The Genius of China

by Peter Fritz Walter
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Quotes Collection

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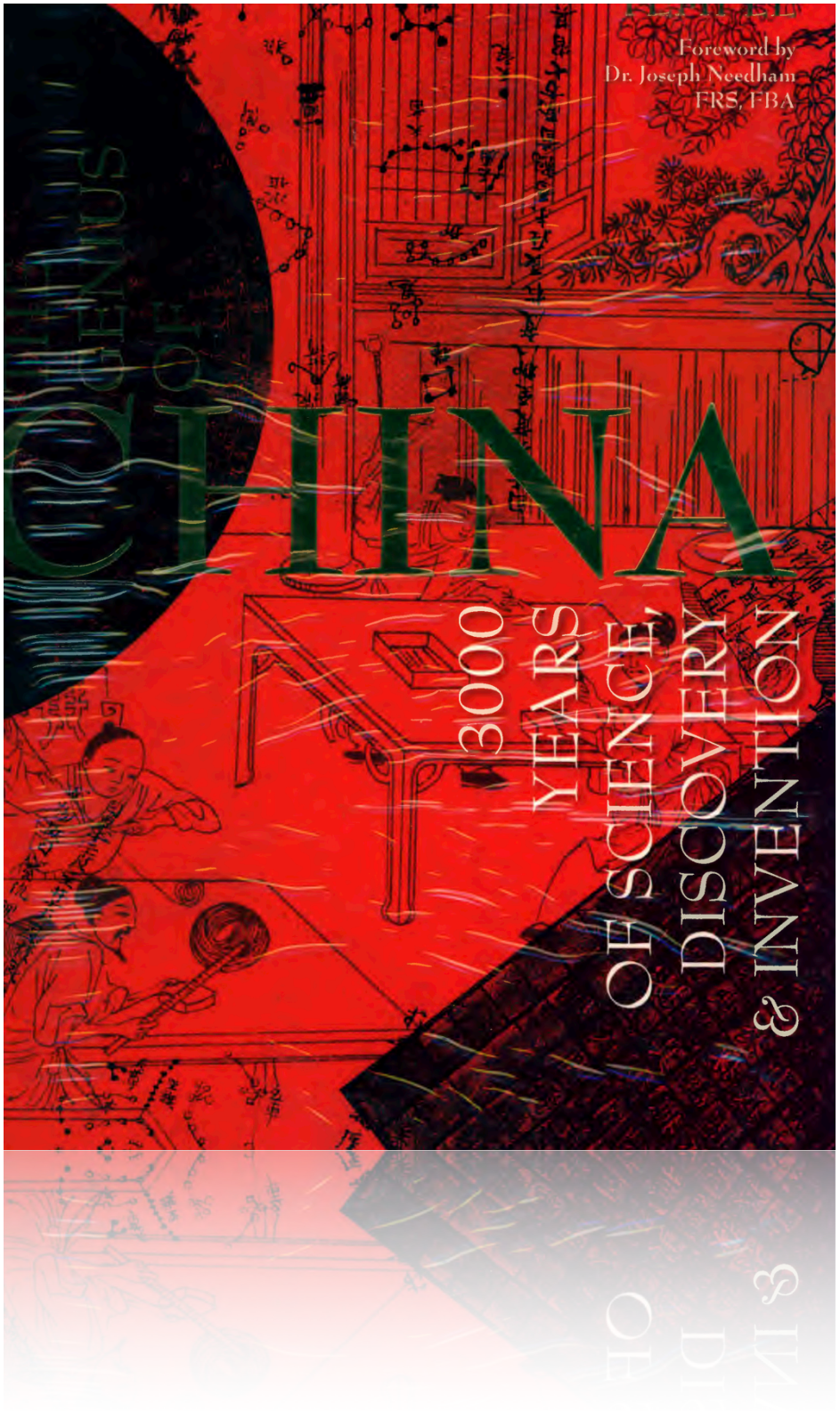

The West's Debt to China

One of the greatest untold secrets of history is that the 'modern world' in which we live is a unique synthesis of Chinese and Western ingredients. Possibly more than half of the basic inventions and discoveries upon which the 'modern world' rests come from China. And yet few people know this. Why?

The Chinese themselves are as ignorant of this fact as Westerners. From the seventeenth century, the Chinese became increasingly dazzled by European technological expertise, having experienced a period of amnesia regarding their own achievements. When the Chinese were shown a mechanical clock by Jesuit missionaries, they were awestruck, forgetting that it was they who had invented mechanical clocks in the first place!

It is just as much a surprise for the Chinese as for Westerners to realize that modern agriculture, modern shipping, the modern oil industry, modern astronomical observatories, modern music, decimal mathematics, paper money, umbrellas, fishing reels, wheelbarrows, multi-stage rockets, guns, underwater mines, poison gas, parachutes, hot-air balloons, manned flight, brandy, whisky, the game of chess, printing, and even the essential design of the steam engine, all come from China.

Without the importation from China of nautical and navigational improvements such as ships' rudders, the compass and multiple masts, the great European Voyages of Discovery could never have been undertaken. Columbus would not have sailed to America, and Europeans would never have established their colonial empires.

Without the importation from China of the stirrup, to enable them to stay on horseback, knights of old would never have ridden in their shining armor to aid damsels in distress; there would have been no Age of Chivalry. And without the importation from China of guns and gunpowder, the knights would not have been knocked from their horses by bullets which pierced the armor, bringing the Age of Chivalry to an end.

Without the importation from China of paper and printing, Europe would have continued for much longer to copy books by hand. Literacy would not have become so widespread. Johannes Gutenberg did not invent movable type. William Harvey did not discover the circulation of the blood in the body. It was discovered—or rather, always assumed—in China. Isaac Newton was not the first to discover his First Law of Motion. It was discovered in China.

These myths and many others are shattered by our discovery of the true Chinese origins of many of the things, all around us, which we take for granted. Some of our greatest achievements turn out to have been not achievements at all, but simple borrowings. Yet there is no reason for us to feel inferior or downcast at the realization that much of the genius of mankind's advance was Chinese rather than European. For it is exciting to realize that the East and the West are not as far apart in spirit or in fact as most of us have been led, by appearances, to believe, and that the East and the West are already combined in a synthesis so powerful and so profound that it is all-pervading. Within this synthesis we live our daily lives, and from it there is no escape. The modern world is a combination of Eastern and Western in-

gredients which are inextricably fused. The fact that we are largely unaware of it is perhaps one of the greatest cases of historical blindness in the existence of the human race.

Why are we ignorant of this gigantic, obvious truth? The main reason is surely that the Chinese themselves lost sight of it. If the very originators of the inventions and discoveries no longer claim them, and their memory of them has faded, why should their inheritors trouble to resurrect their lost claims? Until our own time, it is questionable whether many Westerners even wanted to know the truth. It is always more satisfying to the ego to think that we have reached our present situation alone and unaided, that we are the masters of all abilities and crafts. (…)

The Stirrup

For most of the time that man has been riding horses, he has had no supports for his feet. Stirrups were unknown to most of the great armies of ancient times—the Persians and Medes, the Romans, the Assyrians, the Egyptians, the Babylonians, the Greeks. The horsemen of Alexander the Great made their way across the whole of Central Asia without being able to rest their feet while in the saddle.

When galloping or jumping, horsemen had to hold the horse's mane tightly to avoid falling off. The Romans devised a kind of hand-hold on the front of the saddle which gave them something of a grip when the going got rough; but their legs just dangled whenever they were not pressed tightly against the horse.

A predecessor of the fishing reel is mentioned in the *Mo Tzu (Book of Master Mo)* which dates from about 320 BC. This book was the canon of a group of warrior-philosophers and proto-scientists, the Mohists, who made many innovations in military technology. One of their machines for warfare was an *arcuballista*, an early form of artillery which fired groups of javelins at the enemy. Javelins were too valuable to waste, so they were attached to cords and could be retrieved for re-use by means of a reel and windlass – though probably if a javelin was sticking through somebody's chest, it was left there. It is certainly ironical that this military device led to the development of that most peaceable of inventions, the fishing reel.

LEFT (63) One of the earliest surviving stirrups. It dates from the sixth or seventh century, and is preserved in the Ashmolean Museum, Oxford. This particular stirrup is bronze, but iron was also used.

DOMESTIC AND INDUSTRIAL TECHNOLOGY

THE STIRRUP

THIRD CENTURY AD

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Mounting a horse without stirrups was not so easy either. Fierce warriors took pride in their flying leaps, gripping the mane with the left hand and swinging themselves up; and some bareback riders still do this today. Cavalry-men of ancient times used their spears to help them up, either by hoisting themselves aloft as in pole-vaulting, or by using a peg sticking out of the spear as a foot-rest. Otherwise it was necessary to rely on a groom for a leg-up.

By about the third century AD, the Chinese had remedied this situation. With their advanced metallurgical expertise they began to produce cast bronze or iron foot stirrups. No inventor of the stirrup is recorded and the original idea probably came from the occasional use of a loop of rope of leather to assist in mounting. Of course, such loops could not be used for riding, because if one fell off, one would be dragged along and come to a sticky end. Such loops may have been first used by the Chinese, the Indians, or the nomads of Central Asia bordering on China. The essentials of the stirrup may thus have originated in the steppes, the product of ingenious men whose lives were lived on horseback. Apparently from the third century, the Chinese were casting perfect metal stirrups. The earliest surviving depiction of a stirrup is on a pottery

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Apparently from the third century, the Chinese were casting perfect metal stirrups. The earliest surviving depiction of a stirrup is on a pottery figure of a cavalryman found in a tomb in Changsha and dated to 302 AD.

Porcelain

Ordinary pottery is made from clay baked in a kiln at temperatures ranging from 500°C to 1150°C, and is called earthenware. Porcelain is something quite different: it consists of a body of fused clay covered by a glaze, a glassy substance, and is fired at a high temperature—about 1280°C.

The secret of making porcelain lies in the use of a pure clay, kaolin or China clay, which when fired at a sufficiently high temperature changes its physical composition, a process known as vitrification, and becomes translucent and totally impervious to water.

The reason why China was able to 'invent' porcelain at a very early age compared to the rest of the world was that the Chinese potters both found the clay and were able to produce the high temperature necessary to fuse it.

In practice, pure kaolin is mixed with 'porcelain stone,' a substance which is the intermediate product when igneous rocks decompose into clay over many millennia. Porcelain stone contains a high percentage of feldspar, which supplies the alkali as a flux to lower the vitrification temperature of

the clay and the additional silica to enhance the porcelain's translucency after vitrification.

Porcelain stone is also used for preparing high temperature glazes which also contain a strong flux such as wood ash or lime to enable the glaze mixture to turn into a glass when fired at a temperature for porcelain production.

The result is porcelain, which can often be seen through. Since the clay is opaque while the glass is transparent, the resulting fusion of the two gives a substance which is partially transparent, or translucent.

Just how astounding this was when first seen by foreigners may be judged from the remarks made by the Arabic merchant Suleiman, who wrote in 851 AD in his Chain of Chronicles of porcelain which he had seen in China: 'There is in China a very fine clay from which are made vases having the transparency of glass bottles; water in these vases is visible through them, and yet they are made of clay.'

It was incomprehensible to foreigners that pottery could be translucent and let the light through, since clay wa well known to be opaque. This seemed to be a miracle: how could one see through something which everyone knows cannot be seen through? Pots and vases through which the light could pass? Incredible! Absurd!

Porcelain was not a sudden invention which took place at a particular time. It was arrived at gradually in China. Textual evidence is hopelessly confused and vague, owing to problems of terminology, so that archeological discoveries are the only means of determining when porcelain first came into being. Fresh discoveries keep pushing back the dates further into the past. 'Proto-porcelain' or 'primitive porcelain'

made of kaolin clay, of compact texture, and surprisingly lustrous, apparently goes back to the eleventh century BC. But these wares do not have the fusion of the clay with feldspar and quartz, so that they are not true porcelains.

Historians of porcelain and ceramics are not always in agreement about when the line was crossed from 'proto-porcelain' to proper porcelain. However, it now seems that archeological finds push back the date of true porcelain to the first century AD. By the third century AD, in any case, true porcelain was undeniably in use.

By the Sung Dynasty (960-1279), porcelain had reached heights of artistry which some believe were never surpassed, and have not been equaled since. Porcelain manufacture by this time was a highly organized trade employing hundreds of thousands of people. There were teams of men who specialized in washing the clay, others who concerned themselves only with glazes, others who maintained the kilns, and so on.

One kiln of this period which has been excavated could accommodate twenty-five thousand pieces of porcelain at a single firing. It was built on the slope of a hill, the gentle incline of about 15º reducing the speed of the flames through the kiln.

The sophistication of the kilns was most impressive. Some were fired by burning of wood, while others were down-draught burners of charcoal. Flues were naturally employed, along with sophisticated layers of insulation, buttresses and clay linings. Control of the firing process was of the utmost precision.

Porcelain could be fired either in oxidizing or de-oxidizing (reducing) flames. In the Ming Dynasty, when the famous blue-and-white ware was largely produced, the best lustrous quality of the cobalt blue pigment could only be obtained at certain specific temperatures, and in a reducing flame. Various metals used as pigments spread themselves chemically throughout the bodies of the porcelain objects in quite different ways depending on whether oxygen is being taken in or given off.

A reducing flame forces porcelain to give off oxygen, leading to some of the most beautiful effects. The achieving of certain colors and effects in porcelain is therefore the result of intricate and subtle control of the firing conditions of the kilns.

The secrets of porcelain manufacture were jealously guarded, and visitors from Europe such as Marco Polo could but gape and wonder. Porcelain objects were still a very great rarity in Europe by the fifteenth century. They were gifts for kings and potentates. Not until 1520 did the first sample of kaolin clay reach Europe, brought by the Portuguese. Europeans then thought that if only they could find deposits of this white clay, they would be able to make porcelain. Frantic efforts were made to locate deposits, in ignorance of the fact that kaolin clay alone was far from sufficient for the making of porcelain.

The countless experiments carried on with various earths and solid substances in furnaces eventually had a most unpredictable result. Scientists and craftsmen began to notice that upon cooling down again, molten minerals could crystallize.

Until this began to be observed, Western scientists had been convinced that crystals could only be formed from liquids. About the middle of the eighteenth century in Europe, the idea began to gain ground that perhaps the Earth's rocks could have been formed from the cooling of molten masses of lava. Such an idea was heresy, but a heresy increasingly tolerated.

The Umbrella

The umbrella as we know it was invented in China towards the end of the fourth century AD. An earlier type, made of silk, had been used as a chariot rain-cover for many centuries; the umbrella proper appeared during the Wei Dynasty (386-532 AD). Instead of silk, it used a special kind of oiled heavy paper made from the bark of the mulberry tree, and was used as protection from both rain and sun.

The Wei Emperor used a red and yellow umbrella, whereas ordinary people used blue ones. Umbrellas became common, and in 1086 we find the author Shen Kua using the umbrella as a descriptive analogy, referring to the astronomical 'lunar mansions' in the sky as radiating from the celestial pole 'like the spokes of an umbrella.'

By the fourteenth century silk umbrellas must have been available as well as the oiled-paper ones, for in 1368 an imperial decree announced that silk umbrellas were to be reserved for the exclusive use of the royal family.

This law does not say a lot for the Ming Dynasty, which promulgated it, but perhaps the ruling cliques thought that people with silk umbrellas were getting 'above themselves.' The umbrella seems at this time to have taken a quite sym-

bolic significance. It was used in ceremonies, and the emperor would give special signed umbrellas to his most trusted officials.

How and when the umbrellas came to Europe is apparently not known. Perhaps paper umbrellas sold in China made their way to Europe, where the design was copied and its origin soon forgotten.

Matches

Every time we strike a match, we are using a Chinese invention. The first version of a match was invented in the year 577 AD by impoverished court ladies during a military siege, in the short-lived Chinese kingdom of the Northern Ch'i. Hard-pressed during the siege, they must have been so

short of tinder that they could otherwise not start fires for cooking, heating, etc.

Early matches were made with sulphur. A description is found in a book entitled *Records of the Unworldly and the Strange* written about 950 by T'ao Ku:

> If there occurs an emergency at night it may take some time to light a lamp. But an ingenious man devised the system of impregnating little sticks of pinewood with sulphur and storing them ready for use. At the slightest touch of fire they burst into flame. One gets a little flame like an ear of corn. This marvellous thing was formerly called a 'light-bringing slave,' but afterwards when it became an article of commerce its name was changed to 'fire inch-stick.

There is no evidence of matches in Europe before 1530. Therefore, the Chinese were using them for just short of a thousand years before they arrived in Europe. Matches could easily have been brought to Europe by one of the Europeans traveling to China at the time of Marco Polo, since we know for certain that they were being sold in the street markets of Hangchow in the year 1270 or thereabouts. This is recorded in one of the six-and-a-half thousand ancient topographical books which survive about regions and cities of China.

Chess

Although most historians of chess believed that the game was invented in India, Needham has been able to establish that it originated in China.

Chess took its present form as a militaristic combat game in India but its origins were connected with astrology, magnetism and divination. According to Needham: 'The battle element of chess seems to have developed from a technique of divination in which it was desired to ascertain the balance of ever-contending yin and yang forces in the Universe (sixth-century AD China, whence it passed to seventh-century AD India, generating there the recreational game).'

The surviving form of 'Chinese chess' played today is not the same either as the ancient Chinese forms or as modern Western chess. This has led various scholars to overlook the game's Chinese origins.

The Mechanical Clock

The difficulty in inventing a mechanical clock was to figure out a way in which a wheel no bigger than a room could turn at the same speed as the Earth, but still be turning more or less continuously. If this could be accomplished, then the wheel became a mini-Earth and could tell the time. For, after all, the time is nothing more nor less than how far the earth has turned today.

Accomplishing this mechanical feat was one of the greatest steps forward of the human race. Where would we be today without clocks? The mechanical clock was invented in China in the eighth century AD. But still in 1271, Robertus Anglicus in his commentary on the *Sphere* of Sacrobosco tells us that in Europe 'artificers are trying to make a wheel which will pass through one complete revolution for every one of the [Earth's], but they cannot quite perfect their work. If they could, it would be a really accurate clock, and worth

more than any astrolabe or other astronomical instrument for reckoning the hours.'

By 1310, this had finally been achieved in Europe. And the stimulus for it seems to have been some garbled accounts of Chinese mechanical clocks which came to the West by way of traders. This was the same century that brought to Europe the Chinese inventions of gunpowder, segmental arch bridges, cast iron, and printing.

Apart from the fact that the Chinese are obviously an inventive people, what other factors can account for the fact that they were the first to invent mechanical clocks? Was there some special reason why they urgently needed to know the hours of the day and the days of the year with a precision not required in Europe? The answer is yes, but few could possibly imagine why.

The Chinese emperor was a cosmic figure, the equivalent on Earth of the Pole Star. His every move was regulated in conjunction with astrology. His heir was not necessarily his eldest son. Many examples of Chinese history exist of fourth sons, or other lesser offspring, being selected as the next emperor. How, then, was it determined who should be the heir? Part of the process of selection involved the astrological computation of the moment of the child's conception (since in China horoscopes commence at the estimated time of conception rather than at birth). And the moments when conception might take place were carefully set aside for the highest-ranking wives and concubines of the emperor to sleep with him. Access to the emperor's person had to be precisely timed in order for this to work properly. From the *Record of Institutions of the Chou Dynasty* compiled about

the second century BC, we find the following astonishing passage about the emperor's sex life:

> The lower-ranking women come first, the higher-ranking come last. The assistant concubines, eighty-one in number, share the imperial couch nine nights in groups of nine. The concubines, twenty-seven in number, are allotted three nights in groups of nine. The nine spouses and the three consorts are allotted one night to each group, and the empress also alone one night. On the fifteenth day of every month the sequence is complete, after which it repeats in reverse order.

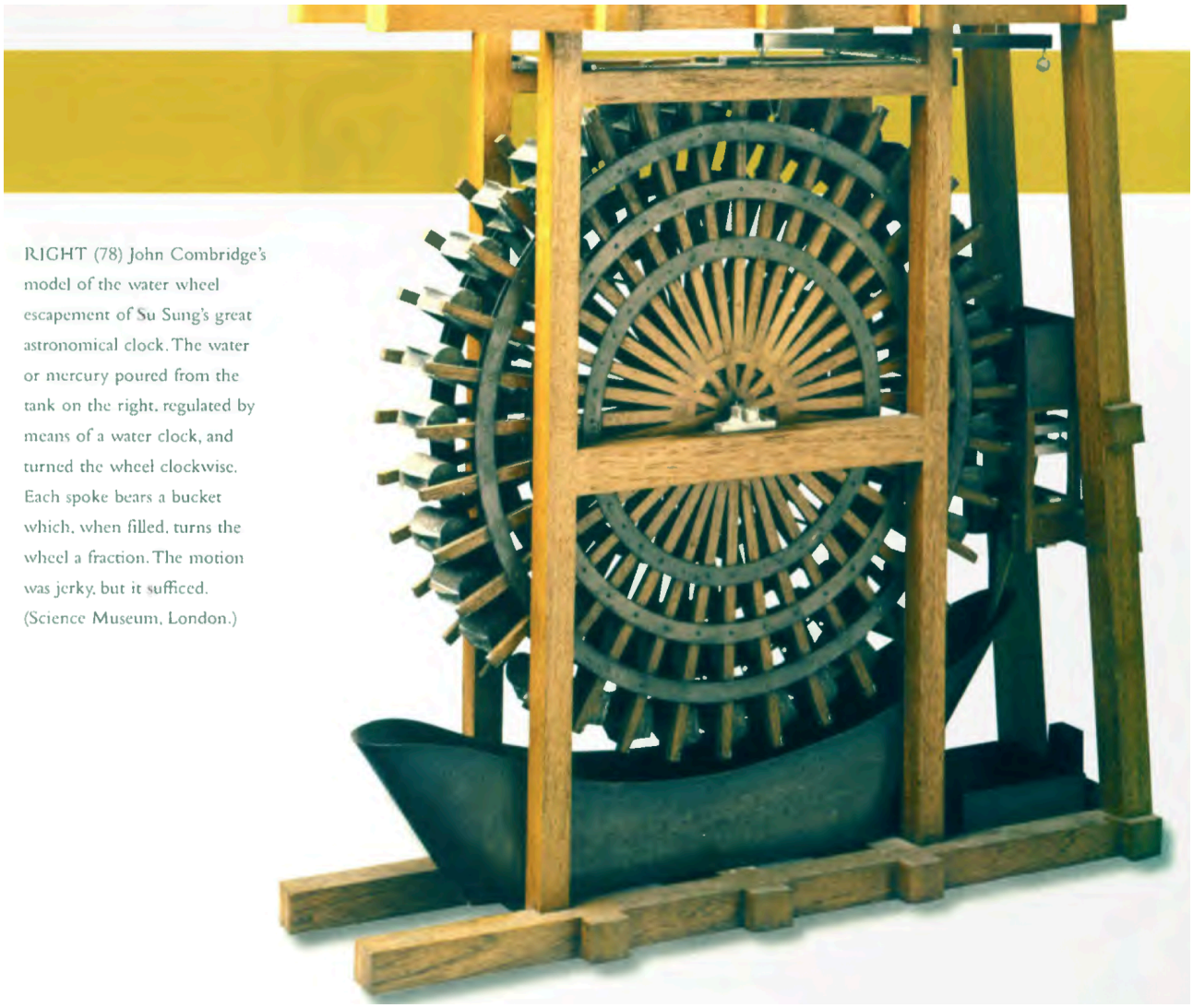
The emperor, known as the Son of Heaven, was full of a powerful *yang* force, which was the essence of masculinity. But he needed to be fed with a matching *yin* force, the essence of feminity, to achieve a balance. At the time of the full moon, when the *yin* force was at its peak, the empress would sleep with the Son of Heaven, feeding him with her powerful *yin*. This would be the most propitious time for a conception to take place. The lesser women, during the time of the Moon's waning, had to sleep with the emperor in groups in order to pool their respective *yin* forces to overcome the lack of the Moon's strength. For most of the nights of his life, therefore, the emperor slept with nine women at a time.

If a likely lad were to be chosen to be the next emperor, the astrologers would go back to the precise time of his conception, plot the stars which were culminating and consider any comets or novae, or other astronomical phenomena. If the astrological configurations were indicative of a strong leader, a valiant warrior, or whatever, this would weigh in the young prince's favor. But the eldest son might well have been born under the influences of stars concern-

ing death or disaster. So he would be ruled out quite early on.

But let us see what the situation was at about the time when the mechanical clock was invented in China. Was the succession principle operating very well? In the ninth century, Tai Hsing-Chien bewails the chaos of the system. We read in his *Poetical Essay of the Supreme Joy:*

> Nine ordinary companions eery night, and the empress for two nights at the time of the full moon—that was the ancient rule, and the secretarial ladies kept a record of everything with their vermilion brushes … But alas, nowadays, all the three thousand palace women compete in confusion.



RIGHT (78) John Combridge's model of the water wheel escapement of Su Sung's great astronomical clock. The water or mercury poured from the tank on the right, regulated by means of a water clock, and turned the wheel clockwise. Each spoke bears a bucket which, when filled, turns the wheel a fraction. The motion was jerky, but it sufficed. (Science Museum, London.)

Clearly, the succession to the throne was in peril. Bad princes might be chosen. The timing of their conceptions was not being noted properly. Time for a clock to be invented! And in 725 AD, this was done.

The Chinese did not invent the first clock of any kind, merely the first mechanical one. Water clocks had existed since Babylonian times, and the earliest Chinese got them indirectly from that earlier civilization of the Middle East, just as they got much of their earliest forms of astronomy from them. The Chinese certainly did invent improved water clocks of various kinds, including a 'stop-watch' portable one which used mercury rather than water and measured small periods of time. It used weighted balances, or steelyards, rather than just a rising indicator in a bucket as water flowed in and buoyed it up. But these were improvements of an invention of either the Greeks or the Romans, and is mentioned by the architectural writer Vitruvius in the first century BC.

Paper

Although the word 'paper' is derived from the word 'papyrus,' paper and papyrus have nothing whatever to do with one another. Papyrus, which existed in Egypt as early as the third millennium BC, is made from the inner bark of the papyrus plant *(Cyperus papyrus)*. Apart from the fact that it gives a sheet on which one can write, it is completely and totally different from paper. The Chinese invented paper, by the second century BC at the latest.

Paper in the modern world is mostly made of wood pulp. But, just to confuse the issue even more, paper in ancient

times was never made of wood pulp. So, what then is paper?

Paper is the sheet of sediment which results from the settling of a layer of disintegrated fibers from a watery solution onto a flat mould, the water being drained away, and the deposited layer removed and dried. The fibers can be of any material whatever, though plant fibers are by far the most commonly used ones, and fibers from trees are the mainstay of the paper industries today. The earliest European paper was not made of wood pulp, but of disintegrated and pounded rags of linen. Anyone who owns or has handled a book printed in the seventeenth century in Europe will be aware of how durable and springy the paper is; this paper is made of linen, and it will still be youthful and fresh when most of the books printed in the twentieth century have disintegrated to dust.

The oldest surviving piece of paper in the world was discovered by archeologists in 1957 in a tomb near Sian in Shensi Province, China. It is about 10 cm square and can be dated precisely between the years 140 and 87 BC. This paper and similar bits of paper surviving from the next century are thick, coarse, and uneven in their texture. They are all made from pounded and disintegrated hemp fibers. From the drying marks on them, it is evident that they were dried primitively on mats woven as pieces of fabric, not on what we know as paper moulds. In these early days, the water just drained slowly through the underlying mat of fabric, leaving the paper layer on top. This was then peeled off and dried thoroughly. But so thick and coarse was the result that it could not have been very satisfactory for writing.

However, paper does not appear to have been used as a medium for writing until a considerable time after its invention. The old surviving piece of paper in the world with writing on it was discovered under the ruins of an ancient watchtower in Tsakhortei near Chü-yen in 1942. The watchtower was abandoned by Chinese troops during the rebellion of the Hsich'iang tribe, and the paper can thus be dated to 110 AD. It contains about two dozen readable characters.

It is probable that paper was in use for a century or more in China before its possibilities as a medium for writing were noticed. Its earliest uses were in connection with clothing, wrapping, lacquerware and personal hygiene. A text of 93 BC records an imperial guard recommending to a prince that he cover his nose with a piece of paper—the first Kleenex! A record of a murder case from 12 BC notes that the poison used had been wrapped in red paper. By the time of the Emperor Kuang-Wu (reigned 25-26 AD), an official of the imperial secretariat was already responsible for 'the seals and cords of office, and for paper, brush, and ink.'

The use of paper for clothing may at first seem strange; we think of paper as being thin today, and hardly the proper material to keep out the cold. But the use of paper as protective clothing against the cold was practiced by the Chinese from the second century BC onwards. We are not certain when the Chinese in the south began making paper of the bark of the mulberry tree, but the pounded bark of this remarkable tree was found to be serviceable for clothing from an early date. And it would seem that not long after paper proper was invented, the disintegrated fibers of pa-

per-mulberry bark were employed, as well as the more common hemp, to make real paper.

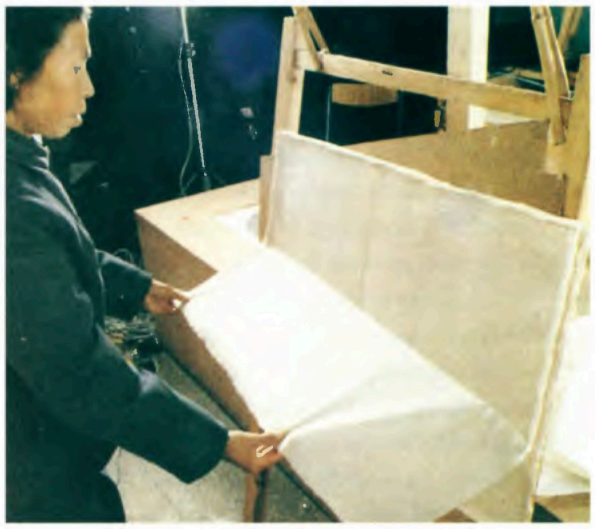
BELOW (54) A late-eighteenth-century painting showing the manufacture of paper. The large vat contains a watery solution of disintegrated fibres. A mould (with mesh screen, similar to the one resting on the side, at left) is being lifted from the vat and drained. The remaining layer of sediment will be dried and peeled away as a sheet of paper. The piles of paper sheets resulting from this process are at the right, resting on planks over the vat. (Victoria and Albert Museum, London.)

However, the earliest uses of paper were derived from the simple pounded bark of this tree. We know that in the sixth century BC, a disciple of Confucius named Yüan Hsien from the State of Lu wore a hat made from paper-mulberry bark. The historian Ssuma Ch'ien records that in the second century BC, huge quantities of this substance were in commercial circulation. A paper hat, a paper belt, and a paper shoe dating from 418 AD were discovered in an excavation at Turfan, and reported in 1980.

But surely articles of clothing made from paper were too flimsy? Perhaps the inferior paper of today, made from wood

pulp, would be. But the paper of those days made from much stronger and tougher fibers, was not. So tough was paper that it was frequently used as a shoe liner. And paper clothing was so very warm and impenetrable by cold winds that people complained that it allowed no circulation of air round the body and was too hot to wear! Beds in winter were kept warm with paper curtains, and thin curtains, also of paper, were used as mosquito nets.

ABOVE (55) A modern demonstration of the traditional Chinese method of paper manufacture at the Ontario Science Centre. Here, the mesh screen mould is being lifted from the vat with its watery solution of disintegrated fibres. Although most paper in the modern world is made from wood pulp, the Chinese never used it, preferring the stronger fibres of linen and a variety of other plant materials, most of which would be too expensive for mass manufacture today.



ABOVE (56) A later stage of the modern demonstration at the Ontario Science Centre. Here, the layer of sediment accumulated on the mould from the vat has dried and is being delicately peeled off – a sheet of paper. Paper (which is completely different from papyrus) was invented in China by the second century BC, but did not reach Europe until a thousand years later. Its secret remained undiscovered for another four hundred years after that, and paper was not made in Europe until the twelfth century.

The poet Lu Yu wrote a letter to the philosopher Chu Hsi about the year 1200, thanking him for the gift of a paper blanket. The letter survives, and we are able to enjoy the amusement of reading Lu Yu's rapturous account: 'I passed the day of snow by covering me with a paper blanket. It is whiter than fox fur and softer than cotton.'

Not only was paper used for clothing, it was used for military armor! In the ninth century a provincial governor named Hsü Shang is recorded as keeping an army of a thousand soldiers ready at all times clothed in pleated paper armor which could not be pierced by strong arrows. Paper armor became common on land and at sea. When two pirate ships surrendered in an amnesty in the twelfth century, 110 suits of paper armor were handed over by them. And in the twelfth century, Chen Te-Hsiu is recorded as saying that he had sufficient weapons at his fort for defense, but of his hundred sets of iron armor, he had kept half of them and traded in the other fifty for sets of the better paper armor. Even bullets from guns were said to be unable to pierce good paper armor, as we read in this account in 1620 by Mao Yüan-I:

> Armor is the basic equipment of soldiers, with which they are able to endure without suffering defeat before sharp weapons. The terrain in the south is dangerous and low, and where for soldiers are generally employed they cannot take heavy loads on their backs when traveling swiftly. If the ground is wet or there is rain, iron armor easily rusts and becomes useless. Japanese pirates and local bandits frequently employ guns and firearms, and even though armor made of rattan or of horn may be used, the bullets can nevertheless pierce it. Moreover it is heavy and cannot be worn for too long. The best choice for foot soldiers is paper armor, mixed with a variety of silk and cloth. If both paper and cloth are thin, even arrows can pierce them, not to say bullets; the armor should, therefore, be lined with cotton, one inch thick, fully pleated, at knee length. It would be inconvenient to use in muddy fields if too long and cannot cover the body if too short. Heavy armor can only be used on ships, since there soldiers do not walk on muddy

fields. But since the enemy can reach the object with bullets, it could not be defended without the use of heavy armor.

The Chinese also invented wallpaper, apparently as a result of hanging up large printed paper sheets which it was found more convenient to glue to the walls. Wallpaper was brought to Europe from China in the fifteenth century by French missionaries.

As for the sanitary uses of paper, there are some staggering statistics for this from China. In 1393, the Bureau of Imperial Supplies manufactured 720,000 sheets of toilet paper, measuring 2 feet by 3 feet each, for the use of the imperial court for one year. In addition, 15,000 special sheets, 3 inches square, 'thick but soft, and perfumed' were prepared for the exclusive use of the imperial family for the same year. Toilet paper was generally made from rice straw fibers, which were cheap and easy to process. Untold millions of sheets of toilet paper were in use in the Middle Ages. In and around the year 1900 in the province of Chekiang alone, the annual production of toilet paper amounted to ten million packages of between 1000 and 10,000 sheets each. This means that Chekiang was producing between ten and one hundred billion sheets per year at a time when barely any at al was presumably used in the West. If we multiply the Chekiang statistics to take in the whole of China, it means that many thousands of billions of sheets of toilet paper were being used there a century ago. How far back did the use of toilet paper go in China? We can trace it in texts from as far back as the sixth century, when the scholar official Yen Chih-T'ui wrote in 589: 'Paper on which are quotations or commentaries from the Five Classics or the names of sages, I

dare not use for toilet purposes.' And an Arab of 851 wrote: 'They [the Chinese] are not careful about cleanliness, and they do not wash themselves with water when they have done their necessities; but they only wipe themselves with paper.'

The other uses of paper in China were so many that it would take too long to enumerate them in this volume. Obviously paper was important for the making of kites, another Chinese invention and the Chinese were also the world's leading paper-folders, as well as paper-cutters for decorative designs. Some ancient paper flowers survive to this day, and the art of *origami* (fancy paper-folding), which originated in China, is now popular around the world.

Paper umbrellas and paper money both originated in China. The large number of substances whose fibers were used for Chinese paper-making make a study in themselves, and include bamboo, straw of rice and wheat, sandalwood, hibiscus, seaweed, floss silk from silk cocoons, rattan, flax, and ramie. Chronologically, hemp was the main material in earliest times, followed by paper-mulberry fibers, then rattan, then bamboo, and later straw. All sorts of fancy, perfumed, glossy and other special papers were prepared in China, some of which probably excel any which have ever been produced in the West.

Paper reached India in the seventh century and West Asia in the eighth century. For five centuries the Arabs jealously guarded the secret of paper-making and would not reveal it to Europeans, but sold them paper instead—at great profit. The Arabs had learned the techniques of paper manufacture from some Chinese prisoners of war captured after a battle

at Samarkand. Europe obtained its first paper through the Arabs at around the end of the eighth century. However, the next signs of paper being used in Europe date no earlier than the eleventh century, and paper seems to have been slow to replace papyrus in the West. The first manufacture of paper in Europe dates from the twelfth century, and it was not until the thirteenth century that an Italian paper industry could be said to be in full swing. This is fifteen hundred years after its invention in China.

Paper Money

The Chinese invented paper money at the end of the eighth or beginning of the ninth century AD. Its original name was 'flying money' because it was so light and could blow out of one's hand. The first paper money was, strictly speaking, a draft rather than a real money.

A merchant could deposit his cash in the capital, receiving a paper certificate which he could then exchange for cash in the provinces. This private merchant enterprise was quickly taken over by the government in 812. The technique was then used for the forwarding of local taxes and revenues to the capital. Paper 'exchange certificates' were also in use. These were issued by government officials in the capital and were redeemable elsewhere in commodities such as salt and tea.

Real paper money used as a medium for exchange and backed by deposited cash, apparently came into being early in the tenth century, in the southern province of Szechuan, as a private enterprise. Early in the eleventh century the government authorized sixteen private businesses or 'banks'

to issue notes of exchange; but in 1023 the government usurped this private enterprise and set up its own official agency to issue bank notes of various denominations which were backed by cash deposits. We can thus probably date the worlds' first governmental currency reserve bank to 1023.

The money issued by this bank had printed on it a notice to the effect that it was good for only three years, and gave the dates. Such a time limit was to be a regular feature of Chinese paper money up until the nineteenth century. By 1107, notes were being printed with multiple blocks in no less than six colors.

The issuing of paper money by the government took on enormous proportions. By 1126, seven million strings (each string being equal to one thousand pieces of 'cash') had been officially issued. Vast amounts of this paper money were not backed by any deposits, and a horrifying inflation occurred. Inflation may be looked upon as a phenomenon which accompanies paper money, arising from its not being backed by anything more substantial.

Other forms of 'inflation' in history should probably be differently described. Accelerating price increases before the use of paper money, such as occurred so scandalously under the Roman Empire, was often caused by debasement of the coinage. The Roman Empire is infamous for having produced fixed valuation coinage out of increasingly cheap and worthless materials.

There was also the deleterious process known as 'clipping' whereby not only individuals but sometimes governments themselves issued and circulated coins with pieces cut off them. The real value of such clipped coins was of course diminished, though the fiction was supposed to be maintained that they were worth the same as ever. But debasements and clipping of coinage should surely be differentiated from true inflation, which resulted from the issuance of paper money and was thus 'invented' in China along with the paper money that gave rise to it.

Another problem which soon arose in China was counterfeiting. If precious metal coins are in circulation which are intrinsically worth their true value, the only kind of counterfeiting possible is with false, disguised metals. This has often been done, and was a major impetus to alchemy, and the

manufacture of spurious gold and silver. But paper money invited counterfeiting by its very nature, since the essence of it is not its inherent substance but the authority on which it was issued. Paper money is a symbol. To counterfeit is therefore not to fabricate a substance but to impersonate the authority issuing it. Since anyone can print on pieces of paper, the authority must make the processes of manufacture of its paper money so intricate that they cannot be exactly reproduced.

Complex manufacturing secrets were thus adopted quite early, and included multiple colorings, immensely complex designs, and a mixture of fibers in the paper. The basic material for the paper of paper money was the bark of mulberry trees, and silk was sometimes incorporated. One could hand

in soiled or worn-out notes for new ones, but had to pay the small cost of the printing of the replacement.

A detailed case of a counterfeiter of 1183 survives, which tells us that he printed 2600 false notes during the six-months period before he was caught. He was a master block-cutter, and he cut a block of pearwood in direct imitation of the design on a real note. It was a three-color process, involving sequential serial number in blue and seals in red. It took the counterfeiter only ten days to cut the block. But counterfeiters did not have an easy time of it when they were caught, for their crime carried the death penalty.

When the Mongols came to power in China they issued a quaint form of paper money called 'silk notes.' The deposits behind this currency were not precious metals but bundles of silk yarn. All older money had to be cashed in an ex-

change for silk notes, and the Mongols spread this unified currency all over the Empire and even beyond it. By 1294, Chinese silk notes were being used as money as far afield as Persia. In 1965, two specimens of 'silk notes' were found by archeologists.

When Marco Polo visited China, he was so impressed by paper money that he wrote a whole chapter about it, describing everything about its manufacture and circulation. He described the manner it was issued:

> All these pieces of paper are issued with as much solemnity and authority as if they were of pure gold or silver; and on every piece a variety of officials, whose duty it is, have to write their names, and to put their seals. And when all is duly prepared, the chief officer deputed by the Kan smears the Seal entrusted to him with vermilion, and impresses it on the paper, so that the form of the Seal remains printed upon it in red; the Money is then authentic. Anyone forging it would be punished with death.

Paper money under the later Ming Dynasty was not so effective. The Ming issued in 1375 a new note called the 'Precious Note of Great Ming.' It was issued in one denomination only through the two hundred years in which it was a legal tender. This was naturally very inconvenient for all commercial purposes, although copper coins were permitted to circulate, and these must have provided the small change necessary in everyday life. Through inflation, the Precious Note gradually lost its value and was replaced by silver. In the middle of the seventeenth century, the Ming tried to reinstate paper money after a lapse of about two centuries, but it was badly implemented, resulting in great inflation, and failed. Paper money on a national scale and a regular

basis died out until European influence brought it back in modern times.

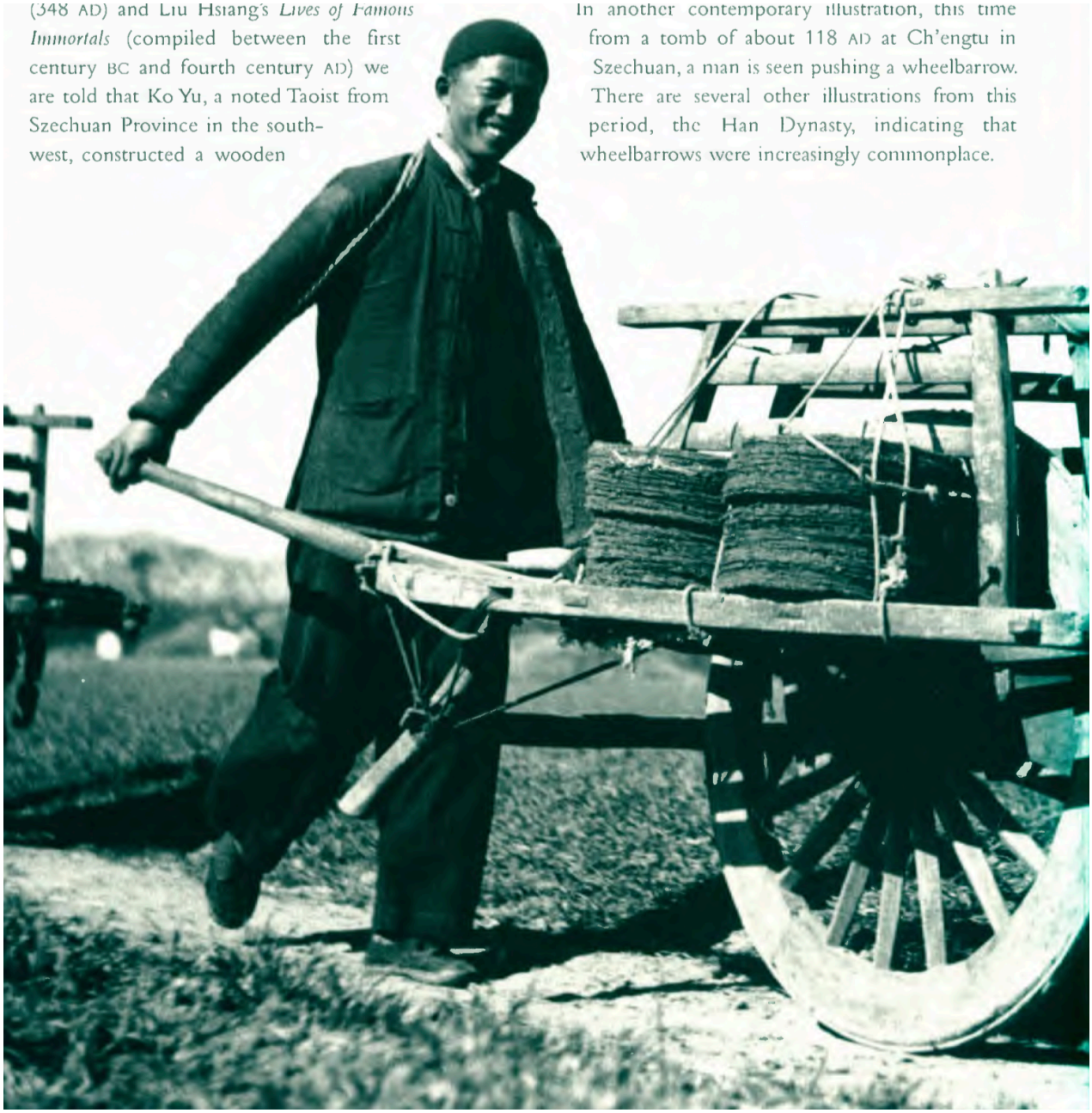
When the older methods of paper money issuance became known in the West, they had a profound influence on Western banking. The old Hamburg Bank and the Swedish banking system were set up on Chinese lines. Thus, some of the fundamental banking procedures of the Western world came from China directly. The first Western paper money was issued in Sweden in 1661. America followed in 1690, France in 1720, England in 1797, and Germany not until 1806.

The Wheelbarrow

It may seem difficult to believe, but wheelbarrows did not exist in Europe before the eleventh or twelfth century. The earliest known Western illustration of a wheelbarrow is in a window at Chartres Cathedral, dated about 1220. Considering that the use of wheelbarrows could cut the number of laborers required for any building project by half, the lack of them before this must have been as appalling as the welcome of them must have been ecstatic.

The wheelbarrow was apparently invented in south-western China in the first century BC by a semi-legendary personage called Ko Yu. We say 'apparently' because, first, it may have existed before that and, secondly, Ko Yu may either have been an actual individual of that name, or otherwise may be a sort of artisan's deity for wheelbarrow-makers. In both *Kan Pao's Reports on Spiritual Manifestations* (348 AD) and Liu Hsiang's *Lives of Famous Immortals* (compiled between the first century BC and fourth century AD) we are

told that Ko Yu, a noted Taoist from Szechuan Province in the southwest, constructed a wooden goat or sheep and rode away into the mountains on it. This was a conventional early way of speaking of wheelbarrows, for in the third century AD, wheelbarrows constructed by Chuko Liang were called a 'wooden ox' and a 'gliding horse.' The former was said to be pulled by shafts in front, while the latter was said to be pushed by shafts behind.



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In another contemporary illustration, this time from a tomb of about 118 AD at Ch'engtu in Szechuan, a man is seen pushing a wheelbarrow. There are several other illustrations from this period, the Han Dynasty, indicating that wheelbarrows were increasingly commonplace.

The oldest surviving picture of a wheelbarrow dates from about 100 AD. It is a frieze relief from a tomb-shrine excavated near Hsüchow, which very clearly shows a wheelbarrow with a man sitting on it. In another contemporary illustration, this time from a tomb of about 118 AD at Ch'engtu in Szechuan, a man is seen pushing a wheelbarrow. There are several other illustrations from this period. the Han Dynasty, indicating that wheelbarrows were increasingly commonplace.

The earliest descriptions of the construction of wheelbarrows are couched in coy and obscure language. For the first few centuries, wheelbarrows were of great military importance, and specifics of their construction were closely guarded secrets. Various sorts were produced which could carry hundreds of pounds each. Some carried men on seats, and others carried supplies. Huge numbers of them were used to supply armies fighting in difficult, hilly terrain, in which China abounds. Many battles could never have been fought and won without wheelbarrow supply brigades. Another use of wheelbarrows was to form protective movable barriers against cavalry charges, which could be arranged in any shape at a moment's notice. The ingenuity of the Chinese at exploiting the wheelbarrow was limitless, and they were even given sails, with which they could achieve speeds over land or ice of 40 miles per hour.

Scenes from medieval China showing wheelbarrows abound. We are fortunate that a great painting by Chang Tse-Tuan of the city K'aifeng (then the capital in the year 1125) survives, in which various types of wheelbarrow may be seen. An empty one stands before a draper's shop, while

a loaded one passes a dyeing establishment. Another is seen being loaded with sack-like objects outside the best hotel, while beside it in the street passes one so heavily laden that a mule pulls it, with one man pushing and another man pulling. Wheelbarrows were thus ubiquitous features of Chinese life—and still by this time they had not yet reached Europe.

A large variety of designs existed, some with wheels in the dead center, with the weight resting entirely on the axle, and others with wheels forward as they are today in the West. Some had tiny wheels, some had huge ones. Additional small wheels were sometimes fitted in front to ease the passage over potholes and other obstacles. Practically any shape and size of wheelbarrow existed—and still exists—in China. Many of these designs have still not passed beyond the confines of China and made their way West, despite the fact that, for particular uses, many of them are far superior to the kind Westerners generally use. One can honestly say that the wheelbarrow in all its forms is still an invention which the West has yet to discover!

Printing

Woodblock printing on paper and silk arose in China around the seventh century AD, and actual specimens survive from the eighth century. But the origins of printing go even further back into the distant past: there were many related techniques which preceded printing.

First, seals were used to stamp impressions of names, and even as many as a hundred Chinese characters at once, onto various surfaces. The Chinese got the idea of seals from the

Middle East, where the Babylonians and Sumerians used them in profusion long before the Chinese civilization arose. Cutting a seal is rather like cutting a woodblock in printing, and it is easy to see how the latter technique derived its inspiration from the former. But that is quite different from saying that the idea of using seals *led to* printing. This did not happen with the Sumerians or Babylonians. It was the need to make enormous numbers of copies of certain writings which led the Chinese to invent ways of mass-producing written material on paper, a substance which already existed in China.

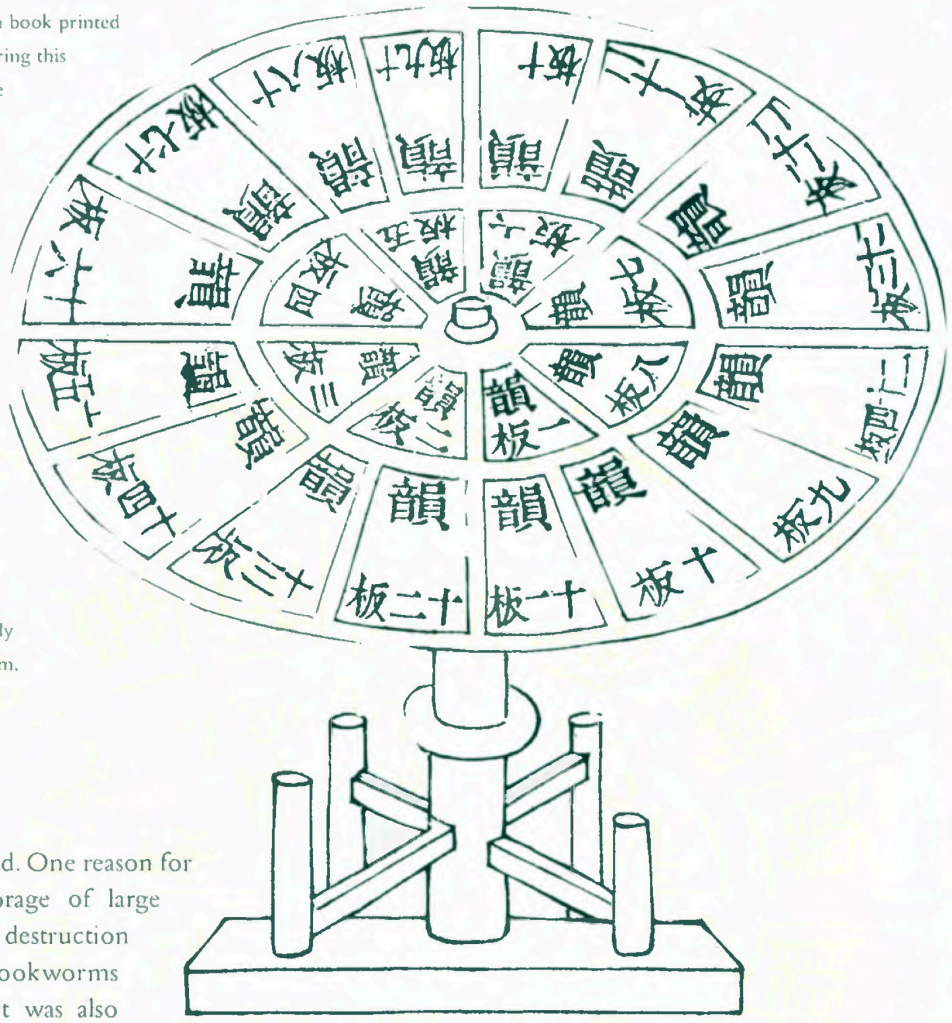
Another proto-printing technique in China was connected with bronze casting. Chinese characters were often incorporated in the designs of Chinese bronzes. But a close study of these bronzes shows that the characters were set into the moulds either separately or in small groups. (This was especially the case when the 'lost-wax' method of bronze casting was used). We therefore find bronze inscriptions using the forerunner of movable type as early as in the seventh century BC. Individual typecasting was therefore in progress nearly two millennia before it was adopted for printing.

Other means of mass-producing written scriptures and sacred texts were by ink rubbings from stone carvings of the original writings. Stone inscriptions of promulgated decrees occur for the least the third century BC. By the second century AD, stone was used to preserve permanent canonical versions of Buddhist, Taoist, and Confucian texts. Between the years 175 and 183, the complete texts of the seven main

Confucian classics, amounting to 200,000 characters, were engraved on forty-six stone tablets. These do not survive, but a similar set made between 833 and 837 still exists near Sian, and is known as the *Forest of Stone Tablets.* Also still surviving are 7000 stone tablets of Buddhist scriptures carved between the sixth and eleventh centuries.

The Chinese were the world's leading experts at stone-rubbing. The devout of all Chinese religions came with their ink and sheets of paper and made as many copies of the standardized sacred texts as they wanted. And indeed this

was done constantly. But just as supply sometimes generates demand, so the availability of rubbings and scriptures seems to have acted as a tempting teaser: many people could now have the scriptures in their homes. But many was not most; for every person who had a rubbing there must have been a dozen who were encouraged to want their own. This new demand must have been an important stimulus leading to the development of actual printing.



RIGHT (81) This drawing is from a book printed in 1313 called (surprisingly, considering this subject: the reason being to illustrate the rotating wheel) the *Treatise on Agriculture* (*Nung Shu*). It shows a wheel-shaped rotating case for the classified storage of fonts of movable type, which were invented circa 1045 by Pi Sheng. All the characters were either carved into wooden fonts or cast into metal fonts and stored according to their rhyming spoken sounds, in twenty-four compartments, consisting of eight inner ones and sixteen outer ones. By spinning the compositor's wheel round, the pieces of type were readily accessed according to this easy system, making for speedy typesetting.

more copies were in demand. One reason for cutting down on the storage of large quantities of copies was the destruction regularly wrought by bookworms in some areas of China. It was also

The Chinese also used stencils and composite inked squeezes, the former being used particularly by the Buddhists. Paper had a pattern made in it consisting of rows of tiny dots. It was then pressed down on top of a blank sheet, ink was applied to the back, and a stenciled design in ink

was the result. This was indeed very close to printing, for it enabled the cheap reproduction of a quantity of clear images—such as the Buddha sitting in meditation.

The composite inked squeezes were remarkable in that in a curious sort of way they anticipated photography. Using these sophisticated techniques, three-dimensional objects could be represented on flat paper with perspective, but with no problems of focus (i.e., no 'depth of field' problem existed). Rubbings would be taken of round bronze vessels whereby the more distant parts would be inked more lightly, and the nearer parts more heavily—giving the perspective effect to an eerie and uncanny degree. Inscriptions and decorations in three dimensions represented on paper could be carried around and kept in multiple copies in the home.

This technique was known as 'whole shape rubbing' and it necessitated very careful study and preparation before being attempted. It ranks as one of the most highly skilled crafts ever practiced anywhere. A good 'whole shape rubbing' looks so startlingly like a photograph in perfect focus that it seems nothing short of an inventor's miracle.

All of these techniques were still not sufficient for the needs of the Chinese. Foremost in pushing back the frontiers of printing technology were the Buddhists; they simply had to have many more copies of their sacred texts than hand-copiers and proto-printing could produce. Therefore it was no accident that the earliest printed text in the world was a Buddhist charm scroll printed in China and preserved in the Pulguk-sa Temple in Kyongju, south-east Korea, where

it was discovered in 1966. It was printed some time between the years 704 and 751.

The print runs of the eighth century were quite literally fantastic—almost unimaginable even by modern standards. The Buddhists took the new technology to Japan where the same Buddhist *sutra* of the Korean scroll was used as the source of a printed charm, and produced in a print run of *one million copies!*

Many of these copies still survive today, even though they were printed in 764 AD.

The first complete printed book is thought to be the Buddhist *Diamond Sutra,* printed in the year 868 and discovered by Sir Aurel Stein in 1907. It is preserved in perfect condition in the British Museum. It consists of a scroll 17 ½ feet long and 10 ½ inches wide and contains the complete text of a Sanskrit work translated into Chinese, with a very elaborate and impressive frontispiece showing the Buddha in discourse with his disciple Subhuti, surrounded by attendants and divine beings. It bears a colophon at the end which says: 'On the fifteenth day of the fourth moon of the ninth year of Hsien-t'ung [868 AD], Wang Chieh reverently made this for blessings to his parents, for universal distribution.'

There were also large print runs for ordinary books. For instance we know that between 847 and 851 several thousand copies were printed of a biography of the alchemist Liu Hung.

Calendars were also very popular in printed form, and were even personalized. One calendar surviving from the year 882 is headed: 'Family calendar of Fan Shang of Ch'eng-tu-fu in Hsi-ch'uan, province of Ch'ien-nan.'

So many of these privately printed calendars were circulated that as early as 835, a regional official in the southern province of Szechuan suggested that they be banned—because they were being sold in marketplaces before the Board of Astronomers could approve and issue them, thus preempting and anticipating the government's important prerogative. (Chinese emperors looked upon it as a sacred and politically essential matter to revise and promulgate calendars; hundreds were produced during Chinese history.)

By the tenth century, *belles lettres* and philosophy were fully represented in print. Collections of the works of individual poets were being printed for them and circulated to friends. The scholar Ho Ning (898-955) collected his poems and songs and had printed several hundred copies as gifts for his friends; in 913, the Taoist monk Tu Kuang P'ing printed his own commentary upon the classic of Lao Tzu, the chief Taoist sage.

During the tenth century, the prime minister Feng Tao decided to print the eleven classics of Confucianism, together with two supplementary books. Feng Tao managed to survive ten reigns of five different dynasties—a miracle of political survival in a troubled time—which alone enabled him to complete his gigantic task. Finally, after twenty-two years, the Confucian classics were printed in 953. Filing 130 volumes, they were the world's first official printed publications, sold to the public by the Chinese National Academy.

By this time, printing had come of age. Vast quantities of certain works continued to be issued, ranging into many millions of copies. Of one Buddhist collection of the tenth century, over 400,000 copies still survive. So we can imagine

what the initial print run must have been! Twenty thousand copies of a printed picture of a goddess on silk still survive from that century, and 140,000 of a picture of a pagoda from the same period. Three other works of that time survive in quantities of 84,000 copies each. Also, during the tenth century, paged books were produced in the modern style, replacing the earlier printed scrolls. This, then, was the establishment of a woodblock printing industry which in the quantities produced rivaled the most modern efforts of our own times.

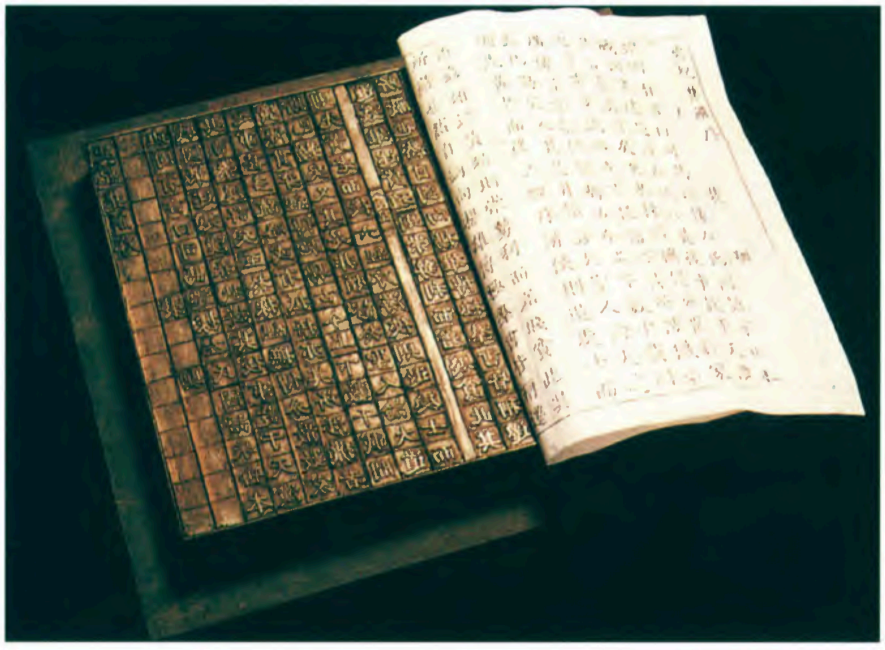
The blocks used by the Chinese for their printing tended to be made of fruit woods. Coniferous woods were found unsuitable, because they were impregnated with resin which affected the evenness of the ink coating. For cutting delicate lines in illustrations, a favorite material was the extremely hard wood of the Chinese honey locust tree. For regular text, the soft and easily worked boxwood was often used. But the best all-round wood for block printing was pear: this has a smooth and even texture with a medium hardiness, and can be carved in any direction with no grain problems. The slightly harder wood of the jujube date tree was probably the second most commonly used. Naturally, there had to be no knots or spots in the wood, and after cutting the blocks it was customary to soak them in water for a month. But if there was insufficient time, they were boiled, then left to dry in a shaded place and planed on both sides, for it was common to print pages simultaneously on each side of a block. Vegetable oil would be spread over the planed surface, which would be polished with the stems of polishing grass.

Printing blocks were normally kept for long periods of time—sometimes centuries—in the same family. Large print runs of books tended not to be the rule: a few tens of copies would be run off, then the blocks would be stored away until a few dozen more copies were in demand. One reason for cutting down on the storage of large quantities of copies was the destruction regularly wrought by bookworms in some areas of China. It was also economically advantageous to wait for orders before buying the paper.

Korea was the first country to which printing spread from China, around the year 700. Many old printing blocks survive: at the Haein-sa Temple high on Mount Kaya in southern Korea, 81,258 blocks of magnolia carved on both sides are preserved intact today, which were used to print a Buddhist classic between the years 1237 and 1251.

Such a large number of printing blocks would not have been exceptional in China. Chinese printing was on a large enough scale to cope with the country and its population, and one individual printer in Chiangsu in the seventeenth century named Mao Chin is known to have printed 600 titles on a variety of subjects. For the *Thirteen Confucian Classics* he used 11,846 blocks, for the *Seventeen Standard Histories* he used 22,293 blocks, and for another collection he used 16,637 blocks. Even during the early stages of his career, this single private printer employed twenty block cutters and had a store of over 100,000 printing blocks. But these quantities are small compared to those of the imperial printers, who produced several editions of the great imperial encyclopedias—over five thousand *printed volumes* each. Many of these sets still survive today.

The Chinese were also the inventors of multi-color printing. Paper money produced in the year 1107 was printed in three colors as a precaution against counterfeiting, though in this case it is possible that the two additional colors may have been *stamped* onto the paper. The money in question had legends in black, a circle design in vermilion, and a 'blue face' in indigo. Two-color printing of texts seems to have begun during the next century, and an edition of the *Diamond Sutra* of 1340 survives, which uses black for the text, and red for prayers and pictures. It became common for commentaries to appear in red beside black texts. The earliest surviving four-color printing dates from the early twelfth century, and is in black, grey, green and red on a large single sheet discovered in 1973 in the cavity of an old pillar. It shows a legendary figure called Tungfang Shuo, and would have been used as a wall decoration.



LEFT (82) A modern reproduction of the movable type invented by Pi Sheng between 1041 and 1048, and a page printed from it. Movable type was not invented by Johannes Gutenberg, as is universally believed in the West. The reproduction was made from the detailed description by Shen Kua which survives from 1086.

Chinese color-printing techniques used watery rather than oily inks, providing subtle effects. The inks in fact exact-

ly matched the ones used in the original artwork, and were made from the same earth pigments. When it was necessary to overlay colors, it was done in a variety of different ways. Sometimes inks were allowed to dry before having others printed over them: others were left wet. Subtle variations in pressure on different portions of the blocks resulted in gradations of printing strength, reproducing the expression and texture of brush strokes. Often the same color would be printed over and over from the same block, with varying portions inked so that deeper tones could be obtained in selected portions of the print. Ink was also allowed to run on the block, or it was wiped away in certain places. One expert on the subject, Dr. J. Tschichold, has said: 'There is hardly another graphic art in the world that depends so entirely on the artistic sympathy and understanding of the printer as does the Chinese color print.'

A traditional Chinese form of printing which required special expertise on the part of the printer and his staff was printing by movable type. Typesetters had to be linguistic experts and scholars knowledgeable in the history of language and literature. This is because of the thousands of characters in the Chinese language, many of which are obscure and rarely used, therefore only known to learned scholars. It is common in traditional Chinese typesetting to have at least twenty different pieces of type for each of the commonest characters. So the imperial printing works had to make 200,000 bronze characters in 1725, and in 1733 250,000 wooden characters were product for another project. In the early nineteenth century, one private printer is known to have had a stock of no less than 400,000 differ-

ent bronze characters. It is obvious that organizing this vast mass of material for printing purposes was a major problem in contrast to the ease with which movable type was used to print in the alphabets of Western languages. This was a major reason for the rare use of movable type in China, despite the fact that it was invented there four centuries before its 'invention' in Europe by Johannes Gutenberg.

Effective movable type was invented between the years 1041 and 1048 by an obscure commoner named Pi Sheng, who lived from about 990 to 1051. In his *Dream Pool Essays* of 1086, the famous scientist Shen Kua recorded the invention as follows:

> During the reign of Ch'ing-li, Pi Sheng, a man of unofficial position, made movable type. His method was as follows: he took sticky clay and cut in it characters as thin as the edge of a coin. Each character formed, as it were, a single type. He baked them in the fire to make them hard. He had previously prepared an iron plate and he had covered his plate with a mixture of pine resin, wax, and paper ashes. When he wished to print, he took an iron frame and set it on the iron plate. In this he placed the types, set close together. When the frame was full, the whole made one solid block of type …
>
> If one were to print only two or three copies, this method would be neither simple nor easy. But for printing hundreds of thousands of copies, it was marvelously quick … For each character there were several types, and for certain common characters there were twenty or more types each, in order to be prepared for the repetition of characters on the same page. When the characters were not in use, he had them arranged with paper labels, one label for words of each rhyme-group, and kept them in wooden cases. If any rare character appeared that had not been prepared in advance, it was cut as needed and baked with a fire of straw. In a moment it was finished …

> When Pi Sheng died, his font of type passed into the possession of my nephews, and up to this time it has been kept as a precious possession.

Earthenware types of the nineteenth century survive in China, but it became more common to use wood, enamelware, or metal in later times. The use of wooden type was perfected two-and-a-half centuries after Pi Sheng by Wang Chen, which he did, intending to use it to print his classic, the *Treatise on Agriculture*, in 1313. The wooden type was made in the years 1297 and 1298, and Wang Chen has left an account of the process.

More noteworthy than perfecting wooden type were Wang Chen's storage and handling arrangements. The type was stored in revolving tables 7 feet in diameter, supported by central legs 3 feet high. Ingenious sorting and classifying schemes were used to enable workers to find the necessary characters quickly. In the end, the *Treatise on Agriculture* was printed with bronze characters. But Wang Chen's 60,000 wooden type characters were used to print the local book, *Gazetteer of Ching-Te County*. One hundred copies of it were printed in less than a month in the year 1298.

Movable type continued to be used sporadically throughout Chinese history. It was revived under the Mongols, when a councillor of Kublai Khan decided to use the 'movable type of Shen Kua' to print books of philosophy. A nineteenth-century teacher named Chai Chin-Sheng, born in 1784, spent thirty years making a font of earthenware type, using everyone in his family to help him. By 1844 he had finally made over 100,000 sets in five sizes, which he used to print his own collected poems under the title *First*

Experimental Edition with Earthenware Type. He is the earliest and perhaps the only author-printer known in China.

Movable wooden type dating from about the year 1300 survives from Eastern Turkestan in the region known as Turfan, where it was introduced by the Chinese after the Mongol conquest. Movable type was much easier to use for the Uigur scripts of Turfan than for the Chinese language. Printing is thought to have spread to Europe through Turfan, and then through Persia, which the Mongols also conquered. Paper money was printed following the Chinese system in Tabriz in Persia in 1294. It was even called by the Chinese name, ch'ao, which then entered the Persian language. Fifty printed pieces of Islamic material printed according to the Chinese method were excavated in Egypt in the nineteenth century; they cannot be precisely dated, but were printed sometimes between 900 and 1350. Generally speaking, however, printing was frowned upon by the Muslims.

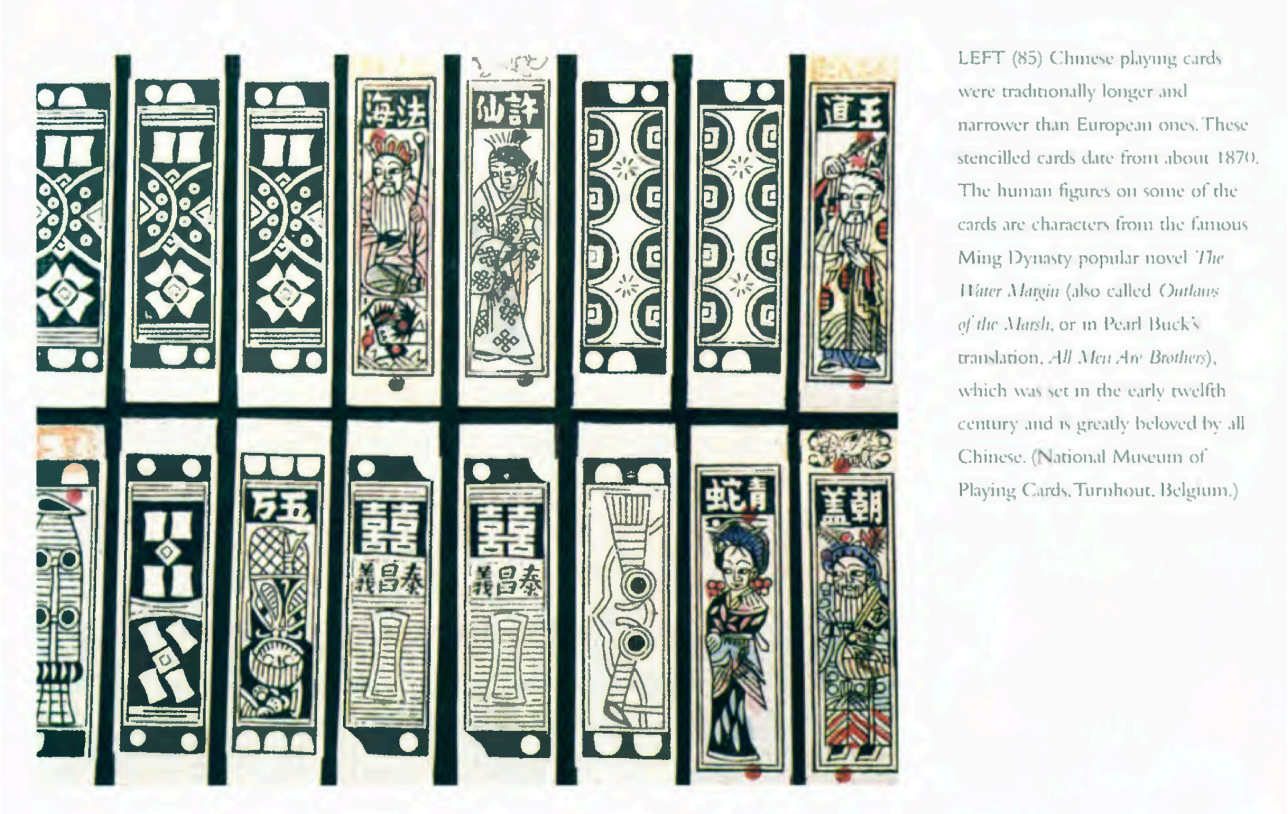
Playing Cards

Paper was invented in China, and it is therefore not surprising that the Chinese were the first to invent paper playing-cards. By the ninth century at the latest these were in use. The first-known book on card games was written by a woman in the ninth century, but it is lost. The scholar Ouyang Hsiu (1007-72) recorded that the use of paper playing-cards arose in connection with the change of book format from paper rolls to paper sheets and pages. The playing-cards were printed by woodcut blocks, and many specimens survive. They were often colored by hand, and popular designs for the backs were drawn by famous artists of fic-

tional characters from the well-known novel *The Water Margin*. The shape of the cards was a generally more elongated than those we use today, being about 2 inches high and only about 1 inch wide. They were of fairly thick paper, which made them more durable than those of today, though doubtless they were more difficult to shuffle.

The Chinese enthusiastically proclaimed the advantages of playing-cards over all other pastimes, pointing out that they were 'convenient to carry, could stimulate thinking and

could be played by a group of four without annoying conversation, and without the difficulties which accompanied playing chess or meditation.' Furthermore, cards 'could be played in almost any circumstances without restriction of time, place, weather, or qualification of partners.' But the Chinese passion for gambling led to the promulgation during the eighteenth century of laws against gambling by officials, and against the manufacture and sale of more than one thousand paper playing cards by a single person.



LEFT (85) Chinese playing cards were traditionally longer and narrower than European ones. These stencilled cards date from about 1870. The human figures on some of the cards are characters from the famous Ming Dynasty popular novel *The Water Margin* (also called *Outlaws of the Marsh*, or in Pearl Buck's translation, *All Men Are Brothers*), which was set in the early twelfth century and is greatly beloved by all Chinese. (National Museum of Playing Cards, Turnhout, Belgium.)

Playing-cards spread to the West from China either through the Arabs or through the travelers such as Marco Polo who circulated during the Mongol Dynasty, when there was such freedom of travel between Europe and Asia. In the seventeenth century, Valère Zani claimed that Venice was the first European city to have playing-cards from China. This may well have been the case, but the earliest appearance of playing-cards in Europe of which we can be certain was in

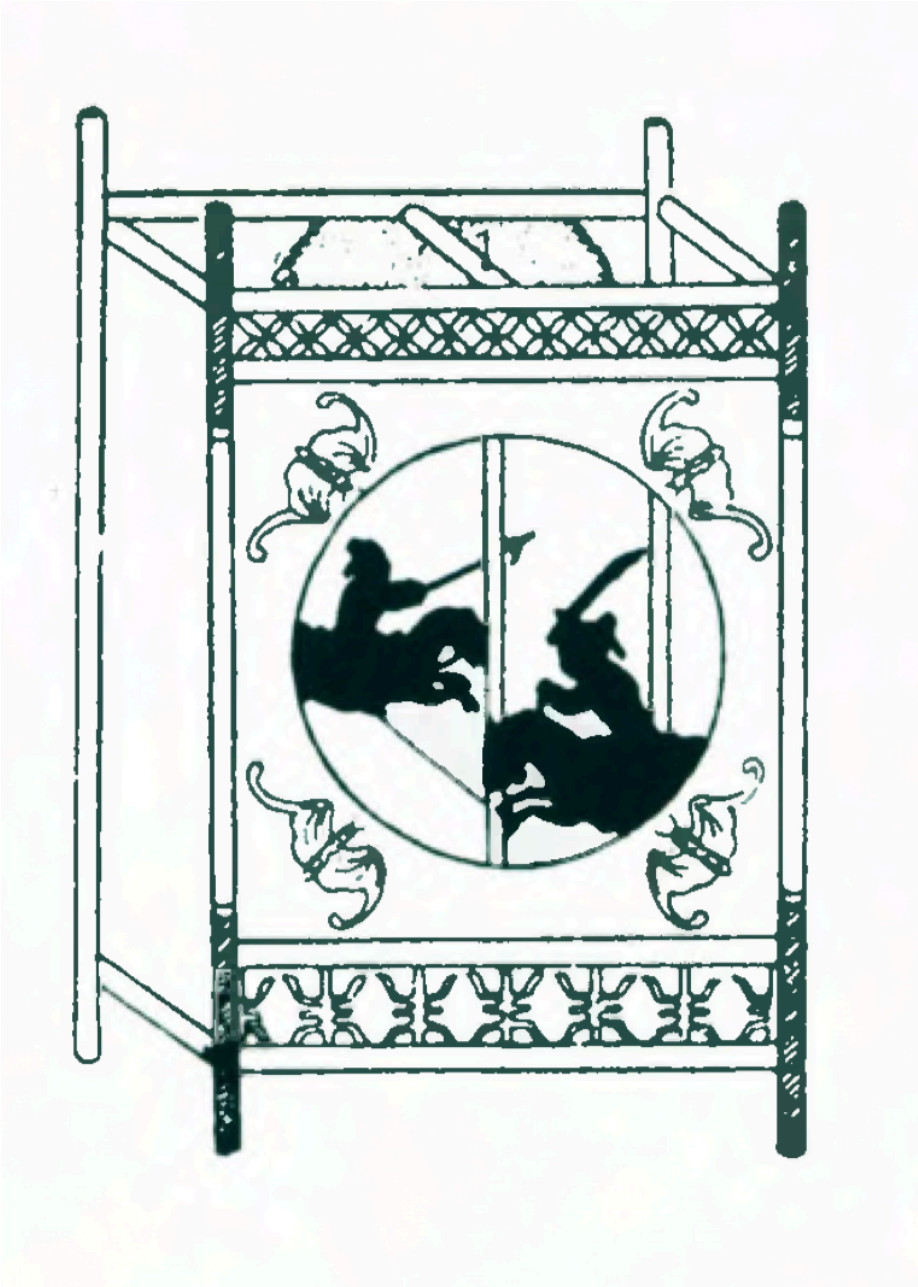
Germany and Spain by the year 1377. By 1379, we know they were being used in Italy and Belgium, and by 1381 in France.

Even Johannes Gutenberg, renowned as the fifteenth-century European inventor of printing by movable type—but see the remarks regarding the anteriority of printing in China under 'Printing'—was involved in playing-card manufacture. He actually developed some of the mechanical means of their production, and when his financial affairs became so desperate that he was forced to close his Mainz workshop, the figures which his artists had prepared to illustrate his famous Bible were used to print the backs of playing-cards. This extraordinary fact certainly highlights the close connection that has always existed between playing-cards and book printing.

The Magic Lantern

The magic lantern, or zoetrope, is a device which held audiences spellbound before the modern era, and has always had a particular fascination for children. It can exist in various forms, but essentially it consists of a series of pictures through which light shines, and which move in succession to give the illusion that the figures in the pictures are themselves moving. It is thus the earliest ancestor of the cinema. The pictures can be turned by hand or automatically (as by vanes turned by hot air currents rising from a lantern). The pictures are generally seen projected on a wall or a screen, though street shows in portable boxes have instead a peephole through which one peers at the moving pictures inside

the box. When projected, it is better that lenses be used, though they are not essential.



In 1868, W. B. Carpenter, the Vice-President of the Royal Society, wrote that the zoetrope, or magic lantern, had been invented by Michael Faraday in 1936, only thirty-two years earlier. This was wrong, since John Bate had described the same thing in his book *Mysteryes of Nature and Art* in 1634. But the real truth is that the zoetrope was invented in China.

The projection of moving images on a screen is recorded as having been practiced in 121 BC., when a magician

named Shao Ong stated a kind of seance for an emperor in this way. But another early form of magic lantern was in the possession of an emperor who died in 207 BC; after the lamp was lit, one could see the sparkling of scales of turning dragons. The same emperor had a similar object called 'the pipe which makes fantasies appear.' It seems to have had a small windmill or air turbine connected to it, for we are told in the book *Miscellaneous Records of the Western Capital* written in the sixth century AD: 'There was a jade tube two feet three inches long, with twenty-six holes in it. If air was blown through it, one saw chariots, horses, mountains, and forests appear in front of a screen, one after another, with a rumbling noise. When the blast stopped all disappeared.'

The next record we find of a magic lantern occurs in about 180 AD. At that time, the inventor Ting Huan had perfected a 'nine-storied hill censer,' which seems to have been a vastly complicated multiple magic lantern. Attached to it were strange birds and mysterious animals, which moved around when a lamp was lit. A similar device is described by T'ao Ku in his book *Records of the Unworldly and Strange*, published about 950 AD: 'Moving shapes were seen and tinkling noises heard, after the lighting of a candle or lamp.'

By the twelfth century, magic lanterns were called 'horse-riding' or 'horse-pacing' lamps, since after the lamp was lit, a succession of prancing horses was projected round about on the walls, moving as if on their own. Europeans discovered these toys when they began visiting China, and a Jesuit missionary named Father Gabriel de Magalhaens has left this description of one from the middle of the seventeenth century:

The Lamps and Candles, of which there are an infinite number in every Lanthorn [lantern], are intermix'd and plac'd within-side, so artificially and agreeably, that the Light adds beauty to the Painting; and the smoak gives life and spirit to the Figures in the Lanthorn, which Art has so contri'vd, that they seem to walk, turn about, ascend and descend. You shall see Horses run, draw Chariots, and till the Earth; Vessels Sailing; Kings and Princes go in and out with large Trains; and great numbers of People both a-Foot and a-Horseback, Armies Marching, Comedies, Dances, and a thousand other Divertisements and Motions represented …

RIGHT (61) A late-eighteenth-century painting of an itinerant peep-show – a box containing a magic lantern. Up to four people can peep through the holes at once, and the effect is of a moving picture show. The magic lantern is the direct ancestor of the cinema, with its illusions of animated figures in continuous motion. Note also another Chinese invention – the umbrella. (Victoria and Albert Museum, London.)

The projected slides which lecturers use, which some people will call 'lantern slides,' derived from those Chinese magic lanterns. Needham says: 'It is not generally known that the first lecturer to use lantern slides was a Jesuit of the

China mission, Martin Martini. His lectures illustrated by the new technique were given at Louvain in 1654.'

The magic lantern itself was also transported to Europe from China. We do not have all the details. Did the Chinese use lenses with their magic lanterns? They certainly used them a great deal for a number of other purposes, and Needham thought it possible 'that someone had the idea of placing one or more lenses at the pinhole of the closed chamber.' He goes on to suggest that this occurred during the T'ang Dynasty (618-906 AD). He also stresses that the 'persistence of vision' of the moving successions of images is the basis of cinematography, and that therefore the Chinese may perhaps be considered the earliest pioneers of the cinema.

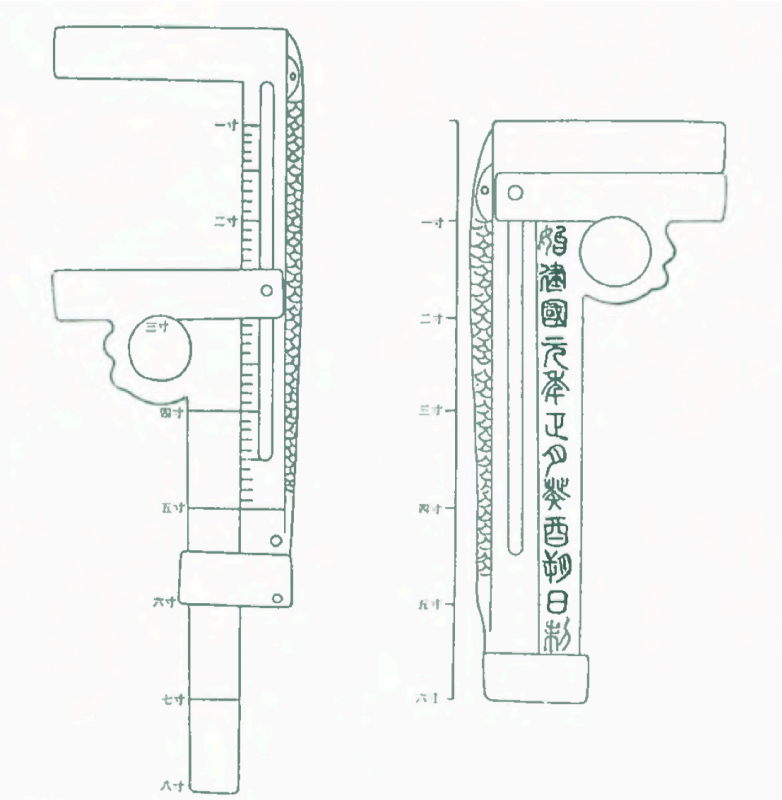
Their images may only have been painted on pieces of paper or mica, and have gone round and round on a closed loop, but the effect for ancient times was surely profound, as the Jesuit father vividly testified. We may look upon it as primitive but the ancient Chinese magic lantern had, in its day, a kind of cinematic glory in its turning picture show.

Sliding Calipers

A measuring tool very much like the modern adjustable wrench (spanner) was used in ancient China at the time of Christ.

The tool which is made of bronze, is an adjustable sliding caliper gauge with slot and pin. The only difference between it and a modern adjustable wrench is that it does not have the small revolving worm (screw). The side which was used for measurement is decimally graduated in 6 inches

and intent of an inch. On the other side there is an ancient inscription which, translated, reads: 'Made on *kuei-yu* day at new moon of the first month of the first year of the Shih-Chien-Kuo reign-period.'



ABOVE (59) These sliding callipers are an adjustable spanner, without the worm. Unknown in Europe before Leonardo da Vinci sketched a set, they first came to be used in France in 1631, but the Chinese invented them in the first century BC. This illustration, published in China in 1925, depicts a surviving example of the measuring tool in bronze, with slot and pin for the sliding adjustment outside the calliper gauge, which dates from 9 AD, and bears an inscription on the right side which says it was 'Made on a kuei-yu day at new moon of the first month of the first year of the Shih-Chien-Kuo reign-period'. The left side of the tool is graduated in 6 inches and tenths of an inch.

This dates the implement to the first year of the reign of the Emperor Wang Mang, at 9 AD. This is the most impressive measuring instrument surviving from any ancient culture. These sliding calipers graduated in inches and tenth of inches must have been developed by the preceding century, the first century BC.

In Europe, sliding-scale calipers were introduced by Pierre Vernier in 1631, and the screw micrometer by William Gascogne in 1638 for use in astronomy. The data of the earliest European caliper gauge is not known for certain before this, though the first such idea seems to have occurred in sketches made by Leonardo da Vinci over a century earlier. For the full sliding-scale caliper, however, the Chinese were in advance of Europe by approximately 1700 years.

The Suspension Bridge

Few structures seem more typical for the modern world and its engineering achievements than the suspension bridge. And yet, the sophisticated form of the suspension bridge, with a flat roadway suspended from cables, was unquestionably invented in China. And it is highly likely that the two more primitive forms of suspension bridge also originated there, the simple rope bridge and the catenary bridge (where the walkway or roadway is not flat but follows the curve of the cables).

The simplest form of 'suspension' bridge—if we can even call it that—is simply a rope thrown across a gorge. Probably, from the very beginning, the technique used for getting the rope across that was still used later for elaborate suspension bridges—was shooting it across, tied to an arrow. After the Chinese invention of the crossbow greater power would have been available for heavier cables over longer distances.

Climbing or scrambling along a single rope above a gorge can be dangerous, and it is hard on the hands. An ingenious solution is still in use in some areas, such as the Tibetan-Chinese border. The rope is threaded through a hollow piece of

bamboo before being attached, and the person merely hugs the bamboo and slides along the rope without burning his hands or straining himself unduly. A more sophisticated method is by a cradle attached to the bamboo tube. Cable bridges of liana vines are now in the Andes mountains of Peru, dating back to at least 1290, and Needham suspects that this may be one of the many Chinese ideas to have spread to the New World across the Pacific.

Bridges of ropes and cables in China and Tibet evolved into multiple-cable bridges of various types. Sometimes three ropes or cables are stretched across together so that the person crossing can walk with his feet on two of them and hold a third above his head for balance. Or a woven walkway of matting is incorporated between the two bottom ropes or cables, to make the going easier. Another variation is to have a series of hanging straps by which the user pulls himself forward. All these and other variations occur in the area between China and Tibet, in the high mountains. A reference in the Chinese dynamic history for 90 AD appears to mention a suspension bridge which has planking and, hence, a proper platform upon which to cross:

> There the gorges and ravines allow of no connecting road, but ropes and cables are stretched across from side to side and by means of these a passage is effected.

This reference is rather vague. The same dynastic history for 25 BC describes a harrowing Himalayan suspension bridge:

> Then comes the road through the San-ch'ihp'an gorge, thirty li long, where the path is only 16 or 17 inches wide, on the edge of unfathomable precipices. Travelers go step by step here,

clasping each other for safety, and rope suspension bridges are stretched across the chasms from side to side. After 20 lie one reaches the Hsien-tu mountain pass … Verily the difficulties and dangers of the road are indescribable.

Fa-Hsien, the first Chinese Buddhist pilgrim to India, crossed this very bridge in 399 AD, and left this account of his experience:

Keeping on through the valleys and passes the Ts'ung-ling mountain range, we traveled south-westwards for fifteen days. The road is difficult and broken, with steep crags and precipices in the way. The mountain-sides are simply stone walls standing straight up 8000 feet high. To look down makes one dizzy, and when one wants to move forward one is not sure of one's foothold. Below flows the Hsin-t'ou Ho. Men of

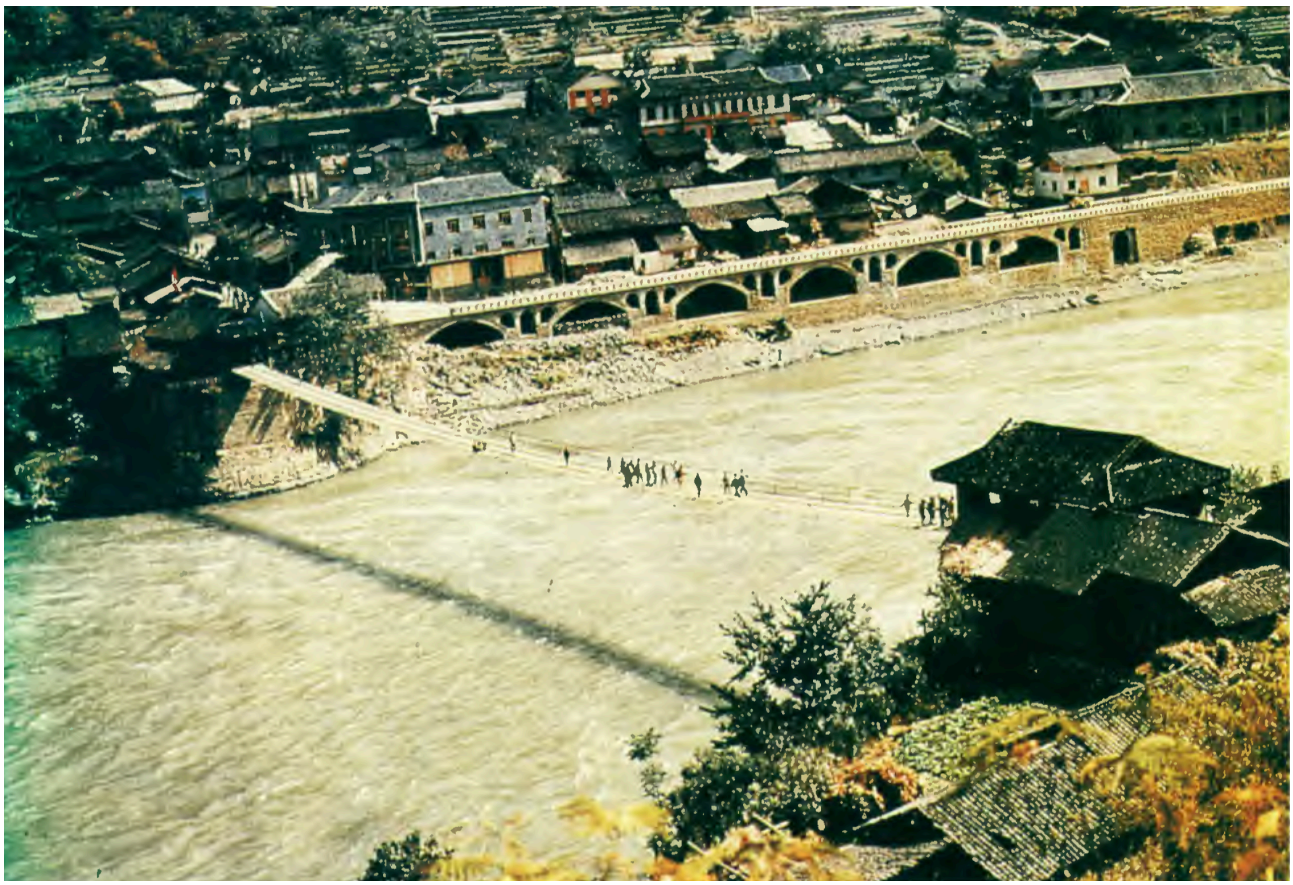
> former times bored through the rocks here to make a way, and fixed ladders at the sides of the cliffs, seven hundred of which one has to negotiate. Then one passes fearfully across a bridge of suspended cables to cross the river, the sides of which are here rather less than 80 paces [400 feet] apart.

Cable bridges in China were most efficient when made of bamboo. The cables were made with a center formed of the core of the bamboo surrounded by plaited bamboo strips made of the outer layers of the wood. The plaiting was done so that the higher the tension, the more tightly the outer strips gripped the inner core. This led to the safety factor that it is the inner strands of a cable which snap first, rather than the outer strips which could otherwise unravel very fast. An ordinary 2-inch hemp rope can stand stresses of only about 8000 square pounds per square inch, but bamboo cables can stand a stress of 26,000 pounds per square inch. Ordinary steel cables will only take twice as much stress (56,000 pounds), so bamboo is remarkably strong. (Modern steel alloys such as used in the Golden Gate Bridge at San Francisco can take stresses of 256,000 pounds per inch).

The most famous Chinese suspension bridge is a catenary bridge (which has a roadway following the curves of the cables rather than hanging flat): the An-Lan Bridge at Kuanhsien in Szechuan. It has a total length of 1050 feet, composed of eight successive spans, and there is not a single piece of metal in the entire structure. An account of a traveler crossing it in 1177 describes only five spans at a time. It has planking on which to walk, originally 12 feet

wide but today only 9 feet wide, and it is believed to have been built in the third century BC by Li Ping.

The true suspension bridge became possible with the invention of the iron-chain suspension technique. The Chinese were in advance of the whole of the rest of the world in their iron and steel technology. Needham believes that they applied wrought-iron chains to suspension bridges by the first century AD. Massive stone abutments were built to contain the chain ends.



From these chains it became possible to suspend the planking gangway increasingly away from the catenary curve of the chains themselves so that it tended towards being a flat surface. The greatest span of which a Chinese iron-chain suspension bridge is known to have been capable is

about 430 feet, at Lu-shan in Szechuan. The longest such bridge which still exists is 361 feet, at Lu-ting in Sikang. Its chains are embedded 40 feet deep into the stone pillars on both sides. In the present form, it was built in 1705, but it is presumed to have replaced earlier versions on the same site. It was the scene of a major incident during the Communist Army's Long March, when they successfully stormed the bridge under heavy fire despite the fact that its planking had largely been removed.