



## chapter five

### Ways of Scientific Exchange

# Observing the Skies



▲ Stone bust of the Greek philosopher and astronomer Democritus (460-370 BCE). He introduced many ideas on astronomy to Greece from the Middle East and Asia.

Technological innovation was not the only form of scientific exchange to be channelled along the Silk and Spice Routes. The more scholarly ideas and learning of many different cultures were also brought together. Ancient science was closely associated with religious and philosophical concerns and, for this reason, few scholars restricted themselves to one area of study – astronomy, astrology, mathematics and alchemy were all closely linked.

One of the earliest sciences to emerge was astronomy. People observed the skies as a way of judging the time and season, when to plant and harvest their crops or when to hold a religious festival. People believed that the movement of the stars in some way revealed the future, giving rise to the science of astrology. The Babylonians of Mesopotamia were probably the first people to study these two sciences. They built huge temples called ziggurats as long ago as 3000 BCE. From these temples they worshipped their gods – the Sun, the Moon and the planet Venus. The priests carefully watched the skies and by 450 BCE had developed the mathematics to predict the movements of the Sun and planets.

The Greek astronomer-philosopher Democritus (460-370 BCE) visited Babylonia and also travelled throughout Asia Minor and Egypt. Amongst other learning, he introduced to Greece the Babylonian method for calculating the movement of the planets and constellations. Also using the discoveries of the Babylonians, another Greek philosopher, Thales of Miletus (c. 640-550 BCE), was able to predict an eclipse of the Sun. He also used Egyptian methods of astronomy to devise a system for navigating ships by the stars. Later Greeks tried to explain the movements of the Sun, Moon and planets. The philosopher Aristotle (384-322 BCE) thought that they moved in perfect circles round the Earth which lay at the centre of the universe, an idea later developed by Claudius Ptolemy (c. 90-170 CE) in his book known as the *Almagest*. This work was lost to Western Europe for

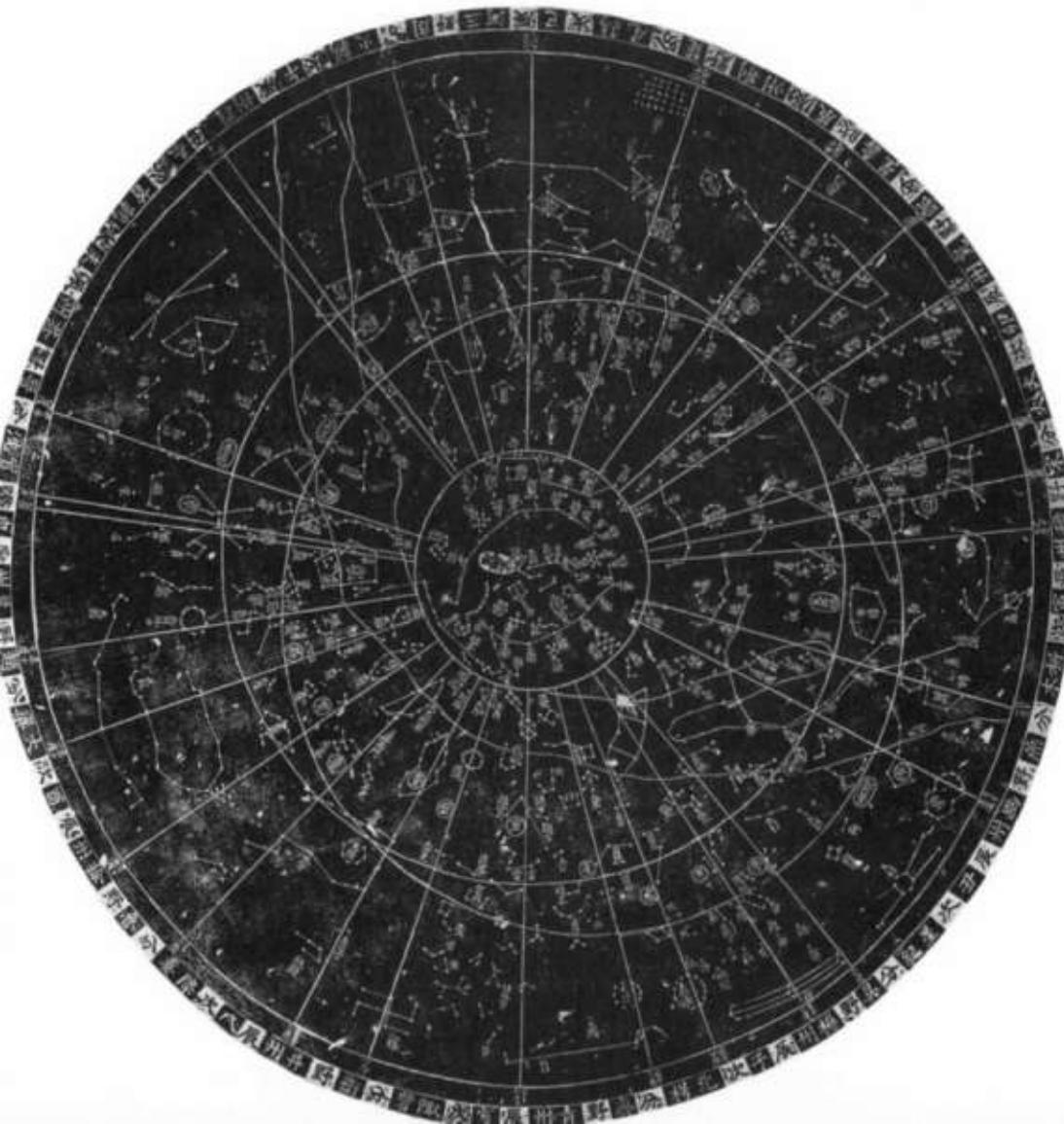


▲ 16th century illustration of an observatory at Istanbul. Astronomers can be seen at work, using instruments such as astrolabes and sextants to calculate the position of the stars and planets.

many centuries, but it was preserved in the libraries of Constantinople and scholars from that city brought it to the attention of western learning when it fell to the Turks in 1453.

Trading contacts and empire building led Indian astronomy and astrology to show strong Babylonian and Greek influences. The Indians translated into their language many Greek technical terms and principles and also methods peculiar to Greek astronomy. The signs of the zodiac which appear in Indian works are similar to those used in Greek astrological works. From the Fourth Century CE there was a steady stream of Buddhist scholars from India to China along the Silk Route. Their main job was to carry out missionary work, but they also spread more secular learning. During the Seventh Century, many Indian astronomical works were taught in China.

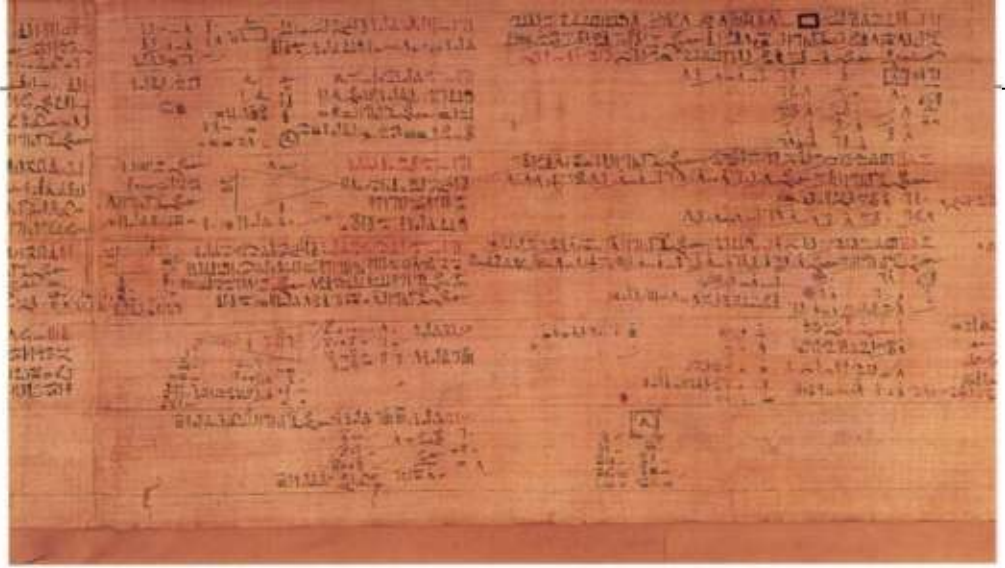
Indian astronomical knowledge, along with Greek and Persian, also played its part in Islamic astronomy and astrology. During the reign of the second caliph of the Abassid dynasty, al-Mansur (754-775), Indian astronomers brought planetary tables and texts for the calculation of eclipses to his court in Baghdad, and many Indian astronomical works were translated into Arabic.



▲ View of the Observatorium at Delhi, India, which is like an open-air planetarium. It was constructed by the Maharaja of Jaipur between 1718-24. The Maharaja was a keen astronomer, following a long tradition of Indian scholarship.

◀ Chinese star map known as Soochow astronomical chart made in c. 1193. Given it was drawn up from observation made by the naked-eye alone, it is remarkable for its detail, showing the curving course of the Milky Way and the Crab Nebula.

► The Rhind papyrus, dated to 1800 BCE. This is one of the earliest known examples of Egyptian mathematical calculations. The Egyptian work played an important part in the foundation of Greek mathematics.



# Mathematics



▲ A mathematics class in progress in China. Notice that alongside the Chinese script, they are working in Arabic numerals, a counting system now used throughout the world.

► The Flagellation of Christ by Peiro della Francesca (c. 1419-92). The picture uses a complex form of perspective, worked out with great mathematical accuracy. Peiro della Francesca was one of several Renaissance artists to investigate ways of applying mathematical rules to his art, reflecting the new awareness of both science and art that occurred at this time.

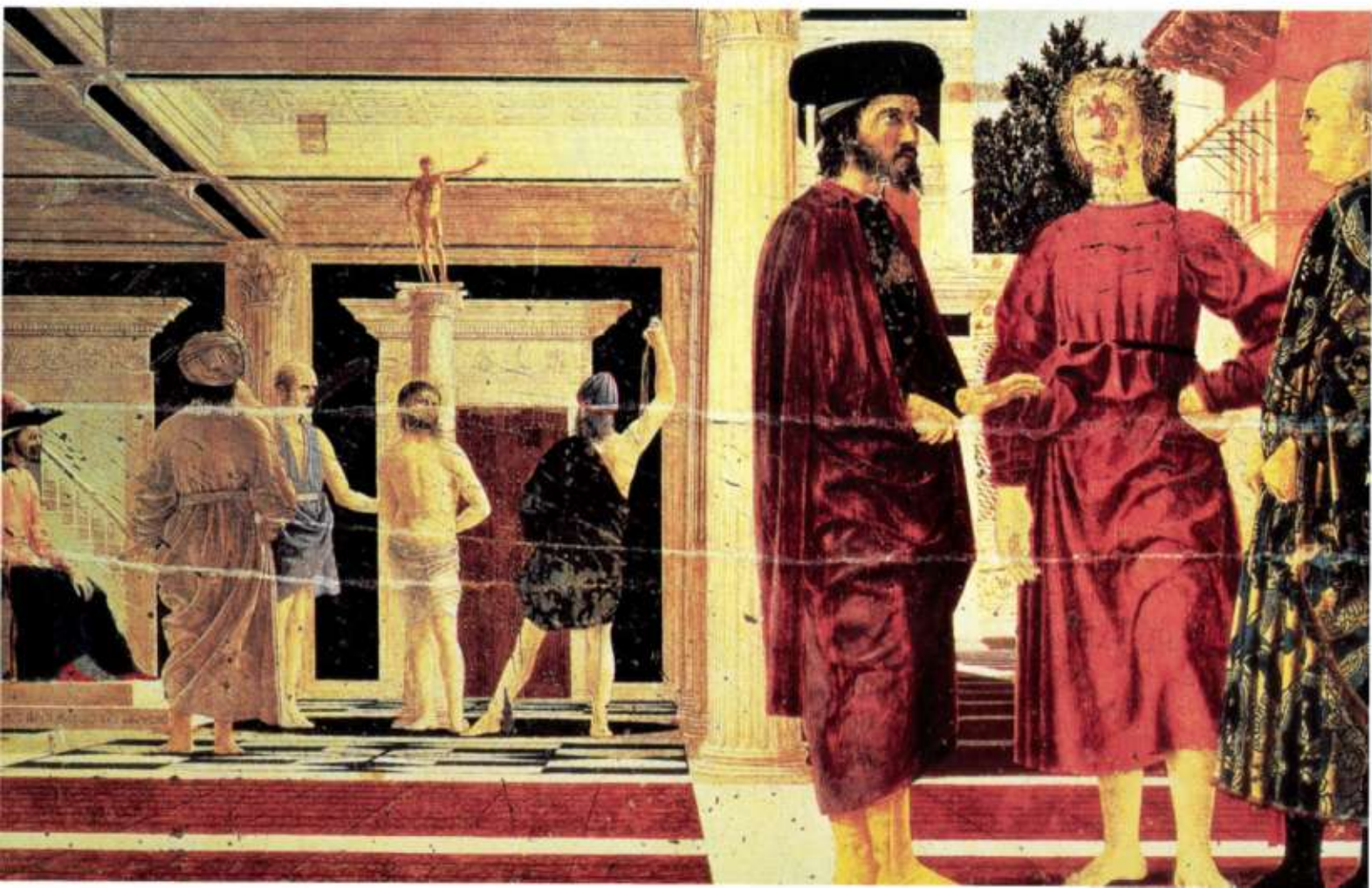
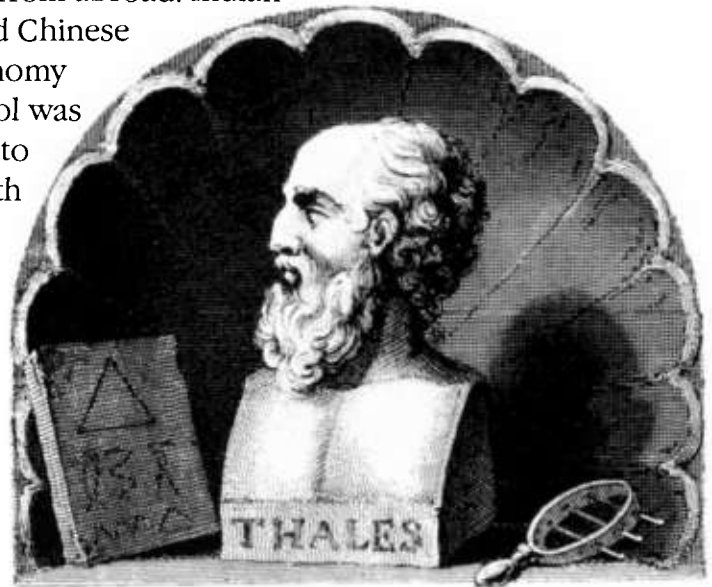
Given the close association between astronomy and mathematics, it is not surprising that the pattern of its development along the Silk and Spice Routes is much the same. Early advances were made by the Egyptians and Babylonians and these were inherited by the Greeks, who gave the science of mathematics its name.

The founder of the first Greek school of mathematics and philosophy was Thales of Miletus, mathematician, merchant and business tycoon – a good grasp of arithmetic has always been important for trade. He had travelled as a merchant to Egypt, and while there had studied the local geometry and astronomy. His work inspired the breakthroughs made by later Greeks, such as Pythagoras (c. 582-507 BCE) and Euclid (c. Third Century BCE). Another, Edemos, wrote a history of mathematics and claimed that Thales ‘after a visit to Egypt brought this study to Greece’.

Islamic mathematics developed from a deep understanding of Greek works. By the end of the Ninth Century, the Arabs had translated the mathematical writings of Pythagoras, Archimedes (287-212 BCE), Ptolemy and many others. The Arabs were particularly concerned with casting horoscopes through astrological science and the work of mathematicians such as al-Battani (died 929) and Abu’ l-Wafa (died 998) made great advances in the geometry used in astronomical calculations. Much of this Arab and Greek learning came to the attention of Western Europe by way of Spain, which was under Muslim rule from the Eighth Century. Muslim power dwindled from the Eleventh Century and in 1185 the university city of Toledo fell into Christian hands, along with its vast library of Arabic and classical texts. Scholarship and mathematics in Western Europe began to be pursued with renewed vigour, in a process that eventually led to the period of great scientific and artistic activity known as the Renaissance.

Amongst other things, European scholars adopted the Arabic decimal system using nine numerals and a zero, which today is used throughout the world, representing a remarkable form of universal language. However, the name 'Arabic' is misleading, for it was probably in India about 2,500 years ago that these numerals were first developed. As with astronomy, India's central position on the Silk and Spice Routes meant that its mathematics was a complex mixture of its own innovations and those it received from abroad. Indian mathematics contributed to both Islamic and Chinese scholarship. Again, its close links with astronomy played a part. In the Seventh Century a school was set up in Chang'an, then the Chinese capital, to study Indian astronomy and during the Eighth Century, a Chinese astronomer called Qutan Xida translated the Indian calendar under the Chinese title *Jiuzhi Li*, which included discussions of Indian decimal notation and arithmetical rules.

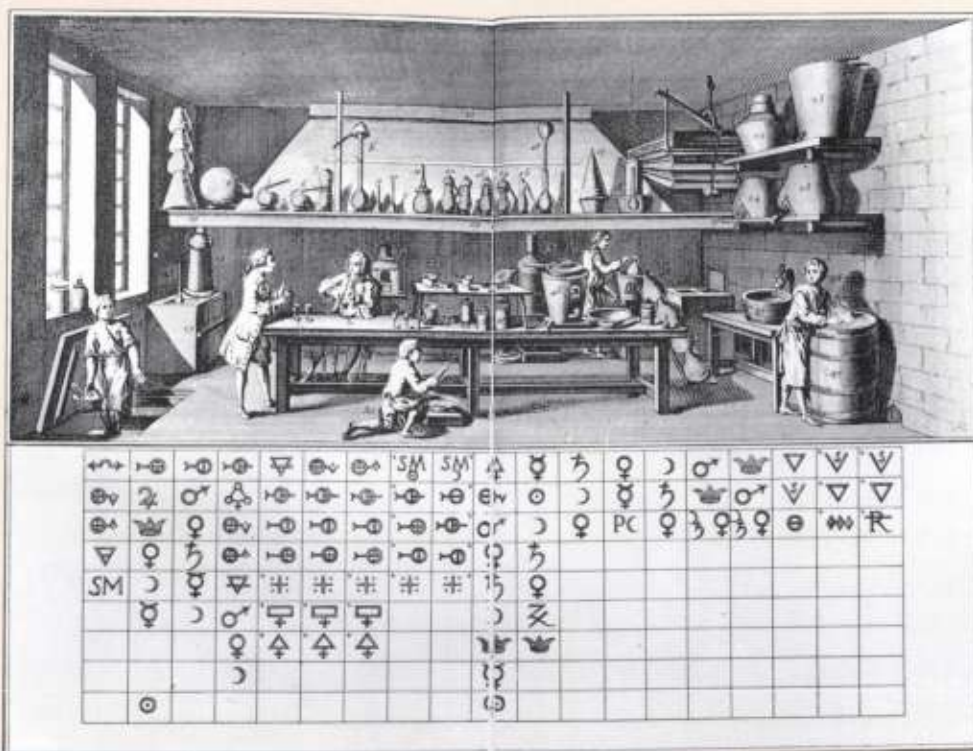
▼ *Bust of the Greek mathematician and philosopher Thales of Miletus (c. 640-550 BCE). He is said to have introduced geometry to Greece from Egypt.*





# Alchemy and Chemistry

Although chemistry as we know it today really only began in the second half of the Eighteenth Century, many processes which have been practised for thousands of years involve chemical changes. Among them are dyeing materials, tanning leather, smelting metals, glazing pottery and making glass. Knowledge of chemical processes was therefore well advanced long before the chemical revolution of the Eighteenth Century.



► Late 18th Century engraving showing a European laboratory. Many of the instruments used in chemical experiments can be seen. The table of chemical symbols below is still based on those used in alchemy, indicating the close links between the two sciences.

Chemistry, the study of the substances that make up the world around us, also has its origins in the ancient practice of alchemy, as well as in industrial processes. The very word 'chemistry' comes from the Arabic *al quemia*, meaning alchemy. Alchemy was an early form of chemistry which began about 2,000 years ago and alchemists were interested in finding a method of turning ordinary metals, such as iron, into gold. There was often a lot of magic and superstition involved but, although alchemy is not considered a real science now, a number of scientific methods were used by alchemists and they made some important discoveries.

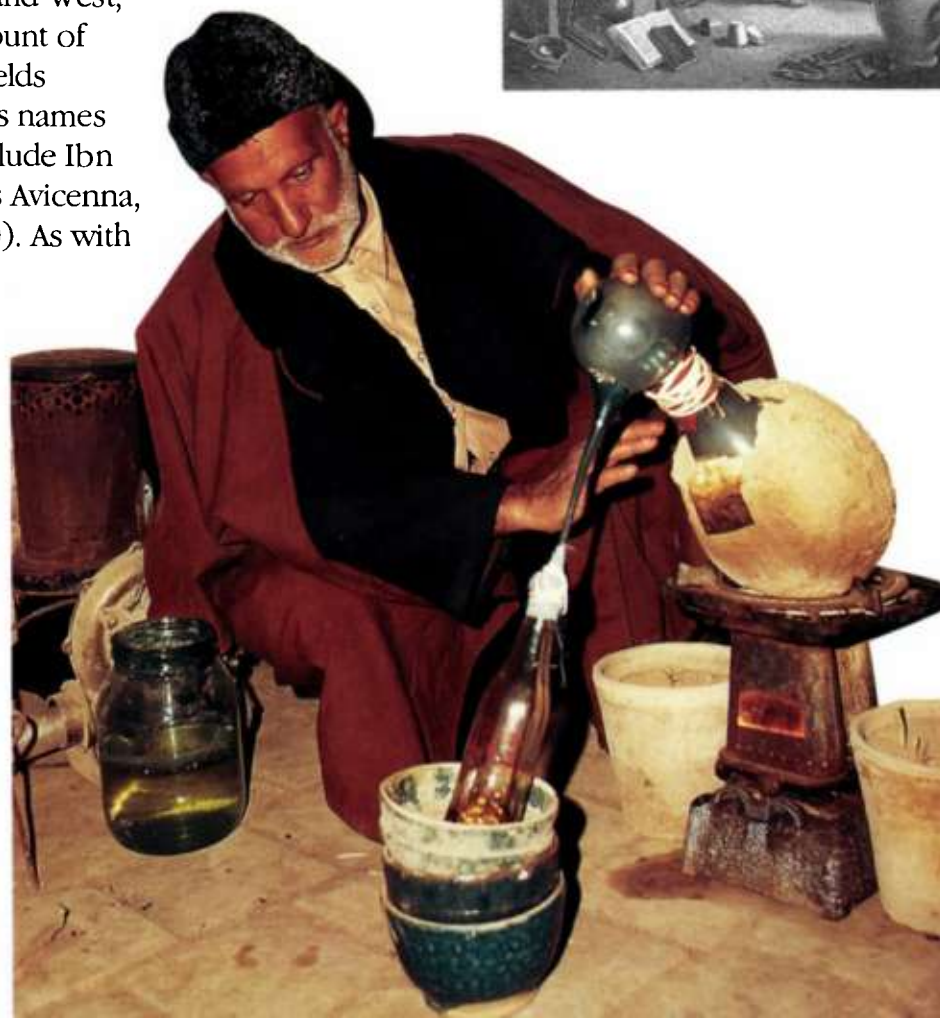
Over the centuries, the Chinese, in particular a religious group called the Taoists, acquired a huge amount of chemical knowledge and made a number of valuable contributions to the subject. Their main aim in alchemy was to find the secret of immortality, a means to arrest the ageing process. Although this eluded them, in seeking it they built up a large body of chemical knowledge, probably including the discovery of gunpowder. This knowledge was gradually transmitted westwards in the hands of Indian and Arab scholars, but a great deal of information reached Europe in the Seventeenth Century through Jesuit missionaries (see page 25).

Alchemy was practised in India much later than in other areas, and it was probably imported from China with the spread of Buddhism. Islamic alchemy, which raised the subject to new heights of sophistication, may also have derived from Chinese sources. Alchemical studies were very important in Islamic thinking, and although they used magic and spells they also involved the use of experiment. This laid the foundations of several modern sciences including chemistry and mineralogy (the study of minerals), an important legacy of Islamic culture to the West.

Islam was also heir to the whole Hellenistic Greek alchemical heritage of Alexandria, a major centre of Greek learning, and Muslim sources contain the names of nearly all the known Alexandrian alchemists. With their conquests East and West, the Muslims also inherited a huge amount of literature on mineralogy and related fields from the Persians and Indians. Famous names in Islamic alchemy and mineralogy include Ibn Sina (980-1037), known in the West as Avicenna, and Abu Rayhan al-Biruni (937-c. 1050). As with other sciences, this knowledge filtered through to European scholars through Muslim Spain and the Byzantine Empire. Arab trading contacts with Venice and Genoa also contributed to the process and, more violently, the Crusades from the Eleventh to Thirteenth Centuries.

► *An alchemist at work in the Middle East today. He still uses a number of the old instruments, such as the alembic shown here, similar to those used in the engraving (above right).*

▼ *Engraving of an alchemist in the 17th Century. One of the aims of the alchemist was to turn base metals into gold and his experiments were often surrounded by secrecy and magic.*



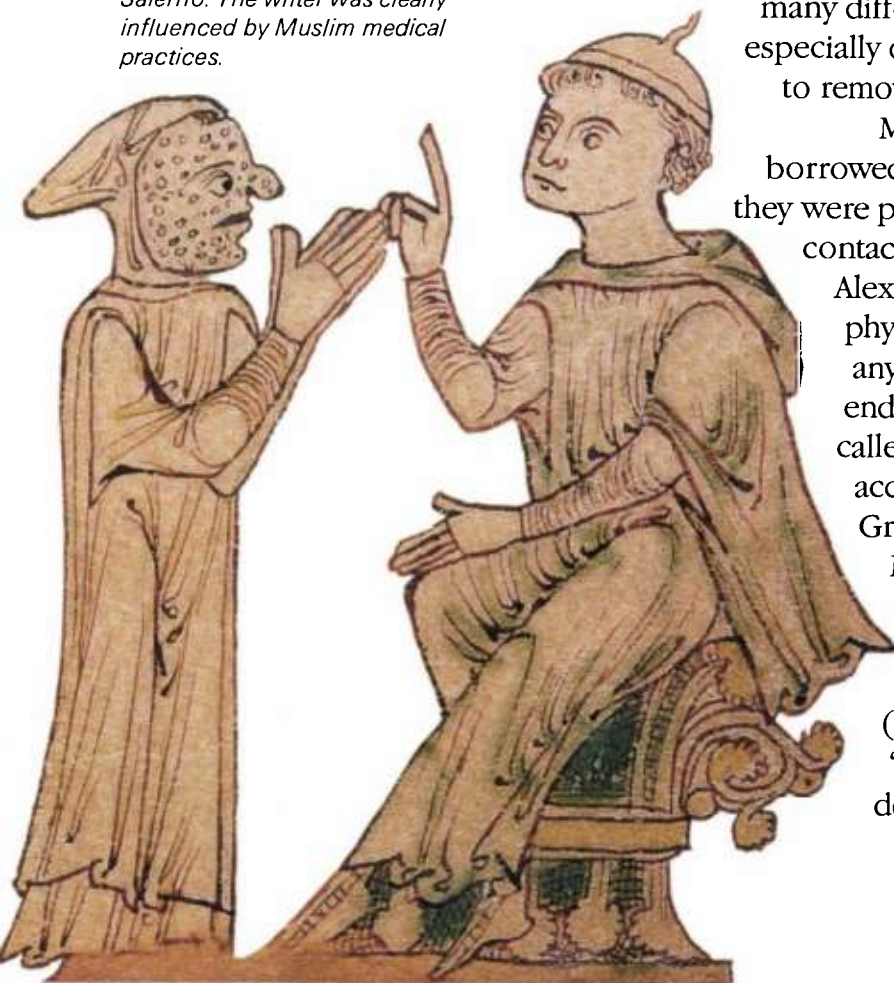


# Health and Medicine



▲ *Bust of Hippocrates of Cos (c. 450-370 BCE), the 'father of medicine'. He believed that diet and hygiene were important in building up a patient's strength.*

▼ *A scene from a 13th Century Italian manuscript by Roger of Salerno. The writer was clearly influenced by Muslim medical practices.*



Chemistry and alchemy also have their roots in the making of drugs for medicine. Throughout history, people have always had to deal with disease, illness and death, although diagnosis and treatments have varied from region to region. In many places, illness was seen either as an invasion of the body by some poison, or it was attributed to the work of an angry god, malignant magic or witchcraft. Early physicians therefore needed to be part doctor and part priest, for while they believed that medical treatment could relieve a sickness, the main cause could only be removed with prayers and sacrifices to the gods.

The best-known ancient Indian medical text is the *Ayurveda*. This was a compendium of medical practice and was compiled about 700 BCE. In it, disease is seen as an imbalance of substances in the body. Doctors used medicines to drive out harmful substances and replace them with good ones. The *Ayurveda* also shows that Indian doctors had a thorough understanding of the human diet and the digestive system. They were skilled surgeons and the text describes many different types of surgical operation, especially on the stomach and bladder and even to remove cataracts from eyes.

Many concepts of Greek medicine were borrowed from the Indians: from early times they were probably imported through trade contacts and later via the Asian conquests of Alexander the Great. Alexander's army physicians, for example, did not know of any cures for snakebites and other diseases endemic to the area. Indian doctors were called in to help and some of them later accompanied the army when it returned to Greece, bringing with them their skills.

Much earlier, in the Fifth Century BCE, a medical school on the small Greek island of Cos became very influential. This was the home of Hippocrates (c.450-370 BCE), often known as the 'father of medicine'. Like modern doctors, he insisted on keeping medical



◀ Illustration from a 13th Century Arabic treatise on medicine. It depicts two doctors mixing ingredients to make a medicine. Plants as well as chemicals were used in the mixtures.

▼ Diagram of a pregnant woman, taken from an 11th Century Arabic work on anatomy by Mansour ibn-Ahmed. Arabic physicians and doctors made considerable advances in the study of anatomy.



records, noting when treatments failed as well as when they succeeded. Greek medicine, passed on by the Muslims, was very influential in Medieval and Renaissance Europe. Even today in Europe doctors make a promise to work for the benefit of the patient at all times. This is known as the Hippocratic Oath.

In biology and medical sciences, Islam inherited a vast amount of material from the Greeks, Romans, Persians and Indians. The result of this amalgamation was the creation of an extensive field embracing nearly every branch of the medical sciences. In particular, Islamic medicine owed much to the work of the Graeco-Roman doctor named Galen (c. 129-200 CE). His works were among the first Greek texts to be translated into Arabic. By the late Ninth Century, Islamic medicine was making great advances of its own. One of the most important physicians of this period was Abu Bakr al-Razi (c. 854-c. 930), known in the Medieval West as Rhazes. Ibn Sina also contributed to medicine when he wrote the *Canon*, a huge book which influenced teaching in Europe until the Seventeenth Century.

▼ View of the Osmania Hospital in southern Pakistan, built by the Nizam of Hyderabad in the 19th Century. Some of the first public hospitals, where doctors were trained and patients treated, were built in the Muslim world.

