UNIT 5 SCIENCE IN THE MEDIEVAL TIMES

Structure

5.1 INTRODUCTION

We have seen in Unit 3 that the centre of science had shifted to the east for about 500 years following the collapse of Rome. We also saw in Unit 4 that the period from the fourth century B.C. to the fifth century A.D. was an age of great cultural advance in India. Science and technology flourished in India during the period of the Guptas (320—480 A.D.). However, by the sixth century A.D., India once again developed a complex religious and caste system. Slowly, the rigid social structure, prevailing religious dogmas and the crumbling empires led to a stagnation in Indian society. The development of science also slowed down in this process.

Meanwhile, between the third and the seventh century A.D., Europe had seen the rise of Christianity. In its early phase, Christianity was associated with democratic tradition and had a popular appeal. However, soon the Roman Empire took over the Christian Church and adopted the Christian faith. This, as we shall see, stifled the growth of science in Europe. Even as the ancient Indian and Roman cultures decayed, a positive development was taking shape elsewhere in the world. The advent of Islam in the seventh century A.D. provided a great stimulus to the Arab culture and science. Even though the Islamic culture had started decaying by the eleventh century A.D., the fruits of Islamic science were not wasted. When Islam came to India in the eleventh century, a large body of knowledge came into Indian possession. This, in a way, shaped the developments in Indian science in the medieval times.

In this unit we will cover a rather long period in the history of science, from around the seventh century A.D. to the end of the eighteenth century A.D. We will, very briefly, touch upon the history of Christianity and then see how the Arab renaissance and the rise of Islam helped in the flowering of Arab science. In the latter part of this unit, we shall concentrate on the development of science and technology in medieval India.

Objectives

After studying this unit you should be able to :

- describe the contribution of Arabs to the body of scientific knowledge,
- describe and assess the level of development of science in medieval India,
- analyse the factors that impeded the growth of science in India in the medieval times.

5.2 THE ARAB RENAISSANCE

We have seen in Unit 3 that, by the end of the second century A.D., the Roman Empire had begun to decline. Its economy was overburdened by a huge army. Stagnating production had led to the imposition of heavy taxes. Consequently, the social structure became extremely exploitative.

Christianity, most probably, grew out of the distress and protest of the slaves and other common people of the Roman Empire. It is no accident that it first arose among the Jews who were the most oppressed. They were also imbued with the spirit of rejecting any compromise with the powers of this world. The popular appeal of Christianity lay in its outward submissiveness combined with absolute determination to have no part in the prevailing oppressive and sinful society. This also led to its persecution, which gave it even greater appeal and strength. Christianity spread rapidly among all people. Very soon it was no more confined to the lower classes. Its teachings became influenced by the prevalent social ideas. Within a few centuries, the Church itself established the rule of dogmas and became a partner in maintaining the state. By the sixth century A.D., people on the eastern borders of the Roman Empire began to identify Christianity with an alien, hostile and oppressive government.

However, we find that to these negative factors, there was soon added a positive one—the appearance and spread of a new religion, Islam, in the seventh century A.D. Islam incorporated what was most agreeable in Christianity. With its message of universal brotherhood, simple but exacting personal conduct and a sure hope of realistic paradise for the believer, it soon found popular support. As the Arabs from Syria and Iraq came to conquer lands stretching upto the Mediterranean with the message of Islam, they very often found little resistance from the local population.

Soon a vast area stretching from Spain to India came under the influence of Islam (Fig. 5.1) and, thus, extensive trade and cultural exchanges became possible. The flourishing trade gave rise to demand for commodities. This, in turn, encouraged invention of new techniques for making steel, paper, silk, porcelain etc.

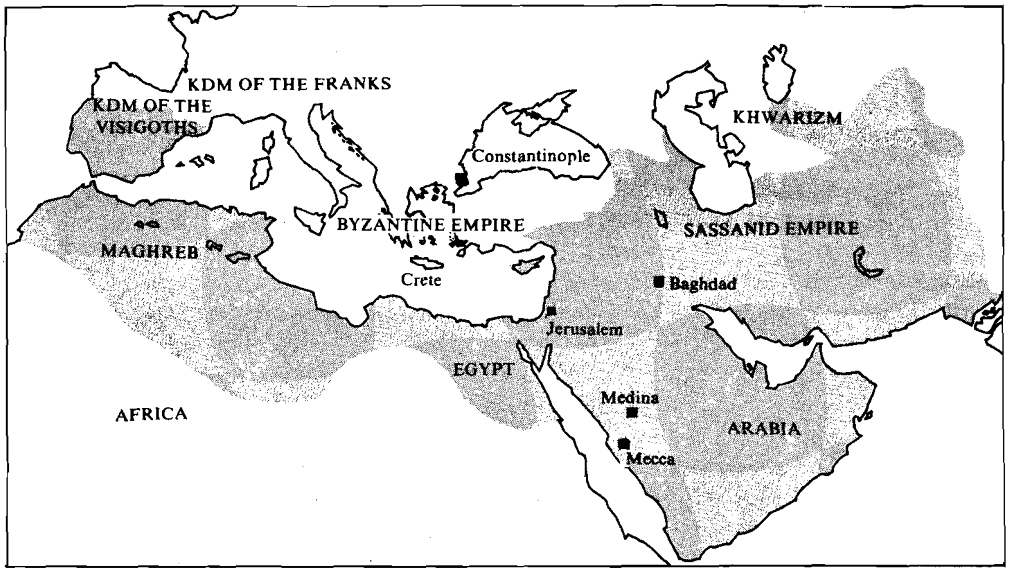


Fig. 5.1: Expansion of Islam upto 750 A.D.

Christianity had, by then, become identified with a decaying and corrupt empire. Therefore, scholars and intellectuals from the eastern and African parts of the Roman Empire started escaping to Persia which was becoming the new centre of learning and scholarship. These people were largely heretics and were safer from persecution under Muslim Caliphs than under the orthodox Roman Empire. In 431 A.D., the Syrian monk Nestor and his followers who challenged the Christian dogma were condemned and persecuted. They fled to Persia where a vigorous culture was being promoted by the Sassanian kings. Similarly, the Egyptian monk Eutyches of Alexandria (378—454 A.D.) and his followers had to flee from Egypt to Persia under pressure from the Church. Both these scholars made significant contributions to mathematics and astronomy. In the next section, we will describe how Arab science took shape. We will also see what contributions the Arabs made to the world of science.

5.2.1 Arab Science

What was crucial about this new Arab-centred civilisation was its willingness to examine and understand the classical scientific and philosophical traditions of the Greeks in the context of its new and vigorous culture. This was possible because of the written documents which reached the Arabs with the spread of the Roman Empire. Besides, they also had a strong feeling of being the heirs of the ancients. They traced the store of knowledge step by step back to the original Greek works. They translated these writings, absorbed them and developed them further. Caliph-al-Mamun founded a bureau of translation, Dar el Hikhma, where the great scholars Hunain ibn Ishaac and Thabit ibn Khurra prepared Arabic texts of most of Aristotle's and Ptolemy's writings and other major Greek classics of science. These scholars prospered under the patronage of the great Caliphs, al-Mansur, Haroun-al-Raschid, al-Mamun and al-Mutawahkil. They also translated the Indian medicinal, surgical and astronomical texts. This was aided by the extensive travels undertaken by merchants, travellers and scholars such as al-Biruni (973-1048 A.D.), who brought back the knowledge of local practices from the distant lands of India, Greece and China.

It is interesting to note that only the scientific and philosophical books were selected for translation, and not history, drama or poetry. Centuries later, when Europe tapped this source of learning, which was preserved in Arabic, they got a lot of scientific and philosophical writings of all the previous civilisations. The social sciences and humanities were, however, to be rediscovered by Europe directly from Greek and Latin. Thus, science and humanities entered into the modern tradition by separate channels. This, perhaps, explains to some extent the persisting divide between these areas of knowledge.

Al-Mansur, al-Mamun, Haroun-al-Raschid and al-Mutawahkil were Muslim Caliphs of the Abbasid dynasty, who ruled Persia between 754 and 861 A.D.

One of the reasons which ensured the growth of Arabic science, apart from flourishing trade by land and sea, was the fact that it was practised in a language used by the kings and slaves alike. This provided strong links between ordinary craftsmen and scholars, links which never fail to provide a great impetus to the growth of science.

The Arab science provided a genuine continuity to classical Greek science, and was also a melting pot for scientific thought of other civilisations. Yet, it seems to have had little ambition to improve upon or revolutionise these traditions. In studying Arab scientific works, we are struck by the rationality of treatment generally associated with modern science. However, mysticism and too much respect for Greek science and its leading figures like Aristotle became a handicap. The main pillars of science were astronomy and medicine. These were united by astrology which furnished the link between the outer big world of the heavens and inner small world of men. We would, however, like to state categorically at this stage, that the greatest figures of Arab science such as al-Kindi, al-Razi (Rhazes), Ibn Sina (Avicenna) and al-Biruni clearly rejected the extravagant claims of astrology and alchemy.

We have described above some general features of Arab science. You may like to work out an SAQ based on these!

SAQ 1

Which among the various factors given in column 2 helped or impeded the growth of Arab science? Indicate by drawing a line between the statements that correspond to each other in columns 1 and 2.

1	2
	i) The Arabs were willing to assimilate the best scientific traditions of classical cultures of Greece, India and China.
a) Features that helped the growth of Arab science.	ii) They had too much respect for Greek works.
	iii) The Arabs travelled extensively to various countries and brought back immense information.
b) Impediments to the growth of Arab science.	iv) Arab science was practised in a language used by kings and slaves alike.
	v) They could not completely escape from the influence of astrology, alchemy and mysticism.
	vi) The Arab treatment of scientific ideas is very rational.

We will now briefly describe the significant contributions of Arabs in some areas of science such as astronomy, mathematics, medicine, optics and chemistry.

Astronomy and Mathematics

Arabs carried on the Greek tradition in astronomy. They translated Ptolemy's Almagest and continued astronomical observations in spite of occasional religious interference. Although they did not add substantially to the Greek methods, the continuity that they provided was to prove invaluable to the sixteenth century astronomers.

The practice of astronomy provided the necessary incentive to develop mathematics. In this, the Arabs adopted the Indian system of numbers and introduced them on a large scale, to the extent that warehouse clerks and traders started using these numerals to conduct their business. The widespread use of the number system simplified calculations and had the same effect on mathematics as alphabets had on writing. Arabs translated Indian works on algebra and trigonometry and applied them to solve many physical and practical problems.

Geography

We have seen that Arabs were great travellers. Arab scholars travelled as far as Russia, Central Africa, India and China. They wrote well-ordered and rational accounts of their journeys and made maps and charts. Their geography was not only descriptive, they also had some idea of the size and scale. In this way, they laid the foundation of modern geography of Asia and northern Africa (Fig. 5.2).

Fig. 5.2: Arabic map of the world.

Scientific Chemistry

The Arab doctors, perfumers and metallurgists made their greatest contribution in chemistry. This was mainly due to the fact that Arab scholars, unlike their predecessors in Greece, never hesitated to take part in laboratory practices in handling drugs, salts and precious metals. The Arabs continued the Egyptian and Babylonian traditions, and learnt extensively from the Indian and the Chinese sources. To these they added their own rich contributions, giving rise to the first statements of scientific chemistry.

Arab chemists greatly improved the earlier distillation apparatus and used it for large scale production of perfume. They also undertook large scale production of soda, alum, copperas (iron sulphate), nitre and other salts which could be exported and used particularly in textile industry. While they perfected new techniques, they were not satisfied till they were able to get at the bottom of the reactions which made these techniques possible. Arab chemists stipulated the positive and negative nature of two reacting constituents. This was the first time that chemical transformation was approached rationally, to lay the basis for modern chemistry.

Medicine

The Arabs continued the Greek tradition in medicine also, but added to it the knowledge of new diseases and drugs which was made possible by the wide geographical spread of Islam. The doctors, who were not only Muslim, but also Jewish, studied a great range of diseases. They concerned themselves with questions of the effect of climate, hygiene and diet on health. They also paid attention to the practical art of cookery.

Fig. 5.3 : Oldest representation of a caesarean section from the works of al-Biruni.

Optics

The prevalence of eye diseases in the desert and tropical countries led to the study of the eye by Arab doctors. Surgical treatment of the eye led to renewed interest in the structure of the eye. This was to give the Arab physicians the first real understanding of dioptrics, the part of optics dealing with the passage of light through transparent bodies like a lens or glass. This also laid the foundation of modern optics. The lens of the eye was to point the way to the use of crystal or glass lenses for magnification and reading, particularly by the old. The 'Optical Thesaurus' of Ibn al-Haitham (about 1038 A.D.) was the first serious scientific treatment of the subject.

SAQ 2

Which three among the following developments in science are contributions of the Arabs? Tick the appropriate statements.

a) The use of number system was greatly popularised.
b) Gunpowder was discovered.
c) Chemistry was treated rationally for the first time, large scale production of salts was undertaken.
d) A heliocentric model of the solar system was given.
e) The first scientific treatment of optics was carried out.

The bare outline of the developments in Arab science that we have given above is just a glimpse of its extent and importance. Arab scholars rescued Greek science from the decadent state it had fallen into under the later Roman Empire. They created a live and growing science. They were able to extend the narrow basis of Greek mathematical, astronomical and medical science by drawing on the experience of Persia, India and China. They also extended the techniques of algebra and trigonometry and laid the foundations of optics and scientific chemistry. These developments continued till eleventh century A.D., after which we find that the best days of Arab science were over. There were brilliant individual scientists like Averroes (about 12th century A.D.) and Ibn Khaldun (about 14th century A.D.). However, the widely based and living movement existed no more. We will now try to analyse the reasons that led to the decay of Arab culture and, as a consequence, of Arab science.

5.2.2 Decay of Arab Culture and Science

The association of science with kings, wealthy merchants and nobles which was initially very fruitful, ultimately proved to be the weakness of Arab culture and science. The patronage provided opportunities to translate, observe, experiment and reflect upon various aspects of science. It also resulted in Arab science getting cut off from the people, who began to suspect that the learned advisors of the elite were upto no good. This made the common people an easy prey to religious fanaticism. The link also tied up the fortunes of science with the strength of the kingdoms. After the eleventh century A.D., both the Byzantine and Islamic empires (see Fig. 5.1) started breaking up internally and grew more dependent for military and economic purposes on local kings. By the time of the Crusades (between eleventh to thirteenth century), the empires broke up into local feudal estates where peasants and craftsmen were subjugated with renewed brutality. This destroyed the market for industry and the need for innovative science. In this situation of decay and stagnation came new barbarians from the steppe lands. They over-ran the Arab lands and effectively stifled their culture.

As a result of the regeneration of the Church and intensified internal religiosity, seven Crusades took place under the leadership of various European kings to subjugate other rulers and to extend the influence of Christianity.

The genius of Arab science lay in the fact that it provided a crucial link between the rise of modern science, and developments in Greece, in India and, to a lesser extent, in China in the classical period. Modern science, as we know it, arose in the sixteenth century after the Renaissance in Europe. The Renaissance took up the classical science as it was transmitted by the Arabs and developed it in a revolutionary sense. Thus started a new age in which science and technology could play pre-eminent roles, roles they had never been called upon to play before. We shall tell you more about this in Unit 6.

5.3 SCIENCE AND TECHNOLOGY IN MEDIEVAL INDIA

Let us now turn our attention to what was happening in India in the medieval times. As you have read earlier in Sec. 5.2.1, al-Biruni (973-1048 A.D.) had visited India and travelled extensively. He had studied the social life, political system and religious beliefs of the Indian people in depth. We get a great deal of information about India from his writings. In his writings he gave a detailed account of the level of scientific developments in India, in the early decades of the eleventh century A.D. His works also include reference to the earlier advances

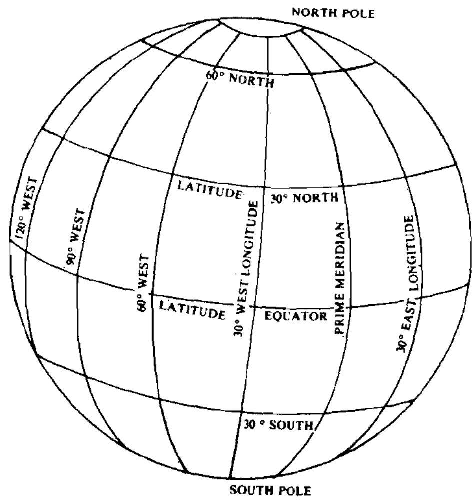


Fig. 5.4: A meridian is an imaginary circle passing through the poles of the earth, which divides the sphere into two equal parts. Twelve equally spaced meridians divide the earth into 24 equal sectors, each passing through the poles and each making an angle of 15° with its neighbour. By international agreement, the first or the prime meridian passes through Greenwich, England. The smaller of the two angles formed by the prime meridian and the meridian passing through any point on the earth is called the longitude of that point. The longitude of any point on the globe is measured east or west from Greenwich whichever makes the smaller angle. The parallels of latitude are lines drawn on the globe parallel to the equator. The latitude gives the angle north or south from the equator. The location of any point on the earth is described by its longitude and latitude.

in Indian science. For instance, he records the Indian contribution to astronomy and refers to the works of Aryabhatta, Varahamihira and Brahmagupta about which you have read in Unit 4. According to al-Biruni, Indians had tried to calculate latitudes (Fig. 5.4) of some places like Kannauj, Thanesar and Srinagar (in Kashmir). The calculation of longitudes was based on timings of the eclipse at different places, as had been suggested by Ptolemy earlier. Their prime meridian passed through Ujjain.

Al-Biruni points out that the Indian views regarding matter were similar to those of the Greeks. You have read about this in Sec 3.4 of Block 1. According to al-Biruni, the greatest Indian contribution was in the use of the decimal system. The numeral signs that the Indians used were the source of Arabic and the present day international numerals.

Al-Biruni's account is not a mere description of things as they were. He also tried to analyse why things were as they were. He realised that Indian science was already on the decline and lamented that "it is quite impossible that a new science or any new kind of research should arise in our days. What we have of sciences is nothing but the scanty remains of bygone better days". He attributed this situation to the lack of patronage to the scholars. This, incidentally, highlights the very elitist character of Indian science. It was restricted to a few people who practised science only as an intellectual exercise. Science in India had lost its connection with the life of common people or productive processes. There was, however, some change in the state of affairs with the coming of Islam to India.

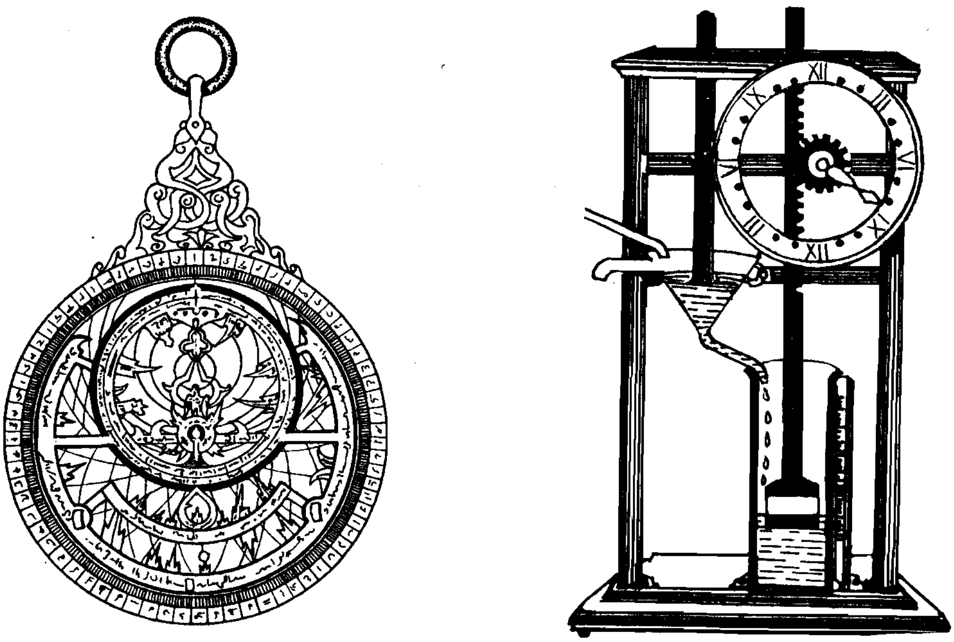
Islam came to India at a time when the vigorous intellectual phase of the Islamic civilisation was largely over. With al-Ghazzali's mysticism, a stiff resistance to rational philosophy had developed. Nevertheless, the Arab body of knowledge had inherited the best of sciences from the Greek civilisation, from China and from India. It also included innovations from within the widespread Arab civilisation. This entire body of knowledge became an Indian possession, all the more so as Indian scholars learnt Persian and Arabic after the establishment of the Delhi Sultanate. This influenced to a great extent the development of science in medieval India.

5.3.1 Achievements in Science

The interaction between Indian sciences and those brought by the newcomers remained limited for some time. However, astronomy and medicine received ready patronage from the Delhi Sultans as well as from Mughal Emperors and their nobility. We shall now tell you about the achievements in various areas of science in medieval India.

Astronomy and Physical Sciences

Astronomy was used not only for working out the calendar, the dates of the eclipses and for the determination of time but also for casting horoscopes for astrological purposes. Astronomy was also needed for fixing the direction of Mecca, in order to properly align the mosques. We find that Firozeshah Tughlaq (1351-88) established an observatory where a special type of astrolabe and water-clock were set up (Fig. 5.5). The interest of the rulers in astronomy continued during the Mughal period. Humayun is reputed to have employed a number of astronomers and with their help, he attempted to make astronomical observations.



(a) (b)

Fig. 5.5: (a) Astrolabe : front surface showing the graduated rim of a spherical astrolabe which is a small portable metal disc with a diameter varying from 4" to 8"; (b) water clock: as water flows into the cylinder, the float rises, turning the pointer on the dial to tell time.

The astrolabes made in India during the seventeenth century, were no doubt an achievement of metal and wood-workers and of mathematical arts. Also, a high degree of accuracy was achieved in circular gradation, which affected all measurements.

The most important stride in the field was made at the beginning of the eighteenth century. Raja Jai Singh, under the patronage of Emperor Muhammad Shah, established observatories at a number of places, such as Delhi (Fig. 5.6), Jaipur, Ujjain, Benaras and Mathura. He paid special attention to the instruments of observation. A noticeable feature was the construction of large sized observational instruments for fixing time and determining latitudes. He succeeded in compiling fairly accurate astronomical tables, rectifying the calendar and in making more accurate predictions of eclipses. Jai Singh's astronomical tables entitled *Zif-i Muhammad Shahi* borrowed heavily from the *Zif-i Ulugh Beg* (1394-1449) in the text, but his actual calculations and figures are different. Nevertheless, in the theory of astronomy, there was hardly any advance over the Ptolemaic system. It is the astrological aspect and preparation of horoscopes which proved to be the mystifying distraction.

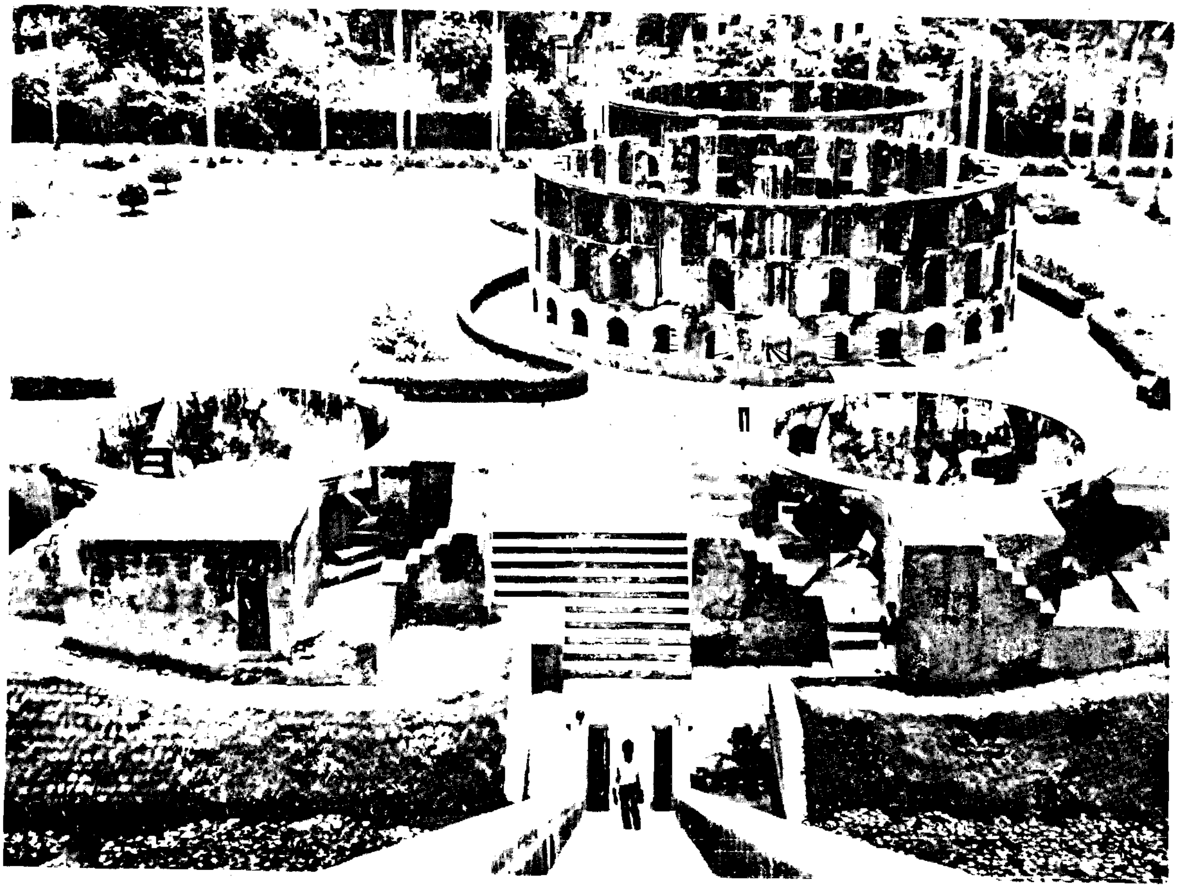


Fig. 5.6: The Ram Yantra, a kind of a cylindrical astrolabe and the Jai Prakas (right-hand corner), Jantar Mantar, Delhi

A familiarity with the knowledge of specific gravity and laws of motion, based on classic sources, was shown by Abu'l Fazl (d. 1603). This is indicated by a full chapter devoted to these matters in his book *A.in-i Akbari*, completed in 1595. In this he shows a clear understanding of the Archimedes principle, and the differences in the weights of bodies in air and under water. He also grappled with the problem of molecular arrangement in various substances and tried to relate it to specific gravity. He reproduced a table from al-Biruni giving the specific gravity of various metals and precious stones. The application of measures of specific gravity were given a practical turn by Akbar when he sought to determine the quality of timber by this means. Abu'l Fazl also gave in his book, a table of specific gravity of seventy two types of wood.

Geography

Geography was another science where development took place. The astrolabes helped determine more accurate latitudes. A big advance was made in the field of cartography when in 1647 Sadiq Isfahani prepared an encyclopaedic work that contained a World Atlas. The maps prepared by him, particularly of India, were fairly accurate in representing India as a peninsula and adding Sri Lanka at its southern tip. Rivers were sparingly shown. In India, only the rivers Ganga and Jamuna were drawn. However, their courses were shown quite accurately, unlike in the contemporary European maps of India. He had also indicated the physical features, for example, mountain ranges by wavy lines and used various colours to mark rivers and oceans. However, Sadiq made no attempt to show routes, a practice that started in Europe around 1500 A.D. By this time, India had also become aware of the discovery of the New World (America). Abu'l Fazl in his *A'in-i-Akbari* mentioned above, entered some remarks about the New World.

Chemistry

In the field of metallurgy too we notice some remarkable developments. Before the close of the sixteenth century, zinc was isolated by a process known neither to the Arab civilisation nor to the Europeans who learnt the art in the early nineteenth century. It has now been suggested by archaeological excavations at Zawar in Rajasthan that Indians knew how to isolate zinc by about the first century after Christ (Fig. 5.7). In China, zinc was isolated only during the ninth century.

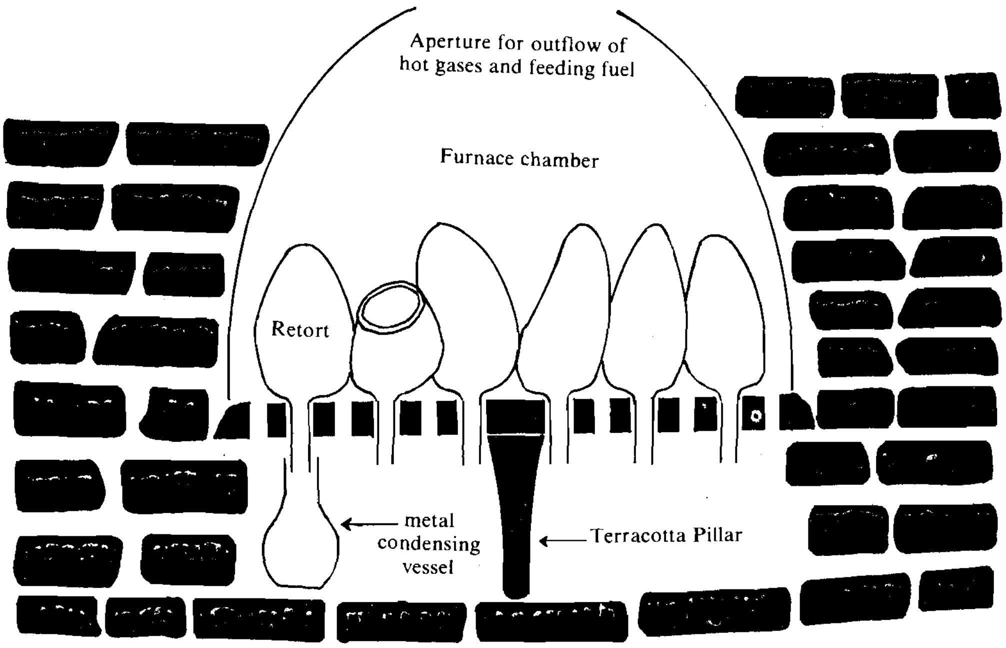


Fig. 5.7: A cross-section of the zinc distillation furnace found at Zawar, Rajasthan.

The isolation of zinc was accompanied by another achievement, namely the manufacture of brass, an alloy of copper and zinc. Abu'l Fazl gave three proportions of zinc and copper for obtaining brass of different varieties.

Tin-coating of copper and brass learnt from the Arab world became prevalent in medieval India, thereby enabling copper vessels to be more widely used. Soldering, particularly of gold on agates, crystals and other brittle materials, was done so efficiently, as to earn commendation from European travellers.

India seems to have discovered the freezing mixture before Europe. Saltpetre (potassium nitrate) was used for cooling water before 1580. This discovery has been attributed to Emperor Akbar.

Medicine

Aristocratic patronage for physicians and surgeons was not wanting, though, perhaps, surgeons did not enjoy a very high status in comparison to physicians.

The Greek (Unani) system of medicine still widely practised in India arrived with the Muslims. One would have expected improvement by the mutual exchange between it and the already existing Indian system of Ayurveda. But the two systems remained separate. Miyan Behwa (about 1500 A.D.) wrote an important work on medicine *Tibbi-i Sikandar Shahi,* based on a number of Ayurvedic sources that are explicitly mentioned. Jahangir's favourite surgeon Muqarrab Khan made use of selections from this book in his two tracts on medicine.

The two systems continued to coexist but probably without any great interaction. Both hakims and vaids were employed by the Emperor and the nobles. In the list of physicians at Akbar's court one finds four vaids, i.e. practitioners of Ayurveda.

In surgery, blood letting, and in orthopaedics, setting right dislocated bones were the known practices. A practice attributed to the surgeons of Kangra was that of treating those whose noses had been cut. They could create an artificial nose by a partial skin transplant. However, unlike in contemporary Renaissance Europe, no important systematic researches in the field of anatomy or physiology were made. Observations, such as plague spreading through rats, were chance observations. An interesting technique, which was pursued by popular practitioners, was smallpox inoculation, since the disease seems to have spread silently all over West Asia and India in the seventeenth-eighteenth centuries. The practice, however, was not safe.

Europeans were also employed as physicians by Mughal nobility but the attempt to make use of their knowledge remained confined to individuals. For example, Danishmand Khan (a Mughal noble about 1660 A.D.) tried to understand Harvey's discovery of blood circulation from the French traveller Bernier who dissected a sheep for demonstration. But such display of interest in European medicine on the part of Indian scholars was exceptional, and even the translations of European scientific works prepared on the orders of Danishmand have not survived.

On the whole, we find that the development of science in medieval India was at a rather slow pace. There was no adequate response to advances in science made in Europe. The lack of endeavour to understand European science is evident from the fact that an Atlas presented to Jahangir by Thomas Roe was returned to him because Jahangir's scholars were unable to understand it. It is difficult to explain this failure when the European merchants, priests, travellers and physicians were found in most parts of the country.

One possible factor could be the narrow social base of learning, i.e. learning was restricted to a small elite group. This was to some extent due to the absence of printing. Printing was introduced in India by the Portuguese. However, the products of their printing press were not aesthetic enough to be appreciated by the Mughal court and nobility. The possession of books was a privilege of the rich. Thus, the spread of knowledge was prevented.

SAQ 3

In the space given below, list at least five significant developments in science in medieval India, one each from the fields of astronomy, geography, physics, chemistry and medicine.

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So far, we have told you about the developments in science. Let us now see what technical innovations and inventions were taking place in medieval India.

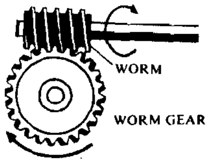


Fig. 5.8: The worm gearing has a short revolving screw (the worm) whose teeth move into the special teeth of a helical gear (the worm gear).

5.3.2 Technical Innovations and Inventions

Medieval India witnessed considerable improvement and changes in the field of technology. While these changes were largely a result of diffusion from outside, some technological innovations also originated in India. Diffusion from outside suggests readiness and ability to imitate, apply and extend the use of technological devices. On the whole, there seems to have been no inhibition against technological change.

We shall now describe some technical devices that were invented or improved upon in medieval India.

Gearing

Gearing provides a device for transforming horizontal motion into vertical and vice versa and for increasing or reducing speed (Fig. 5.8). One form of gearing is that of the parallel worm which originated in ancient India. It was received in Kampuchea, in all probability, from India before 1000 A.D. Parallel worm gearing was used in wooden cotton-gin in medieval times; it was also applied to sugar milling, with wooden rollers.

Right-angled pin-drum gearing came with the Persian wheel (*saqiya*), an improved water lifting device received from the Arab world. India already had water lifting devices such as pulley-system (*ghirni*) and noria (*araghatta*) with pot-chain (*mala*). The application of pin-drum gearing to the *araghatta*, converting it into what is known as the Persian wheel, enabled water to be lifted from deeper levels, in a continuous flow, by use of cattle power. The gear wheel and the shaft were of wood. A horizontal pin-drum, meshing with a vertical pin wheel, was rotated by cattle power. The Persian wheel was being widely used in the Punjab and Sind by the fifteenth century. This improved the means of irrigation and probably resulted in extension of agriculture in the region.

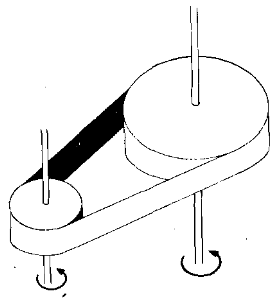


Fig. 5.9: Belt drive found in the charkha, home sewing machine and the fan of an automobile engine.

Belt-drive

The belt-drive is a comparatively simpler device than gearing for transmission of power and for increasing or decreasing the speed of motion (Fig. 5.9). Belt-drive came to India in the form of the spinning wheel. The spinning wheel quickened the speed of spinning by about six fold. This must have resulted in reducing the prices of yarn and, thus, of cloth. The other improvement in the spinning wheel was the addition of crank handle during the seventeenth century. The belt-drive was extended to the diamond cutting drill, by the seventeenth century.

Weaving

Evidence of an improvement in weaving comes from a fifteenth century dictionary which describes the foot-pedals used by a weaver to control speed. The addition of treadles to the loom facilitated the use of feet by the weaver for lifting alternately the heddles and freed his hands to throw the shuttle to and fro (Fig. 5.10b). This could more than double the rate of weaving.

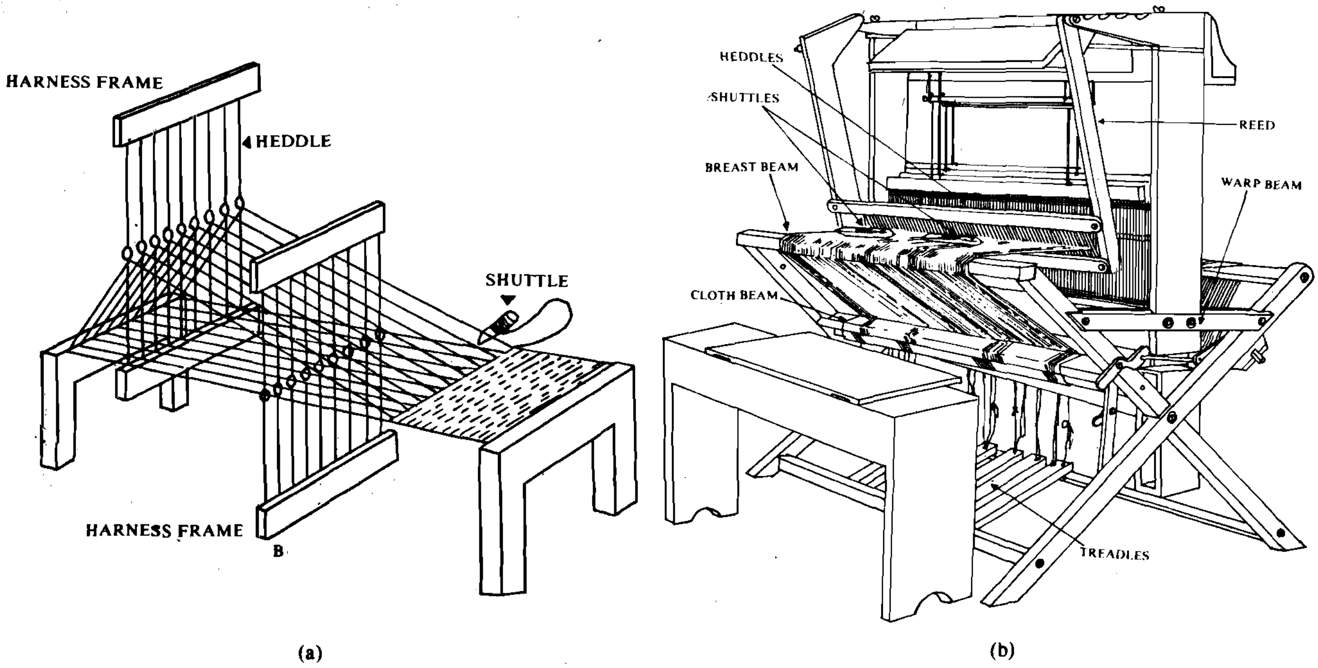


Fig. 5.10: (a) A simple loom. Harness A is raised so that the shuttle goes under those warp threads, but over the warp in B. The harnesses are reversed and the shuttle is passed back under B and over A; (b) in the foot-operated handloom the warp threads are wound on a cylinder called the warp beam. Each thread passes through a heddle or vertical rod. Alternate heddles are separated so as to form two groups held together by harnesses. When one set of heddles is raised and the other is lowered, the warp is separated into two sections, forming a shed through which shuttle is passed. The position of heddles is reversed to form another shed and the shuttle is passed through again. The woven cloth is wound onto a cloth beam.

By the seventeenth century both methods of multi-colour pattern dyeing, namely, the use of resist to confine colours to patterns and of mordant to take colours were used. It was, perhaps, during the same century that direct block printing, a time-saving technique as compared to painting, became popular in India.

Paper manufacture

Paper was not used in India until the eleventh century. This Chinese invention of the first century A.D. reached India mainly through the Ghorian conquerors. Once introduced, its manufacture spread quickly, and by the middle of the fourteenth century, paper became so cheap that it was used not only for writing but also for wrapping purposes by the sweetmeat sellers.

Bridget and Raymond Allchin are archaeologists. Joseph Needham, a scientist, is well known for his works on the history of science and society in China.

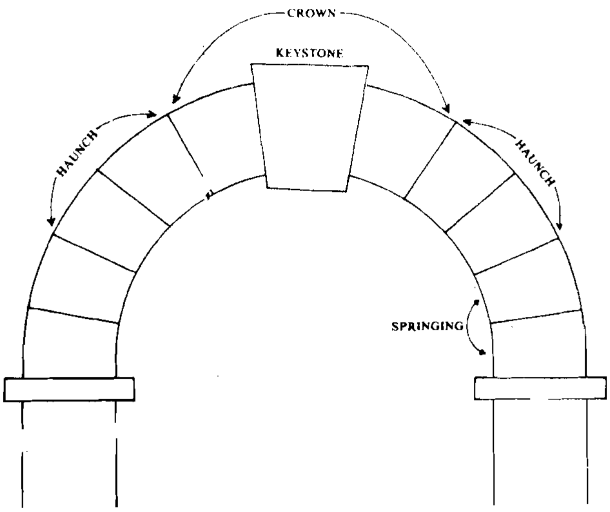
Distillation

The know-how of liquor distillation also came to India during the thirteenth century. Though it has been argued by the famous Indian chemist P.C. Ray (1861-1944 A.D.) and recently by the Allchins and Needham on the basis of archaeological evidence, that liquor distillation was known in ancient India, the stills seem to have been small and inefficient. With the thirteenth century came various types of stills (for liquor as well as for rose-water) and there is little doubt that the manufacture of distilled spirits received great impetus.

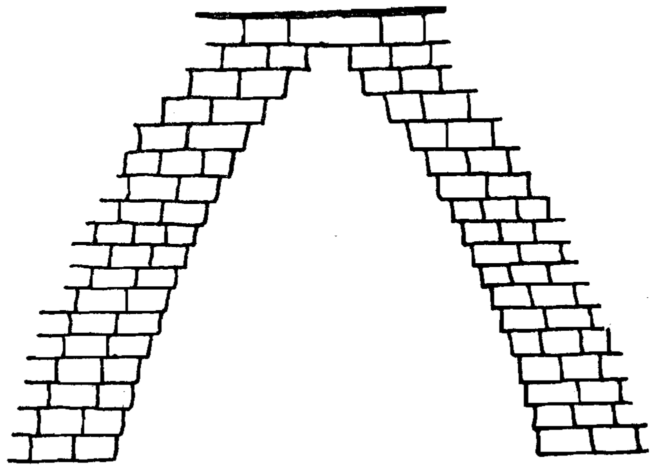
Architecture

The architectural style of India underwent a drastic change after the Turkish conquest. The Sultans and their nobles insisted on having arches and domes and competent Indian masons succeeded in building them. The first surviving example of arch is Balban's tomb, dated 1280, and of dome, Alai Darwaza, dated 1305. It was the change in building technology accompanied by the introduction of lime mortar that made possible the change from trabeate architecture to arcuate style. The principle of true arch seems to have been known in ancient India, but somehow large arches could not be made. However, false arches were constructed in ancient times (see Fig. 5.11).

Use of lime mortar made it possible to waterproof floors and walls for tanks. Thus, it became possible to build tanks and vats such as those needed for producing India's major dye, indigo.



(a)



(b)

Fig. 5.11 : (a) True arch : its lower part is called springing, top is the crown, and shoulder is the haunch. Keystone has a key position in the formation of arch ; (b) false arch is built of horizontal layers so laid that each projects slightly beyond the one below, gradually coming together at the top where the meeting point is covered by a flat slab.

Military Technology

Important changes were introduced in military technology. Rope and wooden stirrups for horsemen were known in India before the thirteenth century. However, the iron stirrup seems to have been introduced by the Ghorians and the Turks. This greatly improved the combat power of horsemen. At the same time, shoeing improved the performance of horses.

Turks also brought with them the cross-bow (Fig. 5.12). The cross-bow had an additional tube at right angles to the bow in which the arrow was fitted; the tube gave greater accuracy of direction to the arrow. This tube seems to be a direct precursor of the barrel of the hand-gun.

The next stage of development in military technology was the use of cannon and gun powder. This innovation came to India during the latter half of the fifteenth century from the Ottoman Empire which had itself received it from Europe.

By Akbar's time, match-locks and their manufacture became common in the imperial arsenal. Some improvements were attempted mainly with a view to do away with the match and strengthen the barrel. Akbar's arsenal succeeded in manufacturing a gun that had most probably a wheel-lock. Here the spring released by trigger caused a wheel with serrated edges to revolve against a piece of pyrites and so send sparks into the priming pan. The flintlock widely used in Europe by the first half of the seventeenth century was adopted in India later on (Fig. 5.13).

Manufacture of the barrel of a gun posed a problem for the gunsmith. The barrel had to be very strong to withstand the explosion within it; the making of the bore and alignment required high accuracy. In Akbar's arsenal, the barrel was made by rolling flat iron sheets and welding the edge. Thereafter, the bore was worked from inside. The same technique was used in Europe down to the eighteenth century.

India was credited with casting the heaviest bronze cannons in the world at the close of the sixteenth century. But the heavy guns were not necessarily efficient as they lacked mobility as well as accuracy. We find that Akbar paid great attention to the manufacture of lighter guns that could be pulled by a single man.

An important device used in the Indian army was *bana* or rocket. This was made of bamboo, with iron cylinders containing combustible materials at the tip. It was this Indian rocket that inspired the invention of rockets by Congreve in early nineteenth century.

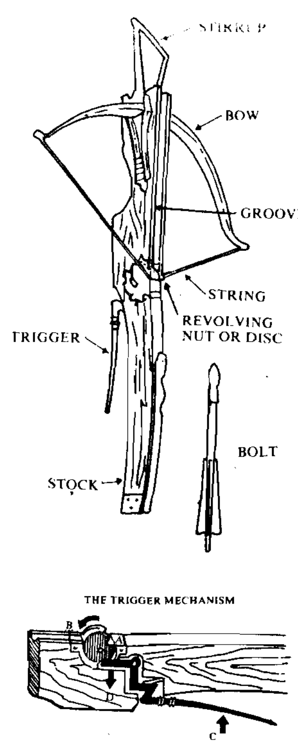


Fig. 5.12: (a) Cross-bow and (b) how it works. String of the bow is drawn back and held in a notch (A). Bolt, a type of arrow used with cross-bow is then laid in a groove on top of the stock (B). When the trigger is pressed upward (C), the rod drops, allowing the circular plate in which the string is resting to spin freely. Force of the released bowstring sends the bolt through the air with great force.

Metal Screw

One important device that had a great potential in the manufacture of precision instruments and machinery was the metal screw. It came into use in Europe from the middle of the fifteenth century for holding metal pieces together. Its use was of great importance in mechanical clocks. The screw began to be used in India by the second half of the seventeenth century and even then it was a less efficient version of the European screw. The grooves were not cut, but wires were soldered around the nail to create the semblance of grooves. This had to be done owing to the absence of lathes which were used in Europe for cutting grooves. Due to this limitation, the Indian screw did not fit properly.

Ship-building

The ship-building industry in the seventeenth century witnessed far-reaching changes that mainly resulted from imitating European techniques. The Indian sea-going ships, until the first half of the seventeenth century, were called 'junks' by the Europeans. These were very large and supported immense main sails. In some ways, the imitations even improved upon the originals. The Indian method of riveting planks one to the other gave much greater strength than simple caulking used by European ship-builders. A lime compound dabbed on planks of Indian ships provided an extraordinarily firm protection against sea-weeds.

However, it was the instruments used on ship where India lagged much behind Europe. Indians failed to fashion modern navigation instruments. The main instrument used on Indian ships still remained the astrolabe. Later, in the seventeenth century, European captains and navigators were employed on Indian ships, and they naturally used telescopes, quadrants, and other instruments that were imported from Europe.

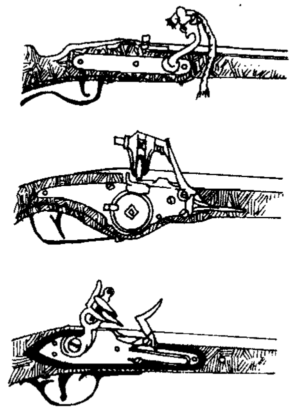


Fig. 5.13: Different firing mechanisms of guns in use in the medieval times; (a) match-lock: when the trigger was pulled, a curved hammer thrust the burning cord into the hole igniting the gunpowdet; (b) wheel-lock: pulling the trigger released a clock-type, hand wound spring, which spun a steel wheel against a piece of flint or iron and gunpowder was ignited by a shower of sparks; (c) flint-lock: a simple spring snapped the hammer down when the trigger was pulled. A piece of flint or iron held in the hammer jaws created sparks igniting gunpowder.

Agriculture

Agriculture has been India's largest industry. The Indian peasants have used seed drill from antiquity; in the seventeenth century they practised dibbling, that is, dropping of seeds into holes driven into the ground by sticks. They also practised crop rotation in most areas. The number of crops grown by Indian peasants was quite large. Abu'l Fazl mentions around 50 crops for *kharif* and 35 for *rabi* seasons, though their number varied from region to region. The most remarkable quality of the Indian peasant was his readiness to accept new crops. The new crops introduced in the seventeenth century that came from the New World were tobacco and maize. These crops came to be grown quite widely. By the fifteenth century, the peasants of Bengal also took up sericulture and by the seventeenth century, Bengal had emerged as one of the great silk exporting regions in the world.

Horticulture developed considerably under aristocratic patronage. Various types of grafting were introduced. In Kashmir, sweet cherry was obtained by grafting, and the cultivation of apricot was also extended by the same means. During Shah Jahan's time, the quality of oranges was greatly improved by use of the same technique. On the western coast, the Portuguese introduced mango grafting and Alfonso was the first mango produced in this fashion. Mango grafting seems to have spread in northern India during the eighteenth century.

To sum up, in this section we have tried to give you a brief overview of the scientific and technological developments in India during the medieval times. If we look at the 600 years of development of science in medieval India, we cannot but be disappointed. There seems to have been progress here and there, in astronomy, medicine and technology, but all within the old frame of thought which is often called Aristotelian : a world which always was as it is now, and will continue to be so: a universe at the centre of which was the earth and all things were made of five elements—fire, air, water, earth and ether. The concept of master and slave of the Greek society or hierarchical structure was so natural that it also pervaded the physical world where everything knew its place and fulfilled its purpose.

There was, indeed, no effort to incorporate the latest findings in each subject, to even be aware of the discoveries being made in contemporary Europe. There was still less effort to develop a theoretical and philosophical understanding in which each element of knowledge could fit. Little interest was taken in such remarkable advances as Copernican model of the solar system, Galileo's work (1610), Newton's great work on gravitation (1665), or even circulation of blood discovered by Harvey (1628). The invention of the printing press which had the potential to make knowldege available to a larger number of people or again the telescope (about 1600) and the microscope attracted no attention. It is remarkable that the few centres of learning that existed propounded theology, either Hindu or Muslim, or explained a body of knowledge that already existed. Their role was not to break fresh ground and develop new things.

Why was it so? We shall now try to analyse why science and technology did not grow in India as in Europe in those times. But before reading further you may like to try an SAQ.

SAQ 4
List at least five technical innovations of medieval India in the space given below.

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5.4 IMPEDIMENTS TO THE GROWTH OF SCIENCE IN INDIA

By the end of the eighteenth century, Indian society had become very complex. Hence it is difficult to discuss even one aspect of it, that of science, as it arose from this society and contributed to it, without over-simplifying. However, if simplification makes sense and does not distort the picture, it is a good thing, because it gives us an overview which helps in understanding the interaction between science and society.

What may have struck you from the brief presentation given here is that Indian science was at the same level as science anywhere else in the world. In particular, it was at the same level as European science, upto about the middle of the sixteenth century. But, then European science took big strides forward and left Indian science way behind in the period that followed. In fact, the British were able to subjugate this country, and make it their colony, on the basis of science, technology and industry which had developed there. The question that naturally arises is what the difference between Europe of sixteenth century and India of that period was. If you get interested in pursuing the question, you would probably have to read history in depth. However, to put it simply, the difference in the two societies was in their social structure, in the degree of the hold of religious orthodoxy, and the intellectual atmosphere. Let us explain what we mean.

We have seen that one kind of pressure for advancing knowledge and technology comes from the necessity of satisfying human needs. There is an old saying that necessity is the mother of invention. Well, it appears that in spite of periodic wars between the rulers of various regions and states in the country, there was a very considerable stability in Indian society. Population was small, the land was fertile and even from small land holdings Indian peasants were able to meet the requirements of subsistence. They could feed and clothe themselves. Although there were poor people, poverty and hunger of the kind we see today did not exist. The deprivation that we see today is largely a result of British policies imposed on us. The hold of religion, particularly in the rural areas, and the existence of the caste system, contributed both to a certain reconciliation with fate, and an acceptance of the social hierarchy. There was a fascination with the idea of an infinitely old universe condemned to an endless cycle of deaths and rebirths, in which nothing fundamentally new could ever happen. What can be called a peculiar kind of satisfaction prevailed, which did not allow pressures to build up for either enhancing production through technological innovation, or to change the society.

Another reason was that those who worked with their hands did not contribute to the stock of knowledge. And those who possessed even out-dated knowledge never had to test it on the touchstone of practice. Either the kingdoms fought wars or settled down to long periods of peace. It seems natural to think that in such a society there was no clamour to develop new products or new processes. Social stability and stagnation can easily go hand in hand. The rich had no need for change. the poor had no power to bring about change.

We have seen that when Islamic influence entered India in successive waves, it tended not to disturb the life of the common people who lived in rural communities. It did not interfere with the prevailing religious ethos, which remained predominantly Hindu, with its ideology tolerant of great variations, but at the same time protecting the caste system which was well established in India. We find that at the level of administering the country, and in the armed forces there was mutual support between the higher strata of people in the two communities. Muslim kings with Hindu Commanders-in-chief, and Hindu Rajas with Muslims at the head of their armies are known to have fought and also defended each other. Naturally, there was give and take, and intermingling of cultures. What we call Indian culture today is a result of centuries of interaction between our people of different areas and of those who came and settled down here in different periods.

At the level of religion, there was coexistence between Islam and Hinduism, perhaps, out of necessity, since the Muslims were in a small minority. They could certainly not afford a confrontation with the vast majority if their rule was to last in India and was to be extended in the centuries to come. This was also because priests had a great hold over people and any interference in each other's affairs would have had serious political consequences. It could have led to turmoil. So, each steered clear of the other. Further, the priests of the two communities were well off, and satisfied with their economic condition. Within the two religious systems too, there were no active controversies and no strong movements of reform. The Bhakti and Sufi movements did arise in the medieval period. These movements preached religious tolerance and were highly critical of the caste system. However, they did not make a wide impact as their word did not reach far.

This was perhaps due to the absence of printing. Typically, when a printed book was presented to Jahangir, he is said to have thrown it away, saying that it was ugly and unaesthetic as compared to the beautiful calligraphy in which they prided. He little realised or was, perhaps, little interested in the possibility of enriching people's life on a large scale through the availability of cheaper books. This was in contrast to the sixteenth century Europe where the availability of printed word greatly helped the spread of knowledge that created a wider and deeper impact for bringing about social change. You will read more about this in Unit 6.

In India education was, by and large, limited to religious teaching and the intellectual atmosphere was not in favour of challenging the established ways of thinking, or of propounding new theories. In such an atmosphere few would venture to propose freedom of thought. It was still more difficult to accept such new things as a sun-centered universe demonstrated by Galileo. For, the new theory changed the order which was believed to have been established by God to give the abode of man a central position in the entire creation. Indeed, astrology was, perhaps, esteemed enough to let astronomy go on! Alchemy still held some promise of converting base metals to gold, howsoever mysteriously or irrationally, to allow dabbling in chemical techniques! The reign of the orthodoxy with its belief in eternal or revealed truths never allowed free thinking and imaginative adventure of ideas. To put it in another way, the learned had fixed ideas which they did not need to change. And those whose social status was low and who were exploited by the feudal order had no access to learning.

If it were not for these factors, we had a tremendous advantage over Europe in the sense that the strong streams of Arab and Indian science coexisted here, and we should have been miles ahead of Europe. In Europe, comprehensive books of Arab authors like *Compendium of*

Astronomy by al-Fargani, *Howi, Liber Continens* by al-Razi, the *Canon* of Ibn Sina and the *Colliget* of Averroes (all medical treatises) were used as text books in the seventeenth century. All these books were available in India and could have been used, but were not. The exciting advances made in science during the sixteenth and the seventeenth centuries in Europe, such as the works of Copernicus, Galileo and even Newton did not attract widespread attention, since they were not close to the hearts of such scholarship as existed in India at that time. Due to this indifference and neglect and the other factors mentioned earlier, we lost the race.

All this can, perhaps, be summarised by saying that a traditional, hierarchical society with a low level of discontent and conservatism promoted by both the religions, made scientific advance superfluous. Naturally, such a society could not bring about a scientific revolution such as was taking place in contemporary Europe in the sixteenth and the seventeenth centuries. It could, and did, devote its attention to the good things of life such as drama and music, dance and painting, architecture and poetry. This, at least, was the saving grace of the medieval society.

5.5 SUMMARY

In this unit we have covered a long period in history starting from about the seventh century A.D. to about the eighteenth century A.D. Geographically also, we have covered a wide region spread from the West Asia where Arab science flourished, to the Indian subcontinent. We now summarise what we have learnt.

- We have seen that Arab science provided continuity between the classical science of the Greek, Indian and Chinese civilisations and science in the medieval times. For the first time a rational approach was adopted by the Arabs in the study of many areas of science as applied to the solution of practical problems. Arab scientists were from the common people, spoke the same language and shared common problems. This gave an impetus to the growth of practical science. We have also seen that about the eleventh century A.D., the vigorous intellectual phase of Arab science faded out due to several reasons.

- Medieval India had the advantage of having a vast storehouse of knowledge which was gained through contact with the Arabs and the Europeans. The Indian people were able to pick up the technical innovations. Many innovations were also made here. However, they failed to imbibe the rational philosophy of the Arabs or appreciate the scientific endeavour taking place in contemporary Europe. The reasons for this attitude may be seen in the prevailing social conditions. This resulted in Indian science being left far behind.

5.6 TERMINAL QUESTIONS

1) Explain in four or five lines how the absence of printing hampered the growth of science in medieval India.

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2) Which three among the social factors mentioned below became impediments to the growth of science in India in the medieval times? Tick the correct choices.

   a) There was stability in society. There were no pressing socio-economic needs to demand scientific innovations. ☐

   b) Art and music, drama and painting thrived. ☐

c) The hold of Hindu and Muslim religions on their adherents was absolute. The reformist movements created very little impact. ☐

d) The intellectuals in the society had fixed ideas that need not have been tested with practice. The peasants and artisans had no access to learning. ☐

e) Mughals made great contributions to architecture. ☐

3) State, in the space provided alongside, whether the following statements about science in medieval times are true or false?

a) Medieval times signify the darkest period in the growth of science in India. ☐

b) Indian scholars of the medieval period did not show much interest in disseminating knowledge by using comprehensive text books on astronomy, medicine etc. ☐

c) The availability of printed works of learned men played a great role in bringing about change in the European society. ☐

d) Indian science was linked with the lives of common people and the productive processes. ☐

e) The Indian people showed remarkable willingness to imitate and extend the use of technology obtained from contact with Europeans. ☐

5.7 ANSWERS

Self Assessment Questions

1) a) (i), (iii), (iv), (vi).
   b) (ii), (v).

2) a), c), e).

3) i) The establishment of observatories by Raja Jai Singh.
   ii) The preparation of a World Atlas by Sadiq Isfahani.
   iii) The measurement of specific gravity of metals, stones, wood etc.
   iv) The discovery of freezing mixture.
   v) Creation of an artificial nose by partial skin transplant; the practice of smallpox inoculation.

4) Persian wheel, rocket, iron stirrup, light guns, ships with riveted planks, astrolabe, grafting.

Terminal Questions

1) The absence of printing meant that learning was restricted to a small elite group. The practitioners could not have access to books. Thus, the gap between theory and practice could not be bridged. You can further expand this answer.

2) a), c), d).

3) a) F b) T c) T d) F e) T.