UNIT 6 RENAISSANCE, THE INDUSTRIAL REVOLUTION AND AFTER

Structure

6.1 INTRODUCTION

In Unit 5 we have described the scientific and cultural developments that took place in the Arab world and in India during the medieval period. We are now going to describe, in brief, the European society of those times. You have read about the Iron Age Greek and Roman societies in Unit 3. You also know that these Iron Age societies were slave societies.

The slave economy of classical times was followed by a feudal system which lasted well into the seventeenth century. The feudal system was technically and economically more fragmented than the slave society which it replaced. It did not contribute much to scientific thought. However, several new productive techniques were introduced on a small scale. These techniques were used by common people and were, therefore, widespread. In this unit we will describe these techniques in brief. As we will see, this, along with the accompanying economic changes, laid the basis for the transformation of feudalism to capitalism and the birth of modern science in Europe.

In Unit 5 we had tried to analyse why science did not flourish in India, the way it did in Europe from the sixteenth century onwards. In this unit we will complete the analysis by outlining the features of European society that helped the growth of science there. We will, once again, cover a long period in the history of science, picking up the thread from the fifth century A.D. We will dwell briefly on the feudal system which contained the seeds of the transition to capitalism, and then describe the Renaissance and the Scientific and the Industrial Revolution, which led to the emergence of modern science. If you want to go into the details of the social conditions prevailing in the European society, you may refer to Units 7, 8, 9 of the Foundation Course in Humanities and Social Sciences.

We also find that the Industrial Revolution created a great demand for raw materials as well as for markets to sell goods. This led to the colonisation of many backward countries, including India, by the newly industrialised countries. In the next unit we will discuss the developments in science and technology in India during the colonial rule and the post-Independence period.

Objectives

After studying this unit you should be able to :

- describe the developments in science and techniques in the European society during feudal times and explain how these led to the transformation of the feudal society,
- describe the social changes brought about by the Renaissance and the consequent developments in science and technology,
- outline the important scientific developments in the post-Renaissance period,
- compare the Indian and European societies of the period from the sixteenth to the

eighteenth century and analyse the features of the then European society that helped the birth of modern science,

- describe the technical innovations leading to the Industrial Revolution, its consequences and some of the major scientific advances made thereafter.

6.2 SCIENCE AND TECHNIQUE IN MEDIEVAL EUROPE

About the second century A.D., the collapse of the Roman Empire and the barbarian invasions by Franks, Goths, Magyars, Vandals, Slavs and others brought about conditions in Europe, in which the slaves could revolt and free themselves. But even in freedom, slaves could not do much since they had no land to produce food for themselves. Though the Romans had conquered the whole of Western Europe and had come as far as England (see Fig. 3.18), agricultural land was limited. Most areas in western Europe were covered with thick forests and even the soil was clayey and heavy. The Romans did not have the agricultural tools and techniques for working such land for cultivation. This led to widespread scarcities of food and other daily necessities, which resulted in discontent. In other words, the breaking up of slave society was accelerated by its own tensions and scarcities. We find that from the fifth century onwards, slaves were disappearing and their place was being taken by serfs.

Towards the beginning of the tenth century, a new productive system and a new society had established itself in many parts of Europe. This was the feudal system. Let us now see what this society was like and the status of scientific and technological development in it.

6.2.1 The Feudal Society

The economic basis of the feudal system was land, and the village was its economic unit. The feudal economy was dependent on local agricultural production and a scattered handicraft industry. In the villages, peasants or serfs shared the land and work. But they were forced to yield part of the produce or labour to their lords in the form of rent, taxes or feudal service. Usually, a lord owned one or more villages or land in several villages. The serfs were obliged to maintain their lords and they were not allowed to leave the land on which they worked.

This obligation of feudal service, that is, of work exacted by force or by custom backed by force, is the characteristic of the feudal system. What distinguished the serfs from the slaves of classical times is that unlike the latter who were owned by the slaveowners, the former were free men and had a secure tenure to cultivate land. Though the serfs were nominally free, their condition was not much better than that of slaves. However, social pressures on them had been somewhat reduced. This feudal order lasted until about the seventeenth century in Europe.

The period from the tenth century to about the fifteenth century is usually called the Middle Ages in Europe. In this period, the Church was the centre of power. It provided a common basis of authority for all Christendom. It was also an instrument for intellectual expression. All intellectual activity was carried on by people who were part of the Church. Thus, the Church dominated all walks of life. Therefore, the clergy had to be trained to think and write, in order that they may be able to defend the faith and take up missionary work. At first, this need was met by setting up cathedral schools. By the twelfth century, these had grown into universities. The first university to come up in this period was at Paris, in France, in 1160. It was followed by the founding of Oxford University in 1167 and Cambridge University in 1209 in Britain. Then came the universities in Padua (1222), and Naples (1224) in Italy, Prague (1347) in Czechoslovakia, and several others. These universities were mainly for training the clergy.

Teaching in these institutions had to be only by lectures and debates because books were still rare. The curriculum comprised grammar, rhetoric, logic, arithmetic, geometry, astronomy, music, philosophy and theology. In practice, the amount of science that was taught was very little. Arithmetic dealt with only numbers, geometry with the first three books of Euclid and astronomy got no further than the calendar and how to compute the date of Easter. There was little contact with the world of Nature or the practical arts, but, at least, a love of knowledge and an interest in argument was fostered. As we know, education by itself can be a positive factor in human development. In this case religious personnel were being trained according to a specific curriculum, and the universities were citadels of conservatism. However, they did

Easter is a Christian Festival commemorating the rising of Jesus Christ from his grave. It falls on a Sunday but the date may change every year.

come in contact with the creative thought of others, particularly the classical Greek thought and, to some extent, Arab, Indian and Chinese thought. This led to an intellectual climate which proved good for the future developments and discoveries in science.

But in the Middle Ages, education was still restricted to a small number of people. What may be called 'scientific' investigation was undertaken only by the clergy. And it was done to somehow justify religious beliefs. There was a constant debate between faith and reason, but even reason was used to prove the supremacy of divine thinking, revelation and every aspect of Christian dogma. We will now describe very briefly the 'scientific achievements' of the Middle Ages.

Medieval Science

We can record the sum total of the medieval achievement in the natural sciences in a few lines. It can be put down as a few notes on natural history and minerals, a treatise on sporting birds, such as falcons, hawks etc., some improvements in Ibn al-Haitham's optics and some criticism of Aristotle's ideas. In mathematics and astronomy, the Arabic algebra and Indian numerals were introduced and Ptolemy's Almagest was translated. The medieval European astronomers could not go much beyond the Arab contribution in observational astronomy although they added a few details. They made some contribution to trigonometry and the construction of instruments. However, there was no radical revision of astronomy. Robert Grosseteste (1168-1253), a Bishop and Chancellor of Oxford University, was a leading scientist of the Middle Ages. He thought of science as a means of illustrating theological truths. He experimented with light and thought of it as divine illumination. There were many other such 'scientists' in the Middle Ages.

Those who questioned the prevalent religious beliefs, were likely to be prosecuted for heresy! Even the idea that man could reach God directly without intermediaries, such as priests, was considered a heresy. The Middle Ages were an era of faith and of regimented thinking. The feudal society in its social, economic and intellectual character was again a stagnant society. The limited contribution of medieval science under such conditions is understandable. It is, indeed, unfair to expect more of such a science than what was demanded from it in its time!

However, the feudal society was definitely on a higher technical level than the slave society of the Iron Age. In fact, the impetus to technical innovations had existed from the beginning of the Middle Ages. This arose from the need for better use of land. It was here that the peasant and the workman could use and improve the classical techniques. For most of the Middle Ages there was a chronic labour shortage with the labour force of slaves no longer available and with the expansion of cultivable land in the countryside. Thus, human labour was sought to be substituted by mechanical means; manpower shortage led to the use of animal, wind and water-power. Thus, we find that many technical developments took place in medieval Europe though most of them seem to have come from the East, especially from China. Let us see what these developments were. But how about trying an SAQ first!

SAQ 1

Which factors among the following led to technical developments and which ones were responsible for very little advances in science in the European society in the Middle Ages? Put a 'T' for the former and an 'S' for the latter against each statement.

i) Expansion of cultivable land. ☐

ii) Only priests conducted scientific investigations to justify religious beliefs. ☐

iii) Shortage of labour due to absence of slaves. ☐

iv) A need for better use of land by serfs. ☐

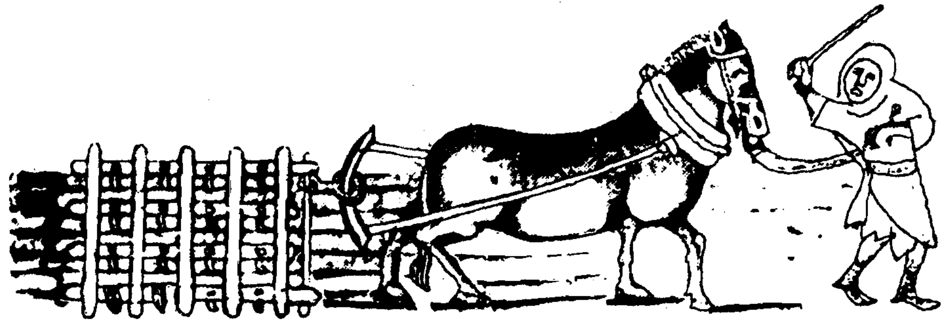
v) To question religious beliefs or say anything contrary was branded a heresy. ☐

Technical Developments in Feudal Society

Major inventions, namely, the horse collar, the clock, the compass, gunpowder, paper and printing, were not developed in feudal Europe. Most of these were being used in China during the first few centuries of Christian era. We need to know about these advances because, in Europe, the use of some of these techniques set in motion a revolution, which contributed to the breakdown of the feudal system.

The **horse collar** and the **mills** were more efficient means of using power. The horse collar originated in seventh-century China and reached Europe in the eleventh century. Its use resulted in a manifold increase in the horse's ability to pull loads and work longer. Horses took the place of oxen at the plough and more acres of land could be cultivated (Fig. 6.1).

(a)



(b)

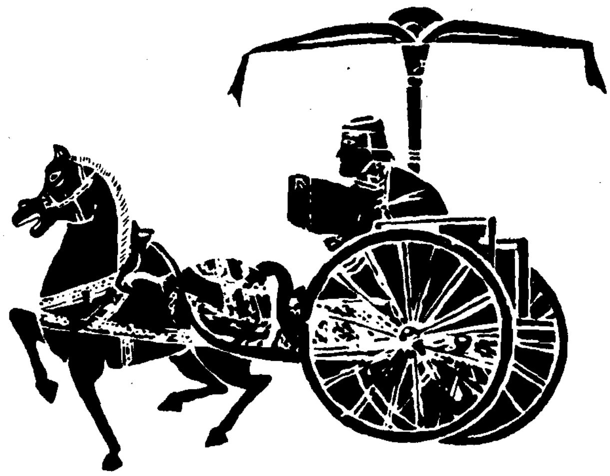


Fig. 6.1: (a) Horse collar in use in the fourteenth century in England; (b) improved horse collar that made a great difference to the load that a horse could draw.

The **water-mills** were also invented in the classical period. But they came to be widely used only in the Middle Ages. The **wind-mills** and **water-mills** harnessed nature for performing mechanical work. These mills were used for grinding grains, extracting oil from seeds and drawing water from wells, thus helping agriculture. They were also used for blowing bellows, forging iron or sawing wood. Mills became so popular that a mill and a miller were found in every lord's domain. The task of making and servicing the wind and water-mills was beyond the skill of most village smiths. Therefore, there grew a trade of mill-wrights who went about the country, making and mending mills. These men were the first mechanics who knew all about the making and working of gears. They also had a hand in the development of mechanical clocks and watches.

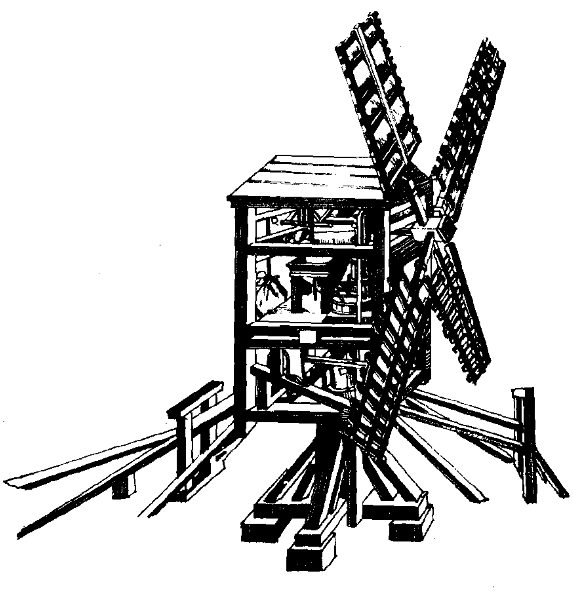


Fig. 6.2: Wind-mill.

There were two navigational inventions, the **compass** and the **sternpost rudder**, that had a profound impact on sea voyages in the Middle Ages (Fig. 6.3). The earlier sea trade routes were along the coastline of various countries (see Fig. 4.11 in Unit 4). With these two inventions, the oceans were thrown open to trade, exploration, and even war for the first time. Open-sea navigation required accurate charts of the position of stars, latitudes etc. and gave an impetus to later developments in astronomy and geography. It also raised the urgent problem of finding the longitude. The need for compasses and other navigation instruments brought into being a new skilled industry.

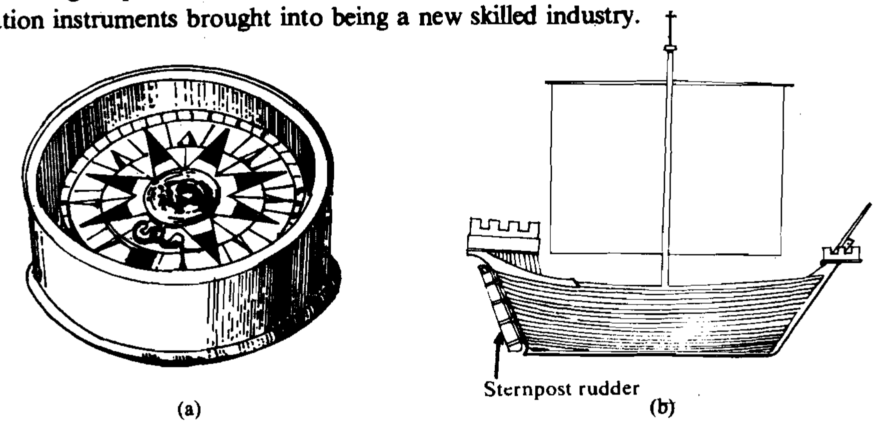


Fig. 6.3 : (a) Mariner's compass; (b) thirteenth century boat showing a rudder in the stern.

Other innovations used and improved by the Europeans were the **lenses** and the **spectacles.** This gave an impetus to the further study of optics and there were some contributions to Ibn al-Haitham's optics, as mentioned earlier. The demand for spectacles also gave rise to the profession of lens grinders and spectacle makers.

Distillation of perfumes and oils was already known in Europe through the Arabs. To this was added the **distillation of alcohol,** which gave rise to the first scientific industry, that of distillers, and laid the foundation of modern chemical industry.

Of all the innovations introduced in the West from the East, **gunpowder** had the greatest effect politically, economically and scientifically. With its use in cannons and hand guns, gunpowder enormously altered the balance of power. In science, the making of gunpowder, its explosion, the expulsion of the ball from the cannon and its subsequent flight, furnished many practical problems. Solutions to these problems and the accompanying explanations occupied the attention of medieval scientists for many centuries and led to sciences like mechanics and dynamics. The preparation of gunpowder required a careful separation and purification of nitre giving rise to the study of solutions and crystallisation. Nitre provides the oxygen needed for explosion of gunpowder. So, unlike ordinary fire, it does not require air. Studies related to the explosion of gunpowder led to attempts to explain combustion, i.e. burning. These attempts were later extended to studies on breathing which provides the oxygen needed to convert food into energy inside the animal body. These explanations were not easy at that time and taxed the ingenuity of medieval chemists most.

Two other technical introductions from the East had a far greater effect in the West than in the land of their origin. They were the inventions of **paper** and **printing.** The need for a writing material cheaper than parchment became urgent with the spread of literacy. Linen rags provided the basis for the first paper of quality. Paper turned out to be so good and cheap that its increased availability led to a shortage of copyists. This contributed a lot to the success of printing, originally a Chinese invention of the eleventh century.

Printing, with movable metal types, was first used by Koreans in the fourteenth century. It was introduced into Europe in the mid-fifteenth century and it spread rapidly, first for prayers and then for books. The new, cheap, printed books promoted reading and created increased access to education for a larger number of people. This, as we shall see, became a medium for great technical and scientific changes as well as changes in the society during the Renaissance.

To sum up, we have seen above that by the fifteenth century a number of small technical changes had taken place. Before we move on to the study of Renaissance and the Industrial Revolution, let us assess the effect of all these technical advances on the economy and ideas of the late Middle Ages. This is necessary because the feudal system contained the seeds of its own transformation.

6.2.2 The Transformation of Medieval Economy

The new techniques led to greater production in agriculture and, therefore, a surplus from the needs of people. Increased productivity led to greater trade which was aided by better modes of transport. Production of other articles such as cloth, chemicals, wine, and iron for tools and weapons also expanded, leading to a considerable increase and diversification in trade. The more the trade grew, the more money it brought in by way of profit to the merchants, who traded the goods produced by peasants and urban workers. The increased profit led to the manufacture of more goods and production of cash crops from the land. With better techniques, better modes of transport and ample markets, the production of commodities for sale increased considerably. Thus, a trading and urban manufacturing economy grew inside the feudal system. These changes succeeded in breaking down the local self sufficiency of feudal economy at the local village level.

Although, the manufacture of commodities was carried on more often in the countryside as a part-time peasant occupation, the markets were dominated by town merchants. By the mid-thirteenth century, the merchants had become rich and powerful enough to acquire a monopoly position in trade. They had formed guilds and used their position to buy goods cheap, and sell them at huge profits. As the markets expanded, the merchants wanted freedom of movement as well as safety along the trade routes which passed through numerous feudal estates with their own laws and restrictions. A clash of authority between the feudal landowners and the new-rich merchant class was taking place all over. Gradually, the merchants gained the upper hand. By the fifteenth century, they had grown so strong that they were beginning to transform the economy. The feudal economy, characterised by agricultural production based on forced services of the serfs, was transforming into one in which commodity production by craftsmen and hired workers, and money payments became dominant.

These economic, technical and political changes were accompanied by changes in the Church. Till this time the Church was all-powerful. It had a monopoly of learning and even of literacy. The Church had a hold on the state and was deeply involved in the maintenance of feudal order. As the rising merchants and artisans of the towns threatened the feudal order, the might of the Church began to be questioned. The Church tried to suppress all such people by branding them as heretics. However, in the last two centuries of the Middle Ages, the Roman Church was considerably weakened. In some places, kings started asserting themselves against the central authority at Rome. In this they were helped by merchants, though the country nobility was still aligned with the orthodox Church. Thus, the unity of the Church began to be threatened. Between 1378 and 1418, the Christian Church was split between two or three Popes. More authority had to be given to the general councils of the Churches. Substantial movements of reform in the Church were initiated and there was soon to be a struggle for power between the Pope and the Emperors.

It is obvious that the European society, in general, was on the threshold of major changes around the beginning of the fifteenth century. The stage was set for the full flourishing of the Renaissance. In the next section we will describe the changes ushered in by the Renaissance and how they moulded the future development of science.

SAQ 2

We are listing the factors responsible for the breakdown of feudal economy. Fill up the blanks to complete the following statements:

i) Better techniques led to increased production of .... With better modes of transport and growing markets .... expanded considerably. This destroyed the locally .... character of the feudal economy.

ii) Merchants dominated the markets and huge .... made them very powerful. They came in conflict with the .... and gradually gained the upper hand.

iii) Production of commodities for sale and payment in terms of .... became dominant and replaced agricultural production by .... based on their forced service.

We have seen above, that the technical improvements introduced in the latter half of the Middle Ages led to a greater available surplus in agriculture and other goods. This spurred a rapid expansion of trade which was also increased by improvements in shipping and navigation. The consequent economic changes from a feudal economy to an economy based on commodity production and money payments were accompanied by momentous social changes. In fact, these changes led to a movement for changing the social system from that based on a fixed hereditary status to one based on buying and selling commodities and labour. The Renaissance and the Reformation are two aspects of this movement. We will now describe what this movement was and examine, in brief, its impact on the scientific and technological developments.

6.3 THE RENAISSANCE (1440-1540)

The Renaissance was a revolutionary movement. It marked a definite and deliberate break with the past. It swept away the medieval forms of economy, of building, of art and thought. These were replaced by a new culture, capitalist in its economy, classical in its art and literature, and scientific in its approach to Nature. The feudal system dominated by the lords and the Church had given way to nation-states, where the kings or princes provided patronage to the new scientists. So they didn't have to depend any more on the Church. With the economy picking up again, the despair of the Dark Ages and the resignation of the ages of faith gave way to a period of hope marked by a frank admission of physical enjoyment. In the changing social milieu, money became much more important than it had ever been before. Even the attitude towards making money changed. Any way of making money was good as long as it worked, whether by honest manufacture of trade, by inventing a new device, by opening a mine, by raiding foreigners or by lending money at interest.

Renaissance was the transitional movement in Europe between medieval and modern times. It began in the 14th century in Italy and lasted into the 17th century. It was marked by a humanistic revival of classical influence expressed in a flowering of the arts and literature and by the beginning of modern science.

In these changed social conditions, the technicians and artists were no longer so despised as they had been in classical or medieval times because they were essential to the making as well as spending of money. The practical arts of weaving, pottery, spinning, glass making, mining, metal-working etc. became respectable. Initially, this enhanced the status of craftsmen. But later, by the seventeenth century the merchant and the capitalist manufacturers started controlling the production more and more. As a result, both craftsmen and peasants were reduced to the status of wage labourers.

In its intellectual aspect, the Renaissance was the work of a small and conscious minority of scholars and artists who set themselves in opposition to the whole pattern of medieval life and thought. The Renaissance also re-established the link between the traditions of the craftsmen and those of the scholars. With this coming together of the doers and the thinkers in the changed economic situation, the stage was set for a rapid growth in science. Let us see what changes occurred in science and technology during this period.

6.3.1 Science and Technology during the Renaissance

This phase in the history of science was one of description and criticism. First came the exploration of ancient knowledge, mainly of the Greeks. The scholars encountered the thoughts of Plato and Aristotle in the original, as well as those of Democritus and Archimedes. Then came the challenge to old authority. At the same time the arts and techniques flourished and provided the material means for the growth of science.

Art

The visual arts, such as painting and sculpture, came to occupy an important place in society. These had a profound influence on the development of science. For instance, painters were required to have a thorough knowledge of geometry, so that they could represent three dimensional figures in two dimensions. For this, they also used many mechanical and optical aids. The realistic life-like paintings required the most detailed observations of nature and thus, laid the foundation of geology and natural history. The anatomy of human beings was also studied in much detail.

The professions of artists, architects and engineers were not separated in the Renaissance. Artists were also the civil and military engineers. They could cast a statue, build a cathedral, drain a swamp or even besiege a town. The great Renaissance artist Leonardo da Vinci is well known to all of us for his beautiful painting 'Mona Lisa'. Not many of us may know of his contributions to the study of human anatomy, study of plants and animals as well as of machines and military devices (Fig. 6.4). His drawings indicate that he was also a keen observer of the operations of metal-workers and technicians who constructed buildings and bridges.

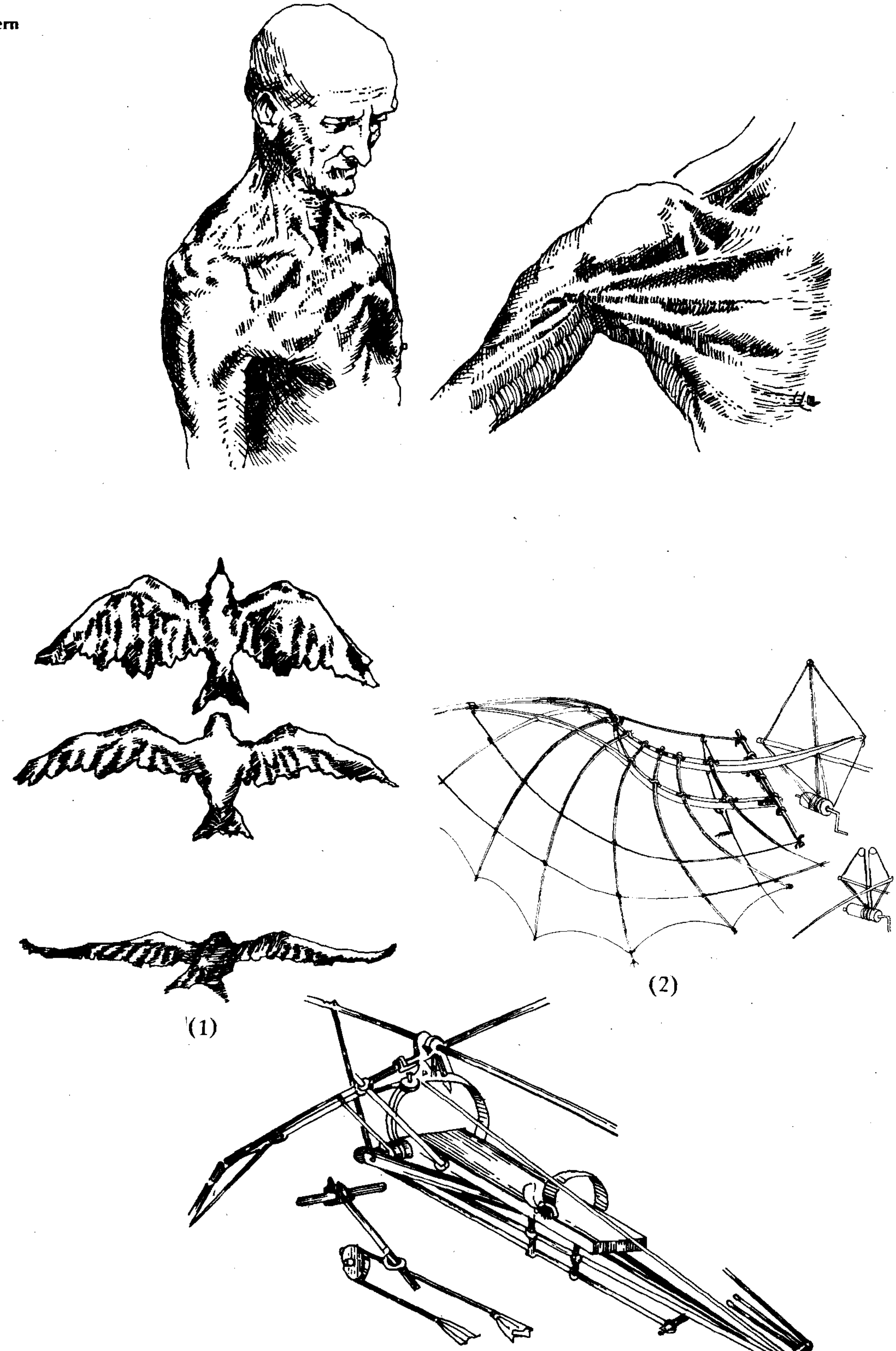


Fig. 6.4: Sketches of Leonardo da Vinci : (a) anatomical studies of muscles; (b) Leonardo designed the first flying machine—he spent years observing birds in flight (1); an early flying machine—a wooden wing hooked up to a hand crank (2); flying machine (3).

Medicine and Technology

The faculties of medicine in the universities, especially in Italy, were the first ones to break out of the general obscurantism. The doctors mingled freely with artists, mathematicians, astronomers and engineers. These associations gave European medicine its characteristic descriptive, anatomical and mechanical bent. The human body was dissected, explored, measured and explained as an enormously complex machine. The new anatomy, physiology and pathology were founded on direct observation and experiment. Thus, the hold of classical ideas of humours and elements, about which you have read in Unit 3 began to be broken.

In technology, the greatest advances of Renaissance were in the fields of mining, metallurgy and chemistry. The need for metals led to the opening up of mines. With growing capitalist production, mining became a large scale operation. As mines grew deeper, pumping and hauling devices became essential. This led to a new interest in mechanical and hydraulic principles.

The smelting of metals like iron, copper, zinc, bismuth, cobalt etc., their handling and separation led to a general theory of chemistry involving oxidation and reduction, distillation and amalgamation. For the first time, metallic compounds were introduced into medicine. Other chemical substances such as alum and clay were studied to improve cloth and leather industries or to make fine pottery. By the end of the Renaissance, the chemical laboratory with its furnaces, retorts, stills and balances had taken a shape that was to remain almost the same till into modern times (Fig. 6.5).

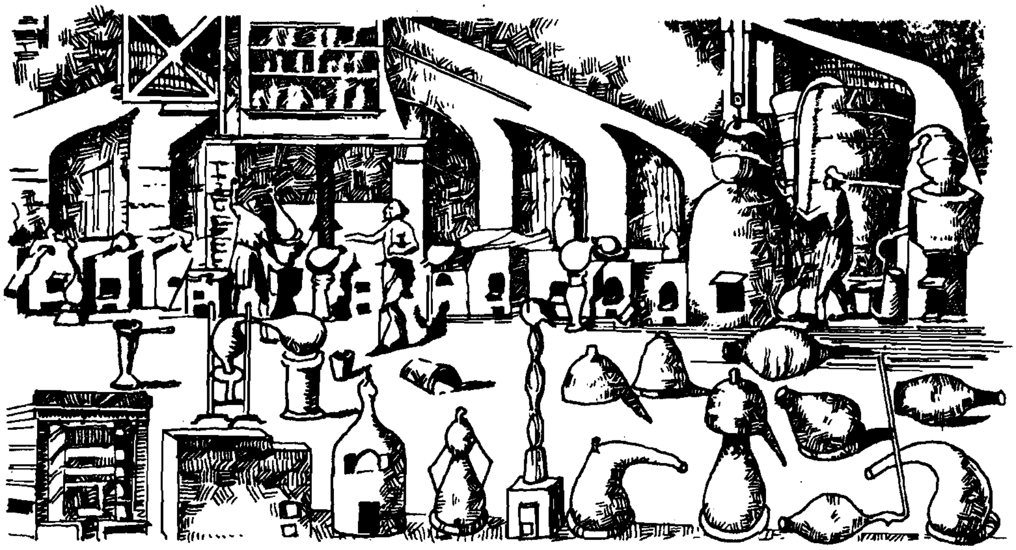


Fig. 6.5: A chemical laboratory of the early eighteenth century.

Navigation and Astronomy

As we have said earlier, by the end of the Middle Ages, trade on land and over the seas was being taken up on a big scale. By the fifteenth century, the Turks had acquired a monopoly of trade routes on land. Therefore, new sea routes for trade were being explored. Great voyages were undertaken. We all know about Vasco da Gama, a Portuguese sailor, who reached India in 1497 via the Cape of Good Hope in Africa. Around the same time, a great and adventurous voyage was undertaken to sail westward on the Atlantic Ocean in the hope of reaching India. Columbus, an inspired adventurer, though a penniless sailor, was able to obtain the assistance of Portuguese, Spanish, English and French courts to undertake this journey. He reached the continent, later named as America, in 1492 thinking that he had reached India. The adventure, the general excitement and ultimately, the great profitability of these voyages created great enthusiasm for building new ships and instruments for navigation. Interest in astronomy was strongly revived.

The Copernican Revolution

It was right in the midst of these developments in the fifteenth century, that there came the first major break from the whole system of ancient thought. This was the work of Copernicus, who gave a clear and detailed explanation for the rotation of earth and other planets on their axis and their motion around a fixed sun which was at the centre. This model simplified astronomical calculations, and also made them more precise. You will read more about the Copernican model in Unit 9. As we have seen in Units 3 and 4, such a model had been proposed by Greek astronomers like Aristarchus many centuries earlier. However, it was not given any importance because it ran counter to the established ideas of those times. This work of Copernicus was published in the very year of his death in 1543. Although his book attracted limited attention and there were objections to his model, his work gave a great boost to further work by Galileo. We will talk about Galileo's work later in Sec. 6.4.

Fig. 6.6: Nicholas Copernicus.

This was the first phase of what we now call the Scientific Revolution. In this phase, the old ways of thought were proving inadequate. By rejecting the old ideas, the men of Renaissance had cleared the grounds for new ideas of the succeeding century. In the use of science for practical purposes too, the Renaissance set the scene for future developments. From now on science had become a necessity for profitable enterprises, trade and war. Later it could extend its service to manufacture, agriculture and even medicine.

SAQ 3

i) List five significant scientific and technical developments during the Renaissance.

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ii) What was the Copernican Revolution?

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6.4 SCIENCE IN THE POST-RENAISSANCE PERIOD (1540-1760)

We have seen above that improved techniques as well as growing trade had led to great voyages to many lands. These were made in search of spices, silver, fur, sugar plantations, slaves, gold and other commodities. The one to have very far reaching effects was the voyage undertaken by Columbus in 1492, which, eventually, resulted in a lot of Europeans going to America. There they cleared the land, settled down and started plantations of sugar and tobacco exploiting the hard labour of African people. The Africans were forcibly taken on board west-bound ships to be transported to the new country and were sold there as slaves. The stealing, selling and exploitation of people as slaves caused terrible suffering. Yet, it was done unashamedly because there was great profit to be made from the new colonies. Money was being piled up for investment in shipbuilding, mining and manufacturing other articles in Europe.

These developments greatly strengthened the merchant class and over the next two or three centuries they were able to replace the feudal lords and landowners in authority over their regions. Society tensions, peasant revolts, religious wars and the race to acquire colonies were all playing a role in changing the feudal society of the Middle Ages into a capitalist society of the eighteenth century in some areas of Europe. The development of capitalism as a leading method of production was accompanied by the birth of a new method of natural science, that of experiment and observation.

In science, this period from the mid-sixteenth century to the mid-eighteenth century includes the first great triumphs of the new observational, experimental approach. This new approach together with the development in science and technology during the Renaissance, amounted to a "Scientific Revolution". Technically, this period was of steady advance without any revolutionary inventions. The increasing demand for iron led to development of new blast furnaces. The shortage of wood for iron-smelting led to widespread use of coal. From then on, the centre of industry was to move towards the coal fields. With time, the demand for limited resources increased, forcing the search for new resources and techniques. This also altered the attitudes towards change and novelty, which could not be shunned anymore. You may recall that in the regimented feudal society, new ideas and change were resisted.

It was in this atmosphere that European science grew to maturity. The first institute for teaching science, the Gresham College, was opened in England in 1579. As we have already seen, the revolutionary Copernican model of the solar system helped in improving astronomical tables. What the theory lacked was an accurate description of the orbits of the planets. This was done by two remarkable men, Tycho Brahe (1546-1601) and Johannes Kepler (1571-1630). Brahe, collected a series of exact observations on the positions of stars and planets with specially made apparatus. His results were theoretically worked over by Kepler. Kepler found that the observations could be explained only if the orbits were taken as ellipses. Thus, he broke away from the idea of circular orbits. Kepler's laws of planetary motion struck a mortal blow to the old Greek thought of perfect circular motion. You 'll find more details of their work in Unit 9.

The telescope, invented around this time, proved to be the greatest scientific instrument of this period. In the hands of Galileo Galilei (1564-1642), a professor of physics and military engineering at Padua, it became a means of revolution in science. Galileo was able to see that the moon was not a perfect round and smooth body but it had ridges and valleys. He also observed that three moons circled around the planet Jupiter, more or less like the system Copernicus had proposed for the earth going round the sun. Within a month, in 1610, he published his observations in his book *Siderius Nuntius*, (Messenger from the Stars). It created a great sensation because the 2000 year old model of heavenly bodies going round the earth was threatened. It challenged the accepted world view that man, specially created by God, lived on earth, hence, it was natural to believe that the whole universe revolved around the earth.

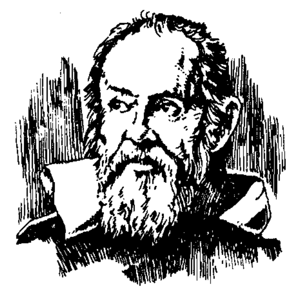

Fig. 6.7: Galileo Galilei.

Galileo's more detailed work, entitled *Dialogue concerning the Two Chief Systems of the World, the Ptolemaic and the Copernican* was published in 1632 and was, indeed, dedicated to the Pope. In this he criticised and ridiculed the ancient Ptolemaic cosmology. The challenge put down by Galileo could not be ignored. Far more was seen to be at stake than a mere academic point about the motion of the earth and planets. If the challenge in one respect was ignored, more such challenges would arise. The new knowledge threatened the stability of the Church and the social order itself. It immediately led to conflict with the Church which resulted in Galileo's trial. He was condemned and forced to go back on his words.

The trial of Galileo dramatised the conflict between religious dogma and carefully observed and analysed scientific data and theory. It is a sheer chance that the year Galileo died, Newton was born. As we shall see later, Newton was to continue Galileo's scientific tradition. He provided a complete scientific theory of motion of all objects, whether planets in the heavens or bodies on earth. This shows that given the socio-economic conditions of those times, it was not easy any more for the Church to suppress the scientific tradition. Whereas earlier Giordano Bruno (1548-1600) was burnt to death and Campanella (1568-1639) was imprisoned for years for opposing the Aristotelian world view and supporting the Copernican theory, Galileo suffered a nominal imprisonment in the palace of one of his friends. By Newton's time, interference from the Church in science had more or less stopped.

Galileo did not stop even after being tried and condemned by the Church. He tried to explain how the Copernican system existed. For this, it was necessary to explain how the earth's rotation did not produce a mighty wind blowing in the opposite direction and how bodies thrown in the air were not left behind. This led to a serious study of bodies in motion. On the basis of carefully conducted experiments, Galileo succeeded in formulating a mathematical description of the motion of bodies. This was the major work of his life expressed in his *Dialogue on Two New Sciences.* Galileo questioned all accepted views. This he did by the new method, the method of experiment. When Galileo's experiments gave him results he did not expect, he did not reject them. Rather, he turned back to question his own arguments. This was the hallmark of experimental science.

Galileo and Kepler could formulate mathematical descriptions of the motion of bodies because they were masters of the new mathematics that had grown during the Renaissance. Algebra, geometry and the decimal system, taken from the ancients and the Arabs, as well as the introduction of logarithm by Napier (1550-1617), greatly simplified astronomical calculations. Forty years later, the observational laws of Kepler were combined with the explanations of Galileo in Newton's theory of universal gravitation. We will talk about it shortly.

There were other important developments in science in this period. Magnetism was experimentally studied for the first time. Another important development was William Harvey's (1578-1657) discovery of the circulation of blood in the human body. Once again, it led to a complete break from Galen's ideas which we have described in Unit 3. A totally new approach was formulated and the human body was analysed on the principle of pumps and valves like the ones seen in machinery. As a result, a new kind of experimental anatomy and physiology emerged.

The developments in the latter half of the seventeenth century paved the way for an outburst of activity which created modern science in most of its fields in the next fifty years. These were helped by the emergence of stable governments in France and England, the two principal centres for scientific activity in those times. The merchants in Britain had arranged a compromise with landlords, in which the king became the constitutional monarch. The economy was dominated by the merchants. But, more importantly, a new class of manufacturers was emerging from among the skilled craftsmen. The courtiers and the learned men of the universities, dependent on the favour of the princes of yesteryears, were being replaced by men of independent means. These were mostly merchants, landowners, doctors, lawyers and quite a few parsons. They financed science out of their pockets. As they grew in number, they tended to come together for discussion and exchange of ideas.

Thus were formed the first well-established scientific societies, the Royal Society of London (1662) and the French Royal Academy (1666). These societies set themselves the task of concentrating on the pressing technical problems of those times, those of pumping and hydraulics, of gunnery and of navigation. In science, it appeared at first that anything and everything could be improved by enquiry. However, certain fields of interest drew special attention. Those were the ones directly related to the needs of expanding trade and manufacture. Foremost among these was astronomy which was an essential need of ocean navigation. The developments in astronomy led to the new mathematical explanation of the universe, finally arrived at by Newton. This was a major triumph of science.

Fig. 6.8: Isaac Newton.

The greatest triumph of the seventeenth century was the completion of a general system of mechanics. This system could explain the motion of heavenly bodies as well as the motion of matter on the earth in terms of universal laws and theories. Many mathematicians and astronomers including almost all great names of science of that period—Galileo, Kepler, Descartes, Hooke, Huygens, Halley and Wren, had worked to find this complete form of mechanics. Standing on the shoulders of these giants, it was ultimately Newton who worked out and proved his theory of universal gravitation and set it down in his *'De Philosophiae Naturalis Principia Mathematica'*.

Newton's theory of universal gravitation applied to all particles or bodies possessing mass, whether on the earth, on the sun, or anywhere else in the universe. Newtonian mechanics, as it is known to us now, provided a coherent explanation for the motion of all bodies in this universe, i.e. how bodies moved as they did. By the use of Newtonian mechanics it was possible to determine the path of any body in motion, if all the forces acting on it were known. Newton's laws of motion are now taught in all the science courses all over the world. The immediate practical consequence of Newton's work was that the position of the moon and the planets could be determined far more accurately with a minimum of observations. It also became the basis for the design of a great diversity of machines and structures which are used today and will be used for centuries to come.

Newton's theory of gravitation and his contribution to astronomy mark the final stage of the transformation of the Aristotelian world-picture begun by Copernicus. Newton established a dynamic view of the universe in which things were changing with time. Yet, he stopped short of questioning the existence of a divine plan. His world moved according to a simple law, but it still needed divine intervention to create it and set it in motion. His theory gave no reasons why the planets went round the same way. He postulated that this was the will of God at the beginning of creation. Newton felt he had revealed the divine plan and wished to ask no further question. By Newton's time, the phase of criticism in the Renaissance was over. A new compromise between religion and science was being sought. Newton's work provided this basis for a compromise between science and religion which was to last until Darwin upset it in the nineteenth century.

There were other developments too, such as in optics and the theory of light, closely linked to astronomy by the telescope and to biology by the microscope. Seventeenth century optics grew largely from the attempts to understand refraction. At the same time, theories about the nature of light were also given. Another development was pneumatics, the science of mechanical properties of gases. The question of vacuum was also important. The actual production of vacuum and the use of air pump for this led Robert Boyle to study the behaviour of air. Thus, it led to his epoch-making work on the gas laws. Robert Hooke, an assistant of Boyle, was the greatest experimental physicist of those times. His interests ranged over the whole of mechanics, physics, chemistry and biology, though he is best known for his study of elasticity.

The world of biology saw great advances with the coming of the microscope. Small creatures were observed and the anatomy of larger ones was refined. In chemistry, new substances such as phosphorus were accidentally produced and new metals such as bismuth and platinum were discovered. The demand for new chemicals led to a growth in the chemical industry.

SAQ 4

In the table given below, match the names of the scientists of the post-Renaissance period listed in column 1 with their works listed in column 2.

1	2
a) Tycho Brahe	i) Developed the table of logarithms.
b) Johannes Kepler	ii) Made observations on planetary motion.
c) Galileo Galilei	iii) Discovered laws of planetary motion.
d) John Napier	iv) Formulated gas laws.
e) William Harvey	v) Established sun-centred model of the solar system; gave mathematical description of motion of bodies.
f) Isaac Newton	vi) Discovered the law of elastic properties of matter.
g) Robert Boyle	vii) Discovered blood circulation.
h) Robert Hooke	viii) Gave the theory of universal gravitation.

Thus, we find that in this period of the Scientific Revolution, the new approach to science, based on observation and experiment, led to pathbreaking advances in many areas like mechanics, astronomy and biology. They also set the stage for further activity which created modern science in many other fields. The prevailing social conditions in Europe were also very conducive to the growth of science. We will now discuss some of the features of European society that helped the rapid development of science there.

6.4.1 Why Science Grew in Europe

Looking back over the development of the new science in the fifteenth to the seventeenth centuries, we can understand why the birth of science occurred when and where it did. We have seen that it closely followed the revival of trade and industry. The profit from expanding trade and successful voyages was being invested in new activities giving rise to a climate of intellectual enterprise. The birth of modern science follows closely after that of capitalism. The merchants and gentlemen of the seventeenth century had cleared the ground for the flourishing of a humbler set of manufacturers. These were the ones who made use of and developed the traditional techniques beyond all recognition in the next century. In science, as in politics, a break with tradition also meant venturing into hitherto unknown areas. No part of the universe was too distant, no trade too humble, for the interest of the new scientists. The fact that these scientists often interacted with each other, established societies and published journals also helped the advance of science.

Science was also able to flourish as it did because of the Church's internal feuds, its friction with the emerging merchant class and a general erosion of its authority. The resistance of the Church to scientific ideas seemed to be quite strong in the beginning. This was evidenced by the trial of Galileo and by the execution of Bruno who uttered the heresy that just like our own world, there may be other worlds in the heavens. But later on the success of the new scientific thinking based on observations was unstoppable.

As we have said earlier, a compromise was being sought between science and religion. Hence, ways and means were explored to find a way of coexistence between science and religion. This was to be on the basis that science should deal with the phenomena which affect the senses, but it should leave aside other matters which are spiritual or aesthetic in nature. An artificial divide which we see even today was, thus, created between science, social science, arts and humanities. On the other hand, from the time of Newton onwards, scientists were able to work with greater freedom, and with practically no interference from religion. As we have seen, scientific societies were established to see that the advancement of science was linked to practical benefits, to business or to society at large.

The success of science in this period was also due to the working together of the people who produced or manufactured different articles, and the scientists who tried to understand the properties of materials that were being handled. This was because manual work was given greater social prestige as it was a source of great profit. The economic and social world had changed from one with the fixed hierarchical order of the classical and feudal period where each human being knew his or her place. Now, it was a world of individual enterprise where each human being paved his own way.

These exciting developments in Europe had two facets. Expanding production and trade and the resulting search for markets led to European entry into many countries of Asia, Africa and North and South America. Colonies came into existence and their wealth began to flow into the European countries, which improved the lot of even the common man in these countries. On the other side, it was a misfortune for the colonial people whose crafts and industry were ruined and whose natural resources were harnessed for export to the ruling countries. The role of the East India Company in bringing India into the colonial system is well known. Extreme poverty and deprivation in India has its origin in the colonial exploitation of our land and our people. We shall talk more about it in Unit 7.

We will now tell you about a major event towards the second half of the eighteenth century, viz. the **"Industrial Revolution"** in Europe, particularly in Great Britain. This arose from the ability to use steam powered machines on a large scale, resulting in a radical change in the means and the mode of production. It also resulted in bringing about deep-seated changes in the structure of the society.

6.5 THE INDUSTRIAL REVOLUTION (1760-1830) AND AFTER

We will first give a brief description of the social and economic changes of this period so that developments in science can be seen in the proper perspective. Already, by the end of the seventeenth century, the stage was set for the further advance of the capitalist mode of production. The feudal and even royal restrictions on manufacture, trade and business had been swept away. The triumph of the bourgeoisie, and of the capitalist system of economy which they had evolved, had taken place only after the most severe political, religious and intellectual struggles.

In Britain, the urban middle class had broken away completely from feudal limitations by the eighteenth century. With an ever increasing market for their products all over the world, they could finance production for profit. With an expansion of markets, growing freedom from manufacturing restrictions and increasing opportunities for investment in profitable enterprise, the time was ripe for great technical innovations.

Thus, we find that by the middle of the eighteenth century, the slow and gradual changes in the production of goods gave way to a rapid change. The new methods of experimental science that emerged from the Scientific Revolution of the sixteenth and the seventeenth century were now extended over the whole range of human experience. Their applications in creating new techniques brought about the great transformation of the means of production which we call the Industrial Revolution. The architects of the Industrial Revolution were artisan inventors. Workmen with their small accumulated or borrowed capital were, for the first time, establishing their claim to change and to direct the production processes. The domination of merchants over the production of small artisans was also being broken.

The Industrial Revolution came mainly from developments in industry, that too within the major industry of those times: the textile industry. As the demand for cloth increased, the old industry could not expand rapidly to meet it. Also, by 1750, the industry came to deal with a new fibre, cotton. Earlier, cotton cloth had been imported from India. With the import of cotton textile from India into Britain being prohibited, there was a great impetus to increase production of cotton textiles. The use of cotton called for new techniques. Here, at last, in the cotton industry there was unlimited scope to substitute machinery for manual work. Thus, from the technical changes which had been taking place for many decades, came the idea of introducing several mechanical gadgets for spinning and weaving. Manual work was greatly reduced as machines replaced the operations that were done by hand (Fig. 6.9).

The textile industry led the way to developments in other areas as well. The market for textile machinery and textile processing stimulated the iron and chemical industries. All these industries called for an ever increasing supply of coal, which required new developments in

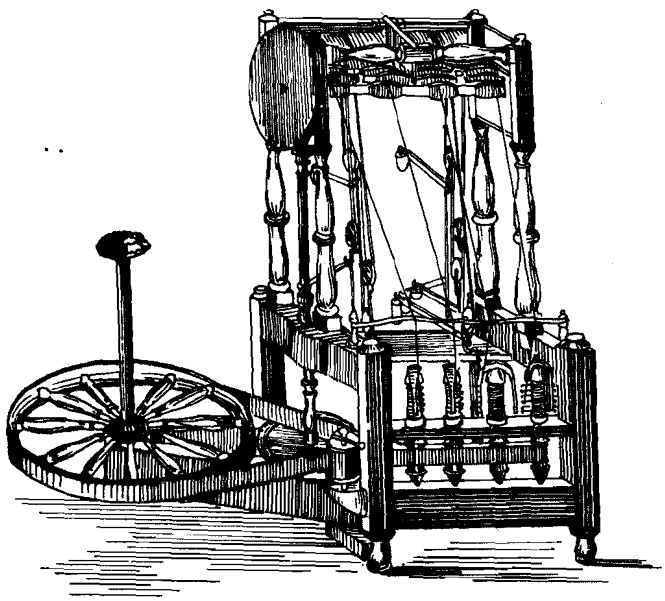

Fig. 6.9: A spinning machine which could spin much faster and produce much stronger thread than the old spinning wheel. It made possible a cloth woven of cotton alone, rather than cotton mixed with flax as in the past.

mining and transport. The new mechanical industry developed around coal fields. However, it was the use of the steam engine for power in the textile industry that really created the industrial complex of the modern world. It revolutionised textile production, so much so, that production of goods increased almost five fold within 20 years.

The idea of mechanisation rapidly spread to other areas such as mining, metallurgy and even agriculture. Very soon the attention of the entire society was drawn to its explosive potential. With soaring profits, the search for markets became more acute. It became necessary to have radically new means of transport and communication to carry on this trade. The steam engine, as a stationary device, had long been used in mines and then in "factories" which had come into existence. Now it was put on rails to draw heavy loads over long distances. Thus, the railways linked the centres of industry; and the steamships collected its raw materials and distributed its finished products far and wide.

While the eighteenth century had found the key to production, the nineteenth century was to find that to communication. Electricity had been used as long ago as 1737 to transmit messages for distances of a few kilometres. But now it was absolutely necessary to transact business over long distances. This was ensured by the successful invention of the telegraph in 1837. Soon, wires were laid for speedier communication between towns, from one country to another. By 1866, across the Atlantic Ocean, on its bed in the form of cables, wires were laid to form a telegraphic link between Britain and America. Within a hundred years from the beginning of the Industrial Revolution, factory towns had sprung up and the appearance of even the countryside had changed. A complete transformation had taken place in the lives of millions of people living in the newly industrialised countries like Great Britain, France, Germany, Holland, USA etc.

Introduction of machines in production centres which moved from homes to specially constructed premises called factories, led to reorganisation of work, and, in particular, to "division of labour". This meant that complex operations were broken down into simpler ones, and one man at his workplace performed only one or two very simple operations. Thus, the production per person was greatly enhanced. However, at the same time, this increased human drudgery, reduced requirement of mental involvement, and, in fact, made human beings work like machines (Fig. 6.10).

It is known these days that, in general, "industrialisation" makes one person produce many times more surplus than agriculture. More surplus yields more profits. Therefore, capital gets multiplied much more rapidly, and it can be used to put up more machines for more production. Hence, the tendency is to multiply production as a whole. What is produced must be sold, and hence the market must also expand all the time. However, in the home market, buyers must also have the cash to buy the product. This creates a dilemma—profits have to be maximised, but what if the workers cannot buy the product? There is no safe formula to determine the worker's share in the profit and hence such a system is prone to social and economic problems.

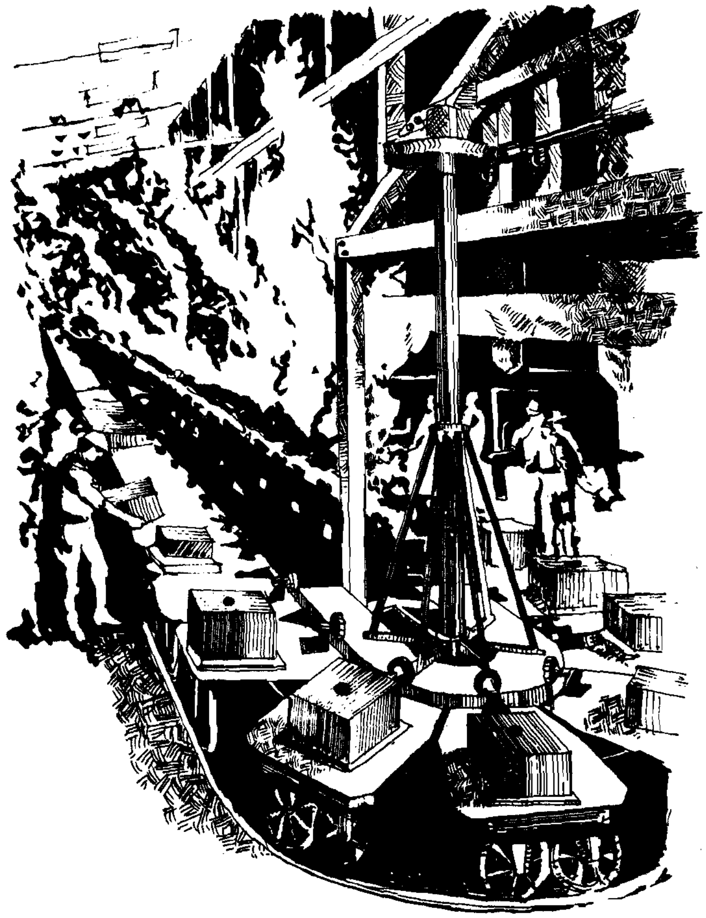

Fig. 6.10: Industrial production in which a worker carried out the same simple task repeatedly. In this sketch, a worker is placing blocks on a series of tables which, put on wheels, move on a track through the casting, moulding and other rooms of a factory.

The history of early industrialisation in all countries shows how workers were exploited, how every ounce of the workers' energy was extracted so that the machines could churn out huge profits; and how miserable were the conditions in which the workers had to live. This gave rise to the new phenomena of trade unions and workmen's struggle to improve their lot.

There was another aspect of this industrialisation. With increase in production, the cost of production came down. Since goods were produced on a large scale, the overhead costs did not increase proportionately. Thus, industrially produced goods turned out to be cheap. This led to goods from industrialised countries swamping markets in the colonies and ruining local industry. Where the industrial goods were not competing well, the colonial governments went out of their way to use their authority to ensure the sale of imported products.

SAQ 5

a) Which three among the following technical innovations led to the Industrial Revolution? Tick the correct answers.

   i) Mechanical clocks.

   ii) Mechanical gadgets for spinning and weaving.

   iii) Use of steam-powered engine.

   iv) Telegraph.

   v) Mechanical devices for use in mining, metallurgy and agriculture.

b) State, in the boxes provided, whether the following statements about the consequences of Industrial Revolution are true or false. In the case of a false answer, write the correct answer also in the given space.

i) Factory towns had come up changing the entire countryside. ☐

ii) The division of labour led to better working conditions for the workers. ☐

iii) Colonisation of countries meant that industrial goods were made in colonised countries and sold in industrialised countries. ☐

iv) Industrialisation also led to increased exploitation of workers. ☐

v) The telegraph was invented to facilitate long distance communication for business purposes. ☐

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It may be said that science did not play a direct role in the Industrial Revolution—but, of course, technology did. On the other hand, technological understanding and design of machines depended on science—particularly Newton's ideas on motion, force, power and energy etc. The steam engine, the centre-piece of the Industrial Revolution which was used in factories, railways and steam ships, owes a great deal to a correct understanding of the nature of heat and the behaviour of gases with change of pressure. Purification of ores, casting of machine parts from iron, and printing of cloth gave further impetus to developments in chemistry. Oxygen was discovered by Joseph Priestley (1733-1804) at around the time of the Industrial Revolution. Based on his experiments on combustion, Antoine Leurent Lavoisier (1743-1794), a French scientist formulated a theoretical framework for a rational and quantitative study of chemistry. John Dalton (1766-1844) proposed the atomic theory a few decades later.

Fig. 6.11: Louis Pasteur.

Other sciences soon gathered momentum and the list of inventions or new laws discovered in the decades following the Industrial Revolution is most impressive. The list ranges from the discovery of Coulomb's law in 1770, about the force of attraction or repulsion between two electric charges, to the invention of electric light and the discovery of radio waves towards the end of the eighteenth century. In the mid-nineteenth century, Louis Pasteur's discovery of bacteria and his theory that diseases were caused by germs, provided a great impetus to medicine. It led to the development of immunisation against diseases like anthrax in cattle and rabies in human beings. Pasteur also demonstrated that many of these microbes bring about chemical changes in foodstuffs and that it is possible to select specific microbes to produce products like wines and vinegar. This discovery forms the basis of industrial microbiology which has enabled us to get many precious drugs, like the antibiotics cheaply today. It has also made it possible to explore alternative sources of fuel like biogas, power-alcohol etc. But, perhaps, the most significant contribution of Pasteur was that through carefully designed experiments, he gave a convincing proof against the idea of spontaneous generation of life. He postulated that living beings can arise only from the living and not from non-living matter. Can you believe that almost till the nineteenth century it was widely held, even by some scientists, that life could arise spontaneously from non-living matter?

Fig. 6.12: Charles Darwin.

Around the same time, a major contribution came from Charles Darwin (1809-82) in his revolutionary ideas about biological evolution. Until this time, it was believed that each form of life was specially and separately created and, thus, had a specific place and function in the hierarchy of creation. Through careful observations and painstaking research, Darwin built up a theory about the evolution of different forms of life from some simpler ones. You will read more about Darwin's work in Block 3. Darwin's work destroyed the last justification for Aristotle's philosophy. And its conflict with the Church continues to this day.

To sum up, we have outlined some of the major developments in science and technology in the eighteenth and nineteenth centuries. In this period, capitalism came fully into its own and with it science came of age. It completely shed the ancient and medieval myths, and replaced them by a rational analysis of observed or experimented phenomena. In this manner, it helped to carry the Industrial Revolution to great heights and to spread it to several European countries. Science and technology are now recognised to be essential ingredients of industrialisation. This has yet to take place in most countries which were under colonial domination till recently.

Science education was introduced as a subject in some universities in Europe even during the eighteenth century. However, it spread widely during the nineteenth century when scientific academies were founded in many countries and scientific research took root in many European centres. The Industrial Revolution and science grew hand in hand, and if the Industrial Revolution bears certain characteristics of science, science too carries several features of that revolution, as we will soon examine.

Unfortunately, these developments in industrialised countries further strengthened or expanded their colonial hold. India came under colonial influence almost at the same time as the Industrial Revolution and we suffered all the negative effects. Our industry was undermined, our natural resources were packed off, as much as possible, to England which would manufacture articles and force them on our market. Disruption of social life and extreme poverty began at the same time. Although science was irresistibly growing in the West, our education and research were completely neglected. Thus, India fell back in the race of economic development by at least a hundred years. Since the international rate of scientific progress is very high, this tragedy nearly means that scientifically we are likely to be dependent on the West, perhaps, forever, unless we take extraordinary measures to pull ourselves up. We will take up this discussion in detail in the next unit.

It would be interesting for you if we went on to explore the relation between science, technology and society in the present-day world. But we would not be able to do justice to such an exploration without discussing the various branches of science and technology and their special role. In this course, through the units that will follow, you will begin to appreciate the present situation by studying problems of health, food, agriculture and industry, which will be presented in our social context.

6.6 SUMMARY

In this unit, we have covered a long period from the fifth century A.D. to the nineteenth century A.D. This was a period of momentous changes which led to the emergence of modern science in Europe. Let us summarise what we have read in this unit.

- The regimented thinking in the stagnant feudal society did not allow significant growth of science in Europe in the Middle Ages. However, there were many technical developments necessitated by the expansion of agricultural land and the need for its better use at the time when there was a shortage of labour.
- Surplus produce led to trade which encouraged further production. Slowly, the hierarchical feudal order based on the forced service of serfs gave way to a trading society in which commodity production and money payments became dominant.
- The hallmark of the Renaissance were criticism and rejection of medieval thought. The Copernican Revolution was an important scientific development of this period.
- The post-Renaissance period saw the emergence of a new method of science—that of observation and experiment. There were a series of path-breaking advances in science in this period, foremost among them being the works of Galileo, Harvey and Newton. It also set the stage for the birth of modern science in many other areas.
- The Industrial Revolution in Great Britain radically altered the means of production. With this, the transition from a feudal economy to capitalist economy was complete in that country. The social structure also changed accordingly. The feudal hierarchical order with a fixed hereditary status gave way to the enterprise and monetary status of an individual. Modern science and technology came of age in this period, and from then onwards, there was no looking back.

6.7 TERMINAL QUESTIONS

1) Against the technical innovations listed below, describe in one or two lines, the social, economic, political or scientific consequences of each of these, which helped the transformation of medieval economy.

   i) The horse collar ....

   ....

   ii) Wind-mills and water-mills ....

   ....

   iii) Compass and sternpost rudder ....

   ....

   iv) Gunpowder ....

   ....

   v) Paper and printing ....

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2) State at least three developments that helped the advance of science and technology during Renaissance.

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3) In the following table we have compared the features of European and Indian societies from the sixteenth to the eighteenth century, that helped or impeded the growth of science in Europe and in India, respectively. Describe the corresponding features of both the societies in the blank spaces left below. You may have to look up Sec. 5.4 once again.

European society	Indian society
i) After severe conflict, the hierarchical feudal order had given way to a climate of individual enterprise and one in which monetary status mattered. This paved the way for greater freedom of thought and action.	....
ii)	The hold of orthodox religious priests had stifled creative and innovative thinking in society.
iii) Manual work had acquired greater social prestige. Artisans and craftsmen who produced goods mixed on equal terms with the scientists and thinkers.	....

iv) .... Knowledge was limited to only a few.

4) What was the difference between the science of classical and feudal times on the one hand and science of the time after the Renaissance on the other?

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6.8 ANSWERS

Self Assessment Questions

1) i) T ii) S iii) T iv) T v) S

2) i) commodities, trade, self-sufficient

ii) profits, feudal lords

iii) money, serfs

3) i) Study of human anatomy; representing three-dimensional figures in two-dimensions; detailed observations of nature; pumping and hydraulic devices in mining; building new ships and instruments of navigation; Copernican Revolution.

ii) Copernicus proposed a model of the solar system in which the sun was at the centre and all planets including the earth rotated around it. It was revolutionary as it completely rejected the ancient geocentric model.

4) a) ii), b) iii), c) v), d) i), e) vii), f) viii), g) iv), h) vi)

5) a) i) × ii) ✓ iii) ✓ iv) × v) ✓

b) i) T ii) F iii) F iv) T v) T

ii) Instead, it increased the workers' drudgery and reduced their mental involvement, turning them into virtual machines.

iii) Colonised countries supplied the raw materials and served as markets for finished goods of the industrialised countries.

Terminal Questions

1) i) More acres of land could be cultivated leading to surplus agricultural produce for trade.

ii) Helped in agriculture, forging iron or sawing wood and in overcoming the labour shortage.

iii) Opened the oceans for voyage leading to increased trade with far off lands which led to developments in astronomy, geography and the industry of making navigational instruments.

iv) Led to studies in chemistry, mechanics and breathing.

v) Aided the spread of literacy and increased people's access to education.

2) i) The status of technicians, craftsmen and artists was enhanced as the practical arts flourished.

ii) Scholars questioned and challenged the medieval thought.

iii) Links between craftsmen and scholars were re-established.

iv) The method of observation, experiment and calculation became the new method of science.

3) i) The social order was stable. There was general satisfaction among the population with no clamour to bring about change.

ii) In the changing social conditions, a compromise was worked out between science and religion. From the seventeenth century onwards there was no religious interference in science.

iii) The learned people in the society did not interact with the manual workers who were not considered respectable.

iv) Printing made education and information about science and technology available to people at large.

4) Earlier works in science were mostly based on speculation about the world around. After the Renaissance, observation, experimentation and calculation, accompanied by a will to question and revise one's assumptions, became the new methods of science.