, Thai Shan; below left is Kou *Yuan Shuai*, Assistant Secretary of State in the Ministry of Thunder; below right is Pi *Yuan Shuai*, Commander of the Lightning.

The scroll is in the possession of the East Asian History of Science Library, Cambridge.

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