UNIT 2 SCIENCE IN THE ANCIENT WORLD

Structure

2.1 INTRODUCTION

In Unit 1, we have explained why we should study the history of science and what we mean by the history of science. We have seen what science is like in today's world. Science, today, is a social institution. It has its own method and practices. The tradition of scientific knowledge has certain distinct characteristics. We have also tried to understand the interaction of science and society at a conceptual level. Let us now see how science has developed through the ages and reached its present stage.

We will have to begin by looking into the origins of science. This task is easier said than done, because, as we go farther back in time, it becomes harder to find what actually happened. The sources that tell us the story of science in those times are hidden in the history of human arts and institutions. They have to be searched for. It is from the life, trades and customs of our ancestors that our science has grown. Therefore, science of the old times has to be gathered from the social and cultural life of those times.

Historians have studied the life, social structure, customs, artefacts and culture of the ancient world. They have found material evidence and written records of the past to reconstruct the life of those times. From this wealth of information based on concrete evidence, we have tried to put together the story of the origins of science, and its growth in early human societies. Even as you read this 'story', remember that it is not fiction. Every feature narrated to you is based on concrete evidence. And this story may change if new facts emerge.

In this unit, we will study about the features of the primitive human society that led to the birth of science later on. We will see how the transition from the primitive society to an agriculture-based society resulted in the birth of science and its development. The primitive people used stone implements. Therefore, that period is called the **"Stone Age"**. With agriculture started another period in human history, which we call the **"Bronze Age"**. We will also discuss the happenings in the Indian subcontinent in those times. In Unit 3, we will talk about the next historical epoch, namely, the **Iron Age.**

Objectives

After studying this unit you should be able to :

- identify and describe the practices, techniques and other features of life in the primitive society that helped the emergence of rational science,
- explain how the transition from the primitive society to an agriculture-based civilisation led to the birth of science,
- describe how the growth of cities, trade between cities and the corresponding socio-economic needs gave rise to various areas of scientific activity,
- outline the social changes that led to stagnation in science in the Bronze Age.

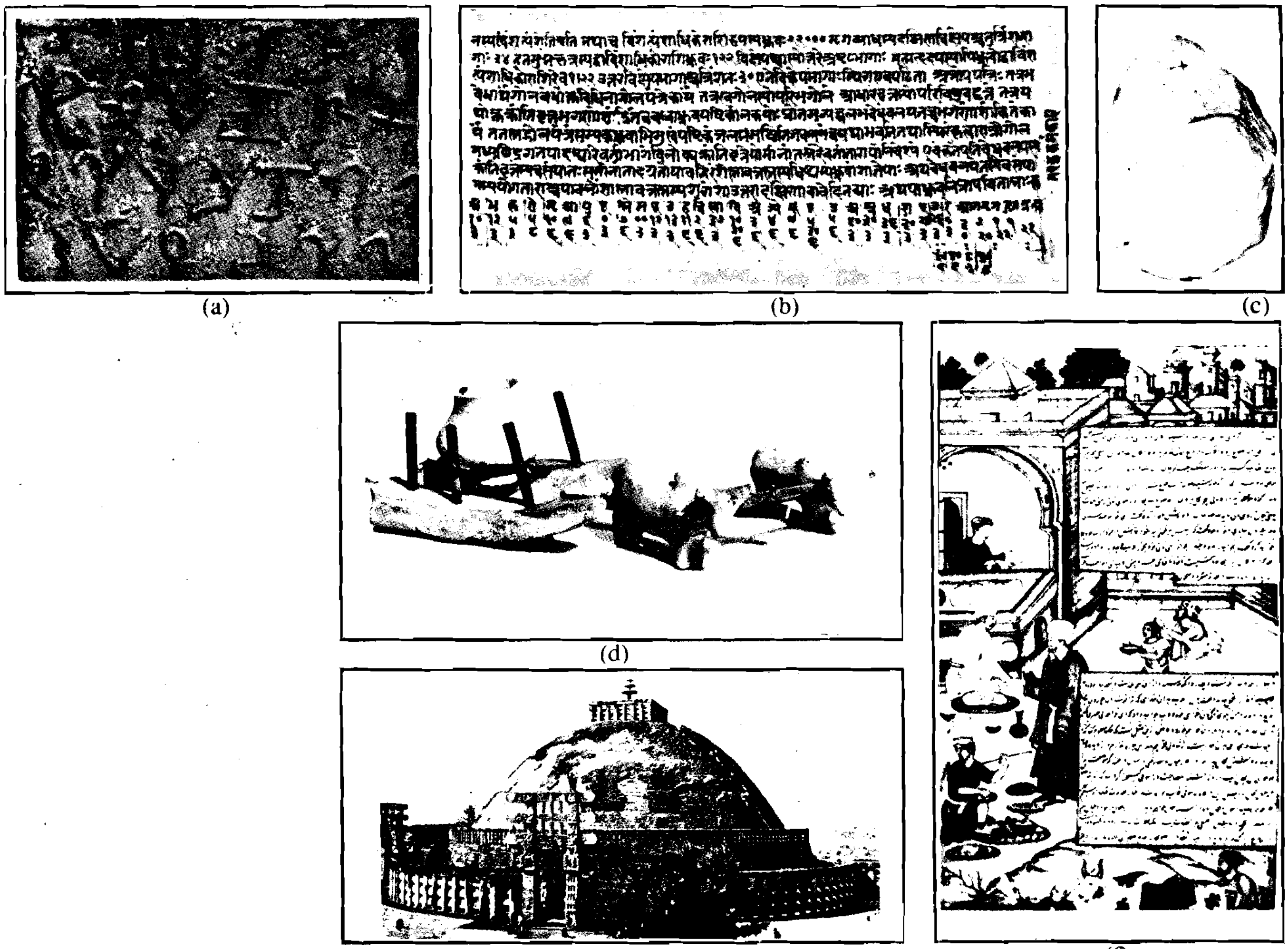


Fig. 2.1: Some historical sources for constructing life and times of a society. (a) Stone inscription from Emperor Asoka's time; (b) sixteenth century transcription of Surya Siddhanta, composed about 400 A.D.; (c) stone axe; (d) toy cart, Mohenjo-daro; (e) Sanchi Stupa; (f) Mughal miniature painting.

2.2 PRIMITIVE HUMAN SOCIETY

And now, we begin the story. To find the origins of science, we must look into the very origin of human society. *In its earliest stages, the human existence revolved around food gathering and hunting.* (Fig. 2.2).

2.2.1 Food Gathering and Hunting

In order to live, man needed to eat and to protect himself from the weather and animals. For both purposes he found it better to be in groups. Wherever human beings lived, they looked for food in plants and trees and also dug the earth for roots. In this way they came to know what the right kind of food was, and where they could get it from. They also found out which animals were dangerous and which were not, and how to protect themselves. This knowledge had to be passed on from one generation to the next, so that the group could survive.

Fig. 2.2: Hunting was a group activity. Cave painting by prehistoric man.

A casually picked up branch or stone aided their efforts to reach the fruit in trees or to dig for roots, strike down animals or provide better protection. As time passed, the primitive tools and weapons were improved upon and regular methods for making them were established. *This specialised knowledge was passed on in the forms of tools and techniques* ***from one generation to another.*** **Under difficult conditions of living, food gathering and** hunting became a group activity. Since food could not be preserved, it had to be eaten fairly soon. This meant that the surplus food had to be shared.

Sharing eventually became a social obligation. Especially, when it became common experience that if more people hunted together, or looked for food together, they got more and better food, and also had better protection. Out of this practice, small societies started to form, with their own distinctions, symbolised by the type of food they specialised in eating, called **'totems'**. The size of each society was restricted by the environment and the total availability of food. In the Indian sub-continent, the stone age population density did not, probably, exceed one per twenty five square kilometres.

These groups met each other as they moved around in search of food. "Exchanges" between these groups or societies started as gifts. The exchange of gifts, between highly specialised food gathering groups, led to a better diet, wider range of food, improved methods of tool making and tool using. The act of sharing food and also the act of exchange between groups, were at first festive and formal occasions. Such occasions gave rise to art, dance and music as well as social customs and rituals. It was but natural that such sharing and exchange required verbal communication and mutually agreed terms of expression and measures of quantity. Language, thus, arose out of necessity. Language helped in knitting the society together and handing down of the accumulated culture to the next generation.

So far, we have painted a very general picture of the primitive human society. In the following pages, we will fill in the details. We will go into specific areas, like the kind of tools and clothes that primitive people used, how fire came to be used for cooking etc. All these features form the material basis of primitive life.

Scientists study the ancient human societies, especially of the prehistoric periods, usually by excavating ancient sites. Such scientists are called **archaeologists. The artefacts, animal** and plant remains, architecture etc., revealed in these archaeological surveys help them to reconstruct the ancient history. Most objects found in the excavations are later kept in museums, where anybody can go and see them.

2.2.2 The Material Basis of Primitive Life

In the primitive society, human beings invented tools for catching animals, and for collecting, transporting and even preparing food. They looked for protection against the elements of nature in the form of clothing and shelter in the caves. The material basis of primitive life is reflected in the tools and other artefacts that have been found in archaeological surveys. The tools are all made up of stones. This is why that era has been named as the **Stone Age.**

Implements and Tools

Stones were shaped to suit a specific purpose like digging, throwing or scraping. Their shapes and sizes became standardised over a period of time in different geographical regions. These shapes and sizes became so stable that they continue in some tribal societies even today. You may like to compare the tools used today for hunting, digging or shaping materials with those of the Stone Age shown in Fig 2.3. Haven't we come a long way?

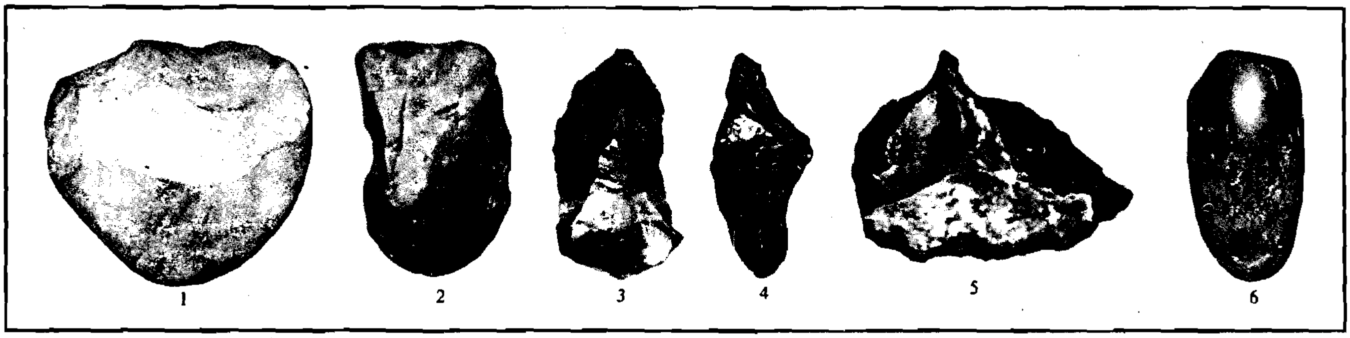


Fig. 2.3: Some stone tools used by the primitive people. 1) Chopper about 7,00,000 years old; 2) cleavers for cutting trees about 3,00,000 years old; 3) blade; 4) arrowhead; and 5) awl about 60,000 to 25,000 years old; 6) polished stone celts used for cutting trees about 4000 years old.

An interesting aspect of tool making is that the "idea" of an implement grew in the mind of the maker before the actual shaping of the stone was done. Archaeological evidence shows that the tools were first shaped out of larger chunks of stone just like an engineer would attempt to fabricate a part of a machine. You should study Fig. 2.4 to understand this better. **This process of conscious foresight was to become an integral part of designing and**

planning, which are the characteristics of science, particularly of the experimental method. This comes from trying out various methods of making an object. Similarly, these days, we find that models or drawings of the desired object are made first, rather than always relying on its straight production. The object can then be improved by trial and error.

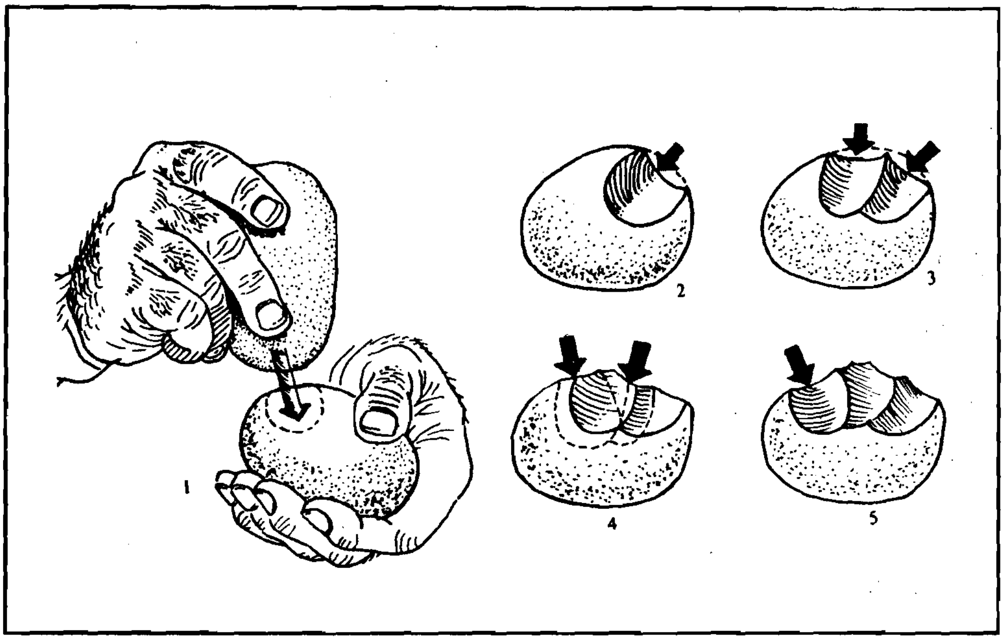


Fig. 2.4: Idea of a tool grew in the mind of the tool-maker before he actually shaped the tool. A chopping tool with a short, irregular sharp edge is being made from a round pebble: (1) Tool-maker strikes a sharp blow at the edge of the pebble with a hammer stone, (see dotted line and the arrow); (2 and 3) two flakes are first struck off; (4) tool is turned over and the process is repeated; (5) when another flake is struck off, the tool gets a short, irregular sharp edge.

The major development at this stage, however, was **the invention of master tools** : the implements to make implements. This created the possibility of producing many different types of implements than could be simply selected or picked up from nature.

The process of making tools laid the foundation for our modern methods of casting, hammering etc. When men made tools and used them for different tasks, they also became aware of the mechanical properties of many substances. For instance, they found out which materials were strong, which could be moulded easily and which were brittle. This laid the basis of the physical sciences.

The tools were used not only for hunting, but also provided a means of shaping and preparing softer materials such as wood, bone and skin for decoration and art, or for protection from cold weather. Food gathering became much more efficient with the introduction of containers, baskets and bins. Certain refinement of tools used for making hunting implements and the knowledge of how to handle soft materials led to pinning, sewing, tying, twisting, twining and weaving (Fig. 2.5). These are the techniques needed for making clothes, rugs, tents etc.

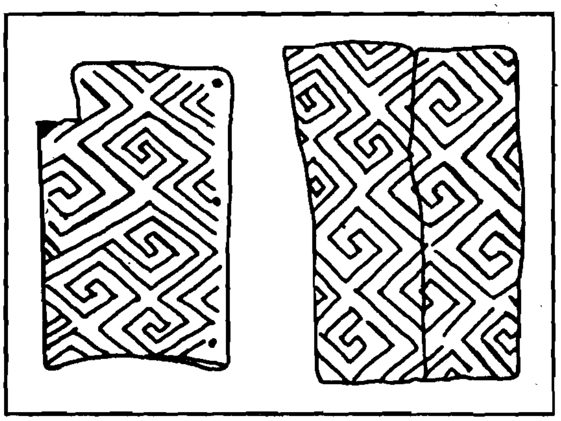


Fig. 2.5: Weaving patterns of the Stone Age from near Kiev, USSR. Note the mistakes and distortions.

Small stone tools or microliths are found at various sites in India. These tools are dated at 3000 B.C. or earlier. The tools are mostly found near minor streams with fishing pools in ancient times, though the pools are now generally silted up. Some precious stones, like agate or onyx, sharpened by chipping or cutting fine teeth in the edge, have also been found. From a comparison with the current practice of African Bushmen, we may infer that these could be parts of compound tools. These chips were set in handles of wood, horn or bone by means of tree gum or some such adhesive, and were used for making javelins, barbed harpoons, arrows, knives, sickles, etc. (see Fig. 2.6).

Fig. 2.6: Small stone tools or microliths dated about 3000 B.C. found in Langhnaj, Gujarat. Microliths were hafted in a bone or a wooden piece to make a compound tool, like a sickle.

The stone tools described above were used for various purposes like chopping wood, digging, skinning animals, scraping off the flesh and breaking the fibres under the skin, as well as for splitting canes for weaving baskets or preparing fish for the fire. A good number of narrow, sharp pointed flakes could be needles or awls (like the tool used by shoemakers) for stitching the hides, presumably with gut. We show you some stone tools and their uses in Table 2.1. Baskets and leather bags were used long before pottery, for grain collection and storage which had by then become an established practice. Some pottery found at these ancient sites in India, is dated at about 6000 B.C.

Clothes

The concept of clothes might have started even before weaving, as an extension of the practice of carrying food and implements about. Attachments with a convenient hold in the hair, around the neck, waist, wrist and ankles might have been used. Feathers, bones and skins were often added to these attachments. The crucial discovery, however, was that furry skin helped to keep people warm. The use of such clothing, together with domestication of animals and their killing when food was needed, helped human beings enormously. It increased their mobility over wider areas, and enabled them to survive cold weather.

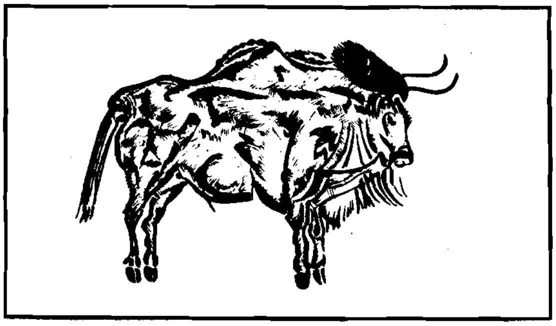


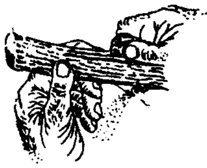
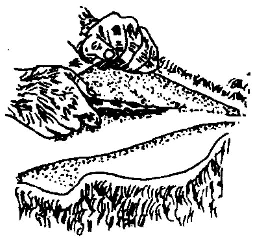
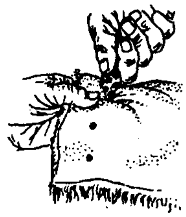
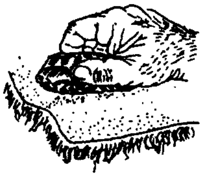
Fig. 2.7: Early human beings had a fair knowledge of animal anatomy. Painting of a bison in Altamira caves, Spain.

Fire and Cookery

Exactly where and when fire came to be used is not known. Fire, to start with, must have been a frightening thing, giving rise to many myths and legends. However, as man slowly learned to control it, he found it very useful to keep himself warm and to frighten away wild animals. It is easy to imagine that chance eating of burnt or charred flesh must have led to the idea of cooking, which then made even tough meat edible and tastier. Thus, it must have tremendously increased the number of things one could eat. It was, perhaps, from the use of fire for cooking that fired clay pottery and melting of metals for making tools arose.

Boiling gave rise to certain difficulties. At first, water was heated by dropping hot stones into water in leather buckets. We find such stones, cracked by heating and chilling, around prehistoric sites. The crucial discovery, however, was that by coating a basket with thick clay it could be put on the fire. Eventually, towards the end of the Stone Age, it was discovered that coated baskets crack while heating, whereas pots made of heat-treated clay do not crack. Fired pottery was, therefore, a very significant discovery. Finally, as the problem of storing liquids for long periods in clay pots was tackled, the slower chemical changes of fermentation could be noted and later used for brewing wine. From the use of dyes, paints and tanning as found in this epoch, we can infer that the use of rudimentary chemistry for transforming materials was also in progress in the later part of the Stone Age.

Table 2.1 : Some stone tools and their uses.

 A chopper	 For hacking wood, cracking bone or as a weapon in fighting.	 Primitive handaxe	 To dig edible roots from the ground.
 A scraper	 For shaping wood.	 A burin	 To make parallel cracks in deer antlers and break slender needles.
 A blade	 Used for cutting flesh.	 A polyhedral stone	 For smashing and splitting or for throwing to bring down animals.
 Later handaxe	 For skinning and cutting up dead animals.	 A borer or an awl	 For punching holes in animal skins.
 Side scraper	 For dressing hides.	 A spear	 Used for throwing and hunting.

SAQ 1

Some practices and techniques of the primitive human society are given below. Which of the particular areas of science, namely, physics, chemistry or technology, could each of these have given rise to? Write your answer in the space provided against each statement.

i) Making and using hunting tools such as javelins, barbed harpoons, arrows etc. ....
ii) Using fire for cooking. ....
iii) Handling soft materials like wood, bone and skin . ...
iv) Storing liquids in containers. ....
v) Using dyes, paints and tanning. ....
vi) Invention of master tools to make other tools . ...

2.2.3 Social Basis of Primitive Life

In the previous section, we gave you a glimpse of how the primitive human beings faced the problems of day to day existence and found some solutions. As their material life became organised by the invention of tools, the discovery of fire and some protection against natural elements, their social life also evolved. Language, customs and rituals emerged as the social basis of primitive life. We will now briefly describe some features of their social life.

Language

Language must have originated as several individuals in a group cooperated in hunting and other activities related to food gathering. There must have been highly specialised sounds specific to each group. As the groups started the process of exchanging surplus food, certain standardisation of spoken word became necessary to ensure better communication. The specialisation meant special terms for specific animals and plants available locally. The general conceptual terms, such as 'animal' for all types of animals, and 'tree' for all types of trees came much later. We can easily surmise this by studying the complicated grammar and words of tribal languages spoken even to this day. This feature is also shared by Sanskrit, Greek and Finnish languages. The word 'colour', for example, originally meant 'red', the colour of blood. It was only later that yellow, blue, green etc. also came to be called 'colours'. The transition from specialised to general language also meant a trend towards abstraction. This led to the use of symbols. Very soon man had to let one word stand for many different things. We have already mentioned above, the examples of 'animal', 'tree' and 'colour'. Similarly, verbal symbolisation also came to be used for feelings, emotions and ideas.

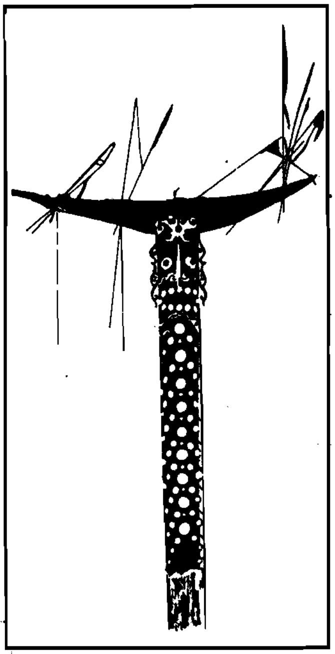


Fig. 2.8: A primitive totem pole, from Borneo, an island near Indonesia. Primitive people probably performed some rituals with their totems around such poles.

Social Life and Rituals

The social life of the earliest human groups or tribes revolved around food gathering. To begin with, they must have collected anything they could eat—seeds, nuts, fruits, roots. honey and any small animals that could be caught with bare hands. The largest food sharing unit tended to concentrate upon a certain type of food which was easily available to them in plenty. Thus, human groups eating one type of food came to consider themselves as 'kins' or fellow beings of the same community or clan. Other human groups who ate different foods were not in the kinship, and at first were not even considered human. As we have told you earlier, this special food item is called "totem".

The act of gathering the totem was associated with special rituals (Fig. 2.8). The rituals sometimes involved sacrifices (including human sacrifice) to secure increased food supply. The food gathering tribes were entirely dependent on nature for their survival. Therefore, in order to avoid scarcity, they also developed certain "taboos". For instance, taboos were enforced on sexual intercourse in order to control their population for the limited supply of food. Attempts were also made to control the group population by a taboo on cohabitation within the totem clan, and by the practice of marriage outside the clan.

Magic, Religion and Caste

You must have realised that the food gathering stage was a period of extreme hardship for primitive tribesmen. They tried desperately to control and manipulate nature for their survival. However, the techniques for this were few. Therefore, they evolved magic to fill in the gaps left by the limitations of technique. By the use of images, symbols, and imitative dances, they believed that the animals or plants could be encouraged to flourish and multiply. Objects were often given inherent powers. Sometimes these were realistic, as in the case of some stones which had the 'inherent' power to attract iron. Most often, these attributes were imaginary. For example, gold was supposed to protect from evil or danger.

Magic of the Stone Age, in a way, helped the growth of science, as it was an attempt to extend the existing techniques. This signified man's quest for further control of his environment. However, magical ideas did not change with changing conditions of life. Rather, often the later generations could not even understand what these ideas meant. Eventually, these ideas turned into superstitions and myths without any meaning.

Fig. 2.9: Australian aborigines dancing around the picture of an animal before hunting.

Another aspect of primitive thought was about the influence of "spirits", may be of dead people, or of gods and demons, on the real world. Therefore, a need was felt to control or to please them. The concept may have originally arisen out of man's inability to accept the fact of death. There were also occurrences which he did not understand and over which he did not have any control. For instance, a drought or a flood, an earthquake or a forest fire or even an infectious disease, which could wipe out most of the population. All these may also have contributed to the idea of 'spirits'.

The origin and evolution of religion is intimately connected with man's attempt at making a living out of nature, his utter helplessness in many circumstances and the totem oriented food gathering life. Many deities in India are simply bits of stone, coloured with red pigment, the colour being a substitute for blood. Primitive religion can also be thought of as man's effort to come to terms with nature, his first attempt to explain what was happening around him and why. When agriculture became prevalent and settled life became possible, smaller groups merged into larger groups. Their totems, taboos and cults also got merged and the new system of beliefs became a 'religion'.

The people who were absorbed into these cults managed to retain some of their identity and to an extent continued their previous totemic separateness. This relationship became codified in India, in terms of castes. Caste system in India has evolved over a long period and has imprints of many epochs and many stages of production. Totemic features are reflected in caste names such as crocodile (Magar), horse (Vaji), peacock (More), peepul tree (Pimple). Mores do not eat peacock flesh, the Pimples do not eat off the leaves of their totem tree etc. Other stages of production such as agriculture with its specialised professions are also reflected in the caste grouping, such as herb-vendors (Vaidu), diggers (Vaddars) etc.

SAQ 2

Which three of the following uses or characteristics of language in the primitive life may have aided the emergence of science? Tick mark the correct choices in the space provided against each statement.

i) Communication while getting food and moving around. ☐

ii) Communication while making and using tools and exchanging surplus food. ☐

iii) Communication while performing the rituals, dancing, singing etc. ☐

iv) Use of symbols to describe material objects, actions and practices. ☐

v) Use of symbols to depict emotions, dances, rituals etc. ☐

2.2.4 The Origins of Science

We have seen that the primitive human beings acquired different kinds of knowledge from the use of implements and tools, from cooking on fire, from hunting animals and gathering fruits or seeds of plants for food. All this knowledge blended into one common pool and together with the rituals and myths of society formed their culture. What we now have to find is the origin of science in the womb of this culture. We can see developments in the following three broad areas, which had implications for science :

a) Rational Mechanics

By making and using tools, man was transforming nature according to his deliberate will. This laid the basis for mechanics of rigid bodies, motion and properties of materials. The handling of bow and arrow, the javelin or the boomerang are some examples (Fig. 2.10). Again, in the use of lever, it was possible to know before hand what would happen to one end when the other end was pressed. In the use of such devices, the useful results of interaction with nature could be 'seen' or 'felt'. Thus, understanding and confidence developed. At least, in one sphere, human beings were realising how things worked.

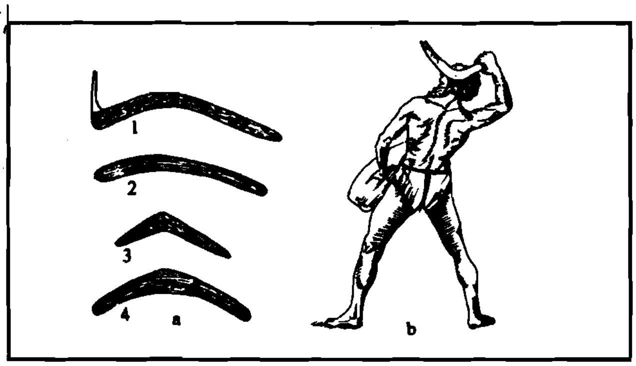


Fig. 2.10: (a) Different types of boomerangs: 1) for fighting; 2) for hunting; 3) and 4) boomerangs that return on throwing; (b) an Australian aborigine throwing a boomerang.

b) Observation and Description

Even without such an understanding, human beings could take advantage of nature whenever they detected regularity. It was enough for them to know what to expect, and when to expect it for taking advantage of a situation. For instance, they observed that earth's fertility changed with seasons. The growth of plants and movement of animals was also affected by the changing seasons. Fruits and nuts were ready to be picked up at certain times but not at others. The migration of birds, buffaloes, deers etc. changed with seasons. All these observations of the Stone Age people arose from their need for survival. This was especially true in land masses such as India and Egypt with their sharp seasons and varied geography. These laid the basis for bringing about the discipline of observation and careful description of nature and environment.

Unlike in the case of mechanics, in the case of cooking or brewing, it was not possible to predict easily what would happen as the consequence of a particular action. For instance, if a stone was thrown up, one could be sure that it would come down. One could also aim a stone at a fruit or an animal and be sure of hitting it. However, in cooking the result would depend on the food being cooked, the amount of moisture in it, and how strong was the fire on which it was cooked. Brewing was even more complex. Thus, there were many uncertainties in these processes.

However, it was possible to know what would happen, if one tried a particular procedure, observed the results and remembered them, so that at the second trial one was better informed. In this field, and even more in that of animal behaviour, knowledge was essentially traditional, handed down by word of mouth from generation to generation. However, the reasons for the phenomena observed or noted were often sought in mythical explanations, by involving totem ancestors or spirits.

c) Classification

There were many similarities between things or phenomena which led to their classification. The first classifications were in terms of beings (the living), things (articles and substances, or non-living) and passions or actions. Here arose a kind of descriptive reasoning; if one of a class behaved in a particular way, it was likely that the other in the same class also behaved in the same way. Thus, the accumulation of knowledge and sifting of experiences had major impact on primitive biology and chemistry.

SAQ 3

Match the three general elements or features of science listed in column 1 with their associated techniques or practices in column 2 of the table given below. We have done one part of the exercise as an example.

Column 1		Column 2
i) Rational Mechanics	a	Throwing a boomerang
	b	Hunting for animals
	c	Study of animal behaviour
ii) Observation and Description	d	Study of living things
	e	Handling a bow and arrow
	f	Gathering fruits or seeds of plants in different seasons
iii) Classification	g	Study of non-living things
	h	Use of lever
	i	Regular cycles of seasons
	j	Cooking food and brewing wine

So far, we have seen that the primitive society had developed a host of techniques for their material comfort. Archaeological records show that towards the end of the Stone Age, primitive human beings were using many facilities such as huts, sewn garments, bags and buckets. They had also evolved technical devices like canoes, hooks and harpoons, spears, slings, throwing sticks, boomerang etc.(Fig. 2.11). Many of these are actively being used among some present-day tribes such as the Eskimos, African Bushmen, Australian aborigines and some Indian tribes.

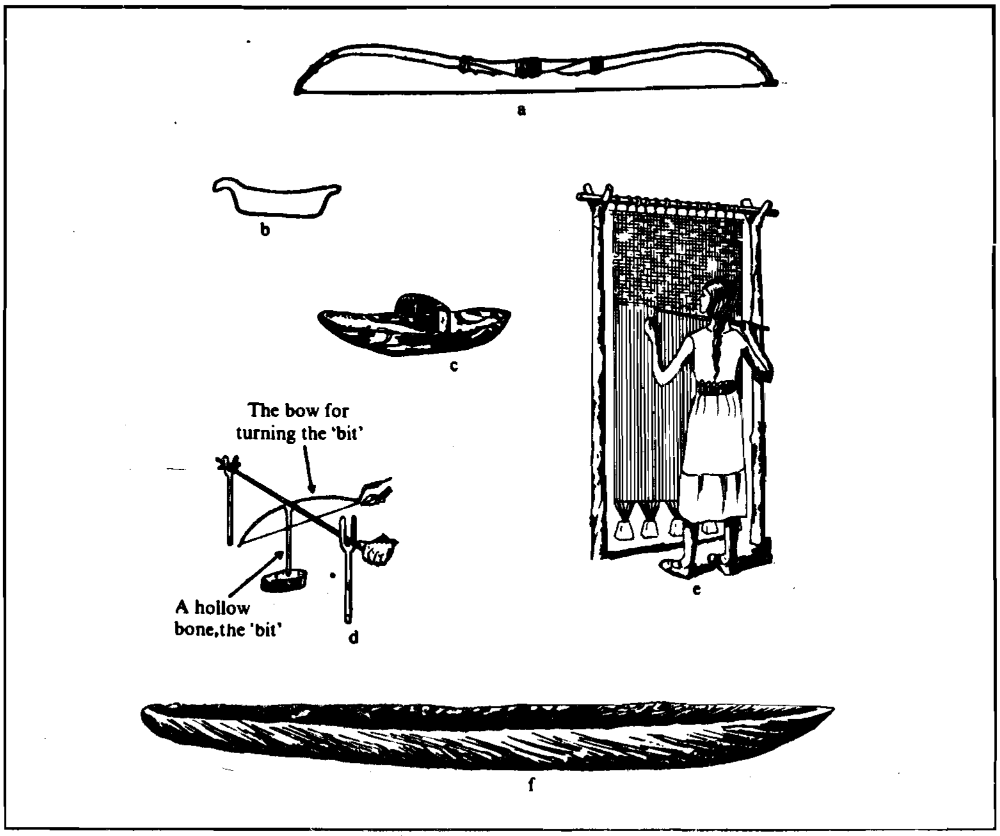


Fig. 2.11: Implements used towards the end of the Stone Age: (a) composite bow; (b) skin boat, outline from Norway; (c) grain milling stone; (d) bow drill for boring stone; (e) weaving loom, reconstructed according to available remains and descriptions; (f) boat hewn out of a tree trunk.

We have also tried to trace the origins of science in the primitive society in a general way. We have seen that the making and use of implements laid the foundation for mechanics and physics. The basis of chemistry lay in the use of fire. and that of biology in the practical knowledge of animals and plants.

Social knowledge was implicit in language and the arts. The character of the society was essentially community oriented. No marked specialisations and class divisions had as yet arisen. Much had been done in using human intelligence to control nature by the use of material instruments.

All this may make you wonder why the primitives were not able to maintain themselves in that state. Indeed, some have done so, but only in the most outlying places. By and large, the food gathering and hunting society was lost in history. Why did this happen? Why did the Stone Age come to an end? We now seek the answers to these questions.

2.2.5 End of Stone Age

The essential feature of the hunting and food gathering society was its dependence on nature. It could eat off nature but could not control nature to increase the food supply when its population grew. Nor could it breed animals for the same purpose. Therefore, whenever the food supply ran out, the population had to move or they would perish. The movement of tribes became difficult as their population grew. Due to their lack of control over natural disasters, at times, most of the population of a tribe was wiped out.

The end of the Stone Age was also brought about by climatic changes. In Europe and in the northern hemisphere, with the onset of very cold conditions (also spoken of as the Ice Age), food gathering and hunting activities became restricted and difficult. The society had to struggle for its survival by developing a different type of production. You will read about this in the next section.

It must be mentioned at this stage that the Ice Age in the Indian subcontinent (including parts of Pakistan, Afghanistan and Burma) was neither so harsh nor so extensive as in Europe. Therefore, food gathering was much easier here in terms of quantity and variety than in Europe. Whereas only half a dozen cereals, peas and beans made up almost the entire variety of European staple food, even a region of average fertility such as Maharashtra had over forty kinds of indigenous staples. This had a profound influence on subsequent developments in these two locations.

This fortunate event, however, also meant that the Stone Age mode of production continued in this subcontinent over a much longer period and over a wider region than in Europe. People could and did survive in the food gathering stage when their immediate neighbours had been forced to move on to agriculture for food production. This meant that, unlike in Europe, the old culture with its elementary ideas of science and techniques survived here for centuries, well into the new epoch. There was also some contact between the two parallel cultures and modes of production, which sometimes turned into a conflict between them. For instance, as we shall see in Unit 3, the search for cultivable land often led to conflict between the Aryans and primitive tribals. The tribals were pushed into the interior regions. In turn, the old beliefs and customs influenced the practices which were characteristic of the new mode of production.

SAQ 4

The following statements explain why the Stone Age came to an end. Fill up the blank spaces using the words given below to complete the sentences :

The end of the .... came mainly because of two reasons. Firstly, there was not enough .... to feed the increasing population. This happened because primitives were unable to control .... to satisfy their needs. Rather, they were .... on nature. Secondly, natural .... also affected the growth of population. The onset of Ice Age was one such disaster. Food gathering and hunting became impossible in the .... conditions. Society had to adopt a .... mode of production to survive. Thus, a transition from the .... society to an agricultural society came about.

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calamities, different, Stone Age, primitive, nature, cold, food, dependent

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With this, we end our description of the Stone Age. In this section, we have tried to give you some idea of the lives, practices, customs and culture of the Stone Age people. We have also seen how the techniques that arose from their daily struggle for existence laid the foundation for many areas of science. At this point, we advise you to take a break. Have a cup of tea and reflect on what you have studied so far.

2.3 AGRICULTURE AND CIVILISATION

The next period in the evolution of human society is known as the Bronze Age, named after the new alloy which replaced stone during this period. This period was, in fact, the beginning of a new type of productive activity, namely, agriculture. We will now study how the practice of agriculture changed the society. We will also see how the rise of cities and the changing socio-economic needs led to the birth of science. The growth of cities brought about a change in the social organisation which later affected the growth of science in Bronze Age cultures.

2.3.1 The Origin of Agriculture and Civilisation

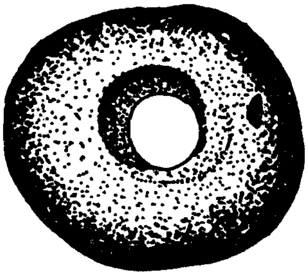


Fig. 2.12: Stone ring used in primitive agricultural practices. A stick was inserted in the hole. The tool was used to break clumps of mud.

There is no historical evidence to tell us exactly how agriculture arose. We can only imagine what may have happened. Cultivation of grain may have arisen without any violent break from food gathering. In regions well stocked with wild grains, enough seeds would get scattered around to produce crops worth reaping. Agriculture, probably, resulted from the understanding that plants could be grown from seeds and that the crops had some relation to the seasons. And, probably, the availability of water helped in this process. *Cultivation, however, marked a break from the primitive era, as human beings stopped being dependent on nature and started to control their livelihood and destiny.*

Cultivation necessarily meant permanent or semi-permanent settlements around regions that were climatically and soil-wise suitable for crop production. These settlements grew into villages, with some community life and leisure. It is but natural that the settlements established in regions most suitable for cultivation, developed the fastest. Thus, we see that in this period, from about 4000 B.C. to 1500 B.C., the four great civilisations of Egypt, Mesopotamia, India and China came into existence in the wide river valleys of the Nile, the Tigris and the Euphrates, the Indus, and the Hwang Ho respectively (Fig. 2.13). The Indus Valley Civilisation, of which we are the descendants, is dated between 2700 B.C. to 1750 B.C.

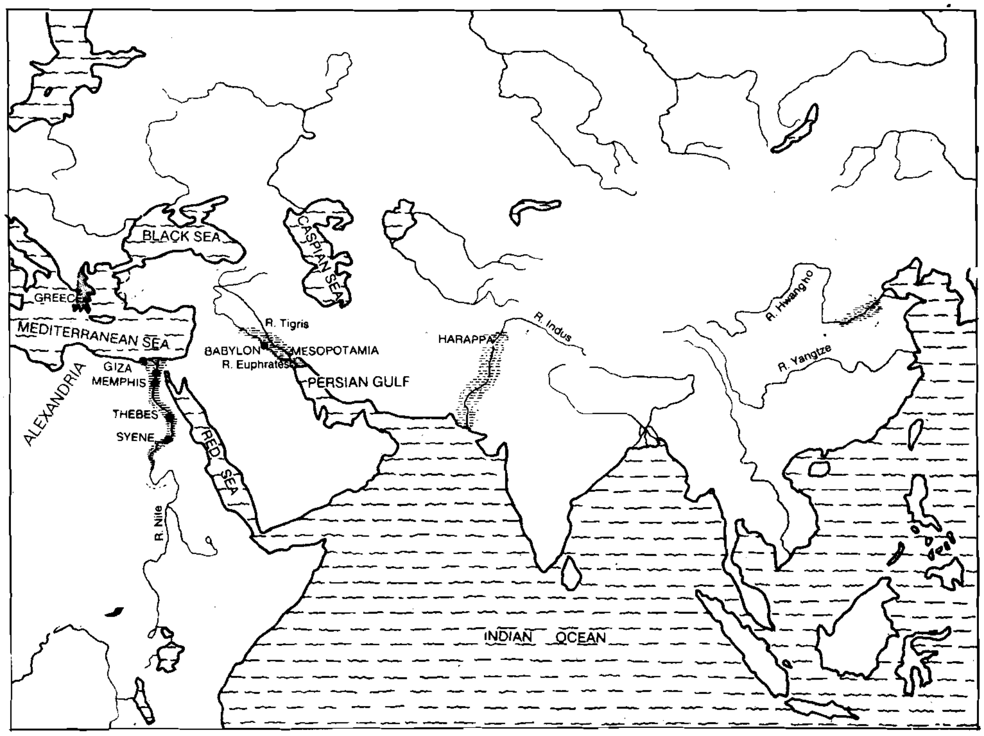


Fig. 2.13: Four major river valley civilisations of Egypt, Mesopotamia (present-day Iraq), India and China. Shaded area shows Greek civilisation of the Iron Age.

Growth of Cities

The people of those times came to understand very well the advantage afforded by the river for food production. They also came to realise that if the river could be systematically used through natural and artificial irrigation, food production could be increased manifold. (Fig. 2.14).

However, this could be achieved best, not by one village alone but by several villages getting together. Further, barter trade led to some places being identified as meeting places for the exchanges. Convenient sites were chosen for displaying goods and exchanging grain for cloth or spices, or shopping for better tools and implements made by expert artisans. Some evidence suggests that cities were founded by bringing together population of several villages. The growth of cities led to the rise of an administrative class who could organise and coordinate production and exchange, but did not take part in it directly.

Fig. 2.14: An Egyptian farmer lifting water by lowering a cone-shaped leather bucket which hangs from a beam, balanced across a pillar. The weight at the other end helps the farmer to lift the filled bucket with less effort. Sketch from a tomb painting about 1500 B.C. In India, even today such a device called 'dhenkli' is used.

We find that the growth of cities was helped by another feature of this new mode of production. Man started producing much more than he could consume locally. Therefore, all people in agricultural societies did not have to be agriculturists. They could produce other useful goods and even excel in music or dance. The surplus could be used to support craftsmen who made the agricultural implements and storage vessels, masons who built shelters, wheel-wrights who made pottery, and others who made carts. There were still others who worked as administrators and priests, and who were not directly involved in the process of production. These groups of people came to live in the cities.

The population of cities used to be supported, as today, by agriculture in the neighbouring as well as distant villages. This resulted in a division between villages and cities, between those who produced and those who supported production through work of other kinds; those who worked with their hands, and administrators or priests who mainly used their mental skills. This division had a very definite effect on the development of techniques and science. For the first time, specialisation of occupations and professions had taken place. As there was enough food available, society could support even those who did not produce. Such people had leisure to think, to improve their crafts, to create art and beauty, and to develop abilities to lead society through institutions of religion and administration.

The surplus also had to be transported by land, river and sea in exchange for other necessities of life and even luxury goods. This provided tremendous impetus for the development of transport, such as rafts, boats and small ships, which brought about new dimensions of trade, cultural contact and exchange of techniques and science among different societies.

Changes in Social Organisation

We find that the above trend in social organisation led to a tendency which eventually stifled the progress of these civilisations and led to their decay. The surplus, or whatever was left of food production after the consumption needs of the society were met, came to be appropriated by a small group of administrators. They eventually became priests and kings and formed an exclusive group. The successors of the original administrators gradually lost touch with agricultural techniques, as well as with knowledge and techniques related to production of other articles of consumption and trade. They gave their time and attention to building monuments, temples and palaces of leisure to impress the rest of the society or to emphasise their exclusiveness. They raised armies to take over more and more productive land. Their priestly influence also grew. They cultivated the idea that they had divine powers and were created by God to show the way to the common people and be their natural leaders. Thus, society got divided into exclusive classes of producers and appropriators.

The tragedy of this process was that those who used knowledge and technique in the beginning to increase production became isolated from the basic production techniques and knowledge which had given them power. Recourse was taken increasingly to magic and spreading of false beliefs instead of scientific observations and use of technology to solve material problems. The farmers and the craftsmen who used the techniques to produce goods were weighed down with the daily problems of existence. They had very little resources for innovations. Thus, the practitioners could not improve the techniques to solve the problems they faced; and the appropriators who had the time, resources and power to do so were no longer interested in these things. As a result of these developments, the progress of technique was thwarted and science stagnated.

In historic periods, stagnation led to the complete decay of civilisations, as in the case of the Indus Valley Civilisation. Sometimes there was readjustment of societies due to their being conquered by others, as in Europe where weak and stagnating cultures and societies were subjected to barbarian invasions. In both cases, the centre of progress shifted geographically, to other locations.

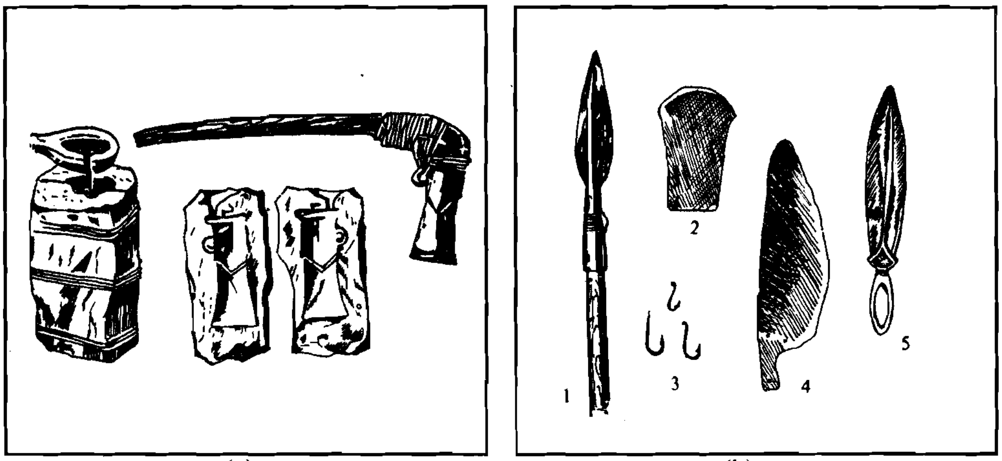
So far, we have given you a broad overview of the social conditions prevalent in the Bronze Age civilisations. We will now indicate a few technical and scientific achievements of that age, which came to have profound influence on subsequent developments.

2.3.2 Scientific and Technical Achievements of Bronze Age

The major technical advance that accompanied the rise of cities was the discovery and use of metals, particularly copper and its alloy bronze. Simultaneously, trade between societies flourished and gave rise to better forms of transport. The wide range of services involved in the operations of a city gave rise to a qualitative change which marks the beginning of conscious science. This was possible, because this initial phase of development required that the practitioners of techniques and the priests who did only mental work solve problems together. Recording of numbers or quantities of goods, standardising their measures, counting and calculating, making of calendars etc. form the basis of quantitative science in the Bronze Age. We shall now study each of these features, in brief.

The Use of Metals

Human beings were attracted by shiny gold and copper which are found free in nature and used them originally as ornaments. Bits of metal have been found in necklaces and other ornaments of Stone Age. However, copper nuggets beaten to different shapes were not of much practical use as tools and weapons, as they were too soft. With the development of fire kilns needed for making pottery, copper ores which could be easily reduced were used to produce copper metal. Later, an alloy of copper and tin was discovered. It was harder and stronger than copper and could be cast into tools and weapons. Casting was done by pouring molten copper and tin mixture into vessels or "moulds". When the mixture was allowed to cool, it took the shape of the pot. Some of the tools thus made were found to be far superior to stone tools and weapons, and were easier to produce. The use of this new metal meant revolution in many techniques, such as carpentry, masonry, making tools, vessels, vases etc.



(a) (b)

Fig. 2.15: (a) Copper axe and a form of casting it; (b) copper tools and weapons: 1) tip of a spear; 2) axe; 3) fish hooks; 4) saw; and 5) dagger.

In the Bronze Age civilisations in different parts of the world, the new metal was widely used for making weapons and tools and it became a commodity of distant trade. In India, the copper ore came from Rajasthan and was available in sufficient quantity for export to Babylon. The problem of carrying ores from inaccessible parts to cities, and to distant places was solved by the development of transport.

(a)

(b)

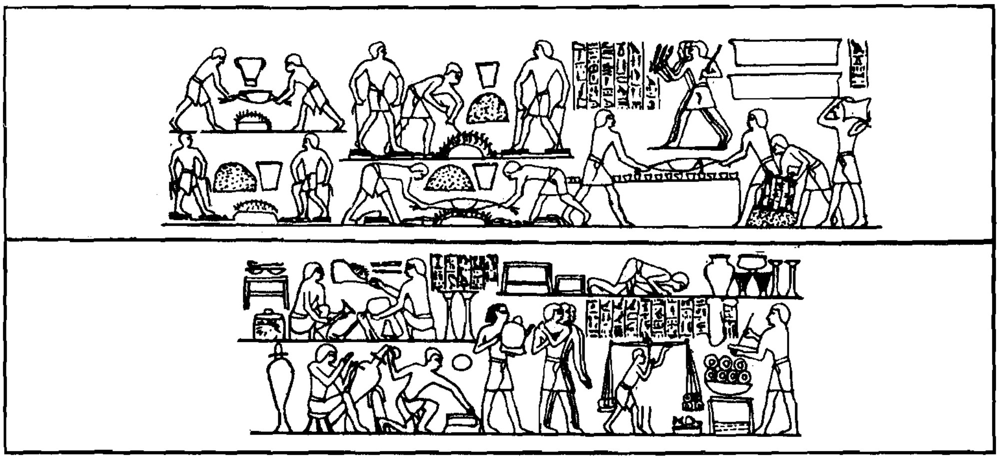


Fig. 2.16: Technology from the tomb of Rekhmire, an Egyptian king, about 1470 B.C. Crafts and works illustrated show: (a) cabinet making (note use of bow drill, chisel, saw and hammer); (b) brick making and building (note balanced loads); (c) bronze casting (note foot operated bellows and use of tongs); (d) finished vases and weighing precious metals (note similarity of balance to brick carrier). Notice also the writings about all these activities.

Transport

River Valley civilisations were characterised by settlements along the rivers and growth of cities which needed, among other things, stones and wood from distant places to make houses and monuments. Cities also signified that everyone need not depend on land. There was surplus production so that some people could trade or take up other occupations. The surplus had to be traded for goods produced in different parts of the world. For example, we have evidence that Mesopotamians traded extensively with India through Bahrain. Besides copper, the Indians exported peacocks and apes, ivory and ivory combs, pearls and some textiles. In return, they received silver and other commodities. Trade, as well as the desire to control large territories, led to the need for efficient transport. Since the rivers were easy flowing, water transport was most probably developed first (Fig. 2.17).

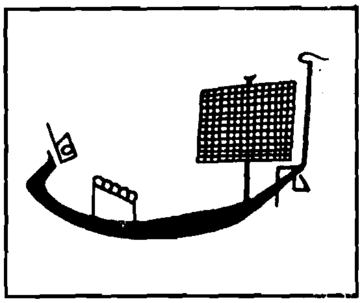


Fig. 2.17: Oldest known depiction of a sail appears in this 5,000 year old Egyptian drawing of a Nile river boat.

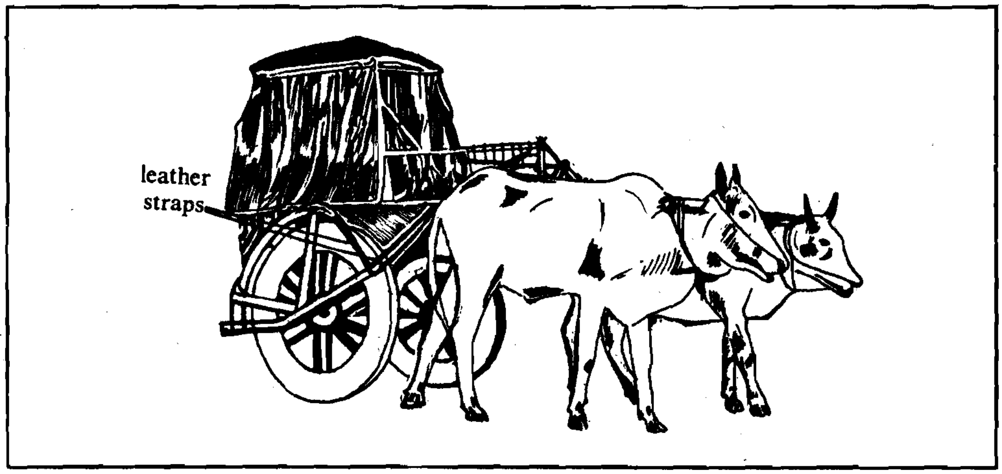


Fig. 2.18: A bullock cart in India. Notice the leather straps holding the wheel supports.

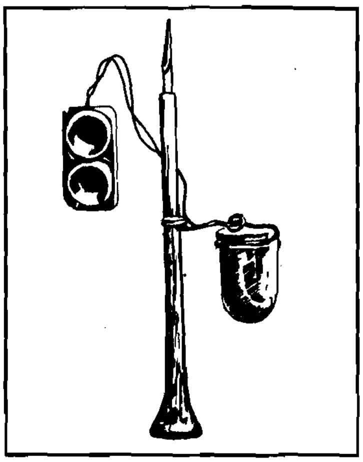
We also find evidence to suggest that dugout canoes and rafts made of reed and bamboo were used for carrying goods in bulk. At some early date, the sail was invented marking the first use of inanimate power for locomotion. When river transport was extended to the sea, it posed new problems of boat construction and navigation. Stronger winds meant stronger fabrics for making a sail, and construction of heavy frames and structures to hold them. Woodwork had to be very strong and durable, too. The river went in a known direction, it was like a road, but one could easily lose one's way on the high seas. New ways of finding location and direction had to be searched. The most primitive method was of the land finding bird. Navigation by sun and stars had also become a common practice.

The rise of cities would also have required heavy goods to be transported over short distances by land. This may have been done by the use of sledges to begin with. Heavy sledges could be eased downhill. However, along the plains, tree trunks came in handy as rollers. The discovery of wheel revolutionised land transport, though it is not possible for us

In those times, the boats sailed along the coast. If the crew lost sight of land, they would release a crow, which would fly towards the nearest point of the coast. Thus, the direction of its flight would indicate where the coast was. You may have read Noah's story in the Bible. He first released a crow from the Ark to find out in which direction the land lay, and then a homing pigeon to make sure that the land was fertile.

to say, from historic evidence, where the wheel was first invented. Its use for making carts which transported goods and passengers was possibly one of the most significant developments of the Bronze Age. The real ingenuity in developing this mode of transport, was in joining the solid roller or wheel to the body of the cart in such a way that it could turn without coming off. In other words, the wheel and the axle were twins from birth. Carts pulled by animals soon developed in Mesopotamia, Indus Valley and much later in Egypt where the boat remained the main mode of transport. In early Mesopotamian carts and even in some present-day Indian carts, the axle turns and is held in place by leather straps (see Fig. 2.18).

The motion of the wheel, use of the lever to dislodge boulders, use of the inclined plane to push things up or slide them down in the construction of granaries and temples, provided a great impetus for the understanding of mechanics. Mechanics was to have a dramatic impact in increasing man's mobility. Today, we can move anywhere on earth at high speeds, span the oceans, fly in the sky and go out into space.



(a)

(b)

Fig. 2.19: (a) Writing materials in ancient Egypt: ink-pot, sharpened reed and jar for water; (b) some Egyptian hieroglyphs.

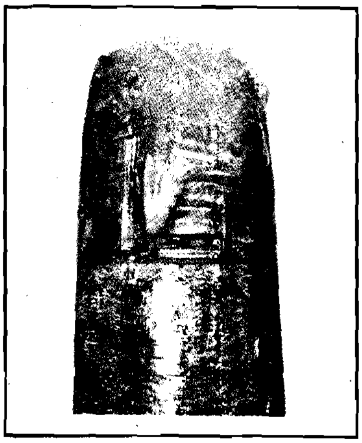


Fig. 2.20: Mesopotamian cuneiform: the laws of king Hammurabi (about 1800 B.C.) of Mesopotamia, carved on a pillar. The top of the pillar shows the Sun god offering the code of laws to Hammurabi and below is the code. A replica of this pillar is kept at the National Museum, New Delhi.

Quantitative Science

With the availability of surplus in agriculture and the production of non-agricultural goods by craftsmen, exchange and trade became a part of life. With the passing of time, exchange dealt with increasingly different types of commodities as well as increasingly large quantities of these commodities. Therefore, what should be exchanged, with what, and in what quantity, could no longer be simply memorised. Some **standards,** such as **numbers** and **measure** of amounts of grain etc., and **weights,** became necessary so that proper quantities of goods could be set apart or marked off for collection and exchange.

For the record, the symbol for measure was followed by a picture or shorthand symbol of the particular object which was to be traded. Gradually, symbols were introduced to cover actions as well as objects, and so writing emerged. **Writing** developed, either as a sketched symbol standing for a whole idea as in Chinese, or symbols and sounds going together as in Mesopotamian cuneiform or the Egyptian hieroglyphics (Figs. 2.19, 2.20). The standardisation of exchange in the form of weight led to the use of **balance,** a scientific invention of great consequence. Exchange also necessitated simple calculations such as **addition** and **subtraction** of numbers, which led to **arithmetic.**

The use of bricks for building houses gave rise to the ideas of **right angle** and the **straight line,** which led to the birth of what we call **geometry.** A strong school of modern historians and archaeologists, such as Debiprasad Chattopadhyaya of Calcutta and Allchin of Oxford, believe that the base of geometry was also laid at this time in the Indus Valley Civilisation. The geometrical ideas of this civilisation were followed by the Greek geometricians of the Iron Age, and thus, these came to profoundly influence modern geometry. The practice of building in brick also gave rise to the concept of areas and volumes of figures and solids, which could be calculated from the lengths of their sides. At first, only the volume of rectangular blocks could be estimated. Later, in Egypt, mathematics became sufficiently advanced to make it possible to calculate the volume of a pyramid.

The ability to count and calculate found immediate use in certain other areas such as **making of calendars** and in the consequent development of **astronomy** (Fig. 2.21). We have seen earlier in this section how the study of the stars, the sun and the moon was needed for navigation. The need for practical astronomy was also felt in planning

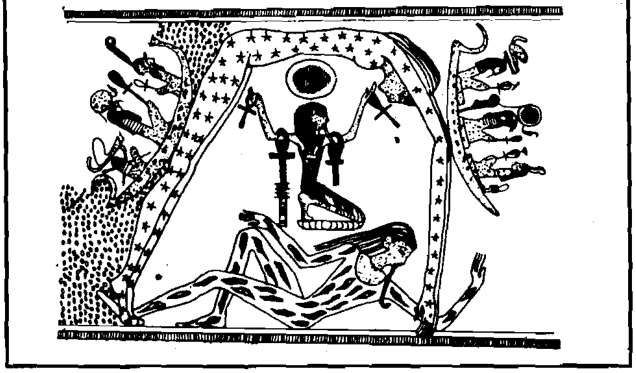


Fig. 2.21: Early Egyptian ideas about the universe. The star studded figure at top is the sky goddess Nut. Beneath Nut is Shu, the god of air, shown holding symbols of immortality in his hands. Under him lies the earth god Geb, his body covered with leaves. The boats on each side of the drawing carried the sun on its daily journey across the sky.

agriculture on a large scale. Crops had to be planted and harvested in the right season. Floods were a recurrent phenomenon in the river valleys, for which it was essential to be prepared beforehand. The observation of sun and stars to fix the length of a year became so precise that already in 2700 B.C., the Egyptians were able to fix it at 365.2422 days!

Sumerians and their successors in Mesopotamia adjusted the solar (sun-based) and lunar (moon-based) calendars through accurate observations. They invented the sexagesimal system of 360 degrees in a circle (near enough to the days in a year), 60 minutes in an hour, 60 seconds in a minute. The exercises were carried out using mathematical tables and led to algebra and arithmetic of the later epochs.

A lunar year consists of 354 days ($12 \times 29\frac{1}{2}$). This has to be adjusted to the solar year of 366 days, by adding 12 days each year, or a thirteenth month of 30 days every $2\frac{1}{2}$ years.

Another occupation that came to be very prestigious with the growth of cities was that of **medicine.** Although the practice of medicine was limited to treating wounds, dislocations, fractures etc., the practitioners could successfully diagnose many diseases. They could compare cases with one another, notice different diseases and record them. From such descriptions, orally passed on to later generations, arose the sciences of anatomy and physiology. Practitioners of medicine also had the knowledge of plants and mineral substances to prepare drugs for various diseases. They grew plants and herbs for this purpose. It is from this source that the science of botany arose later.

The basis for **chemistry** was laid in the observations and practices of jewellers, metal-workers and potters. They knew about at least nine chemical elements—gold, silver, copper, tin, lead, mercury, iron, sulphur and carbon, and also about a variety of dry and liquid reagents. The process of smelting ores, of purifying metals, of colouring them, of adding enamels—all involve complex chemical reactions that were learnt by many trials and experiments. However, chemistry never rose to the rank of a recognised science in the Bronze Age.

To sum up, we have seen that *the socio-economic needs of growing cities and trade between cities gave rise to many broad areas of quantitative science, such as standardisation of measures, arithmetic, geometry, astronomy, medicine etc. The base for the future development of many other areas such as chemistry, algebra, anatomy and physiology, botany etc. was also laid in this era.*

SAQ 5

In the following table, we have listed the variety of services required in the operations of a city, together with the scientific and technical advances that helped in carrying out those services. Fill in the blanks that we have left in the table. To illustrate, we have filled in the first blank.

Services or needs of the city based civilisations	Corresponding scientific and technical advances
i) *Requirements of tools for agriculture, carpentry, masonry, etc.*	Discovery of copper, its alloy bronze and their use in casting various tools.
ii) Exchange of a large number of different types of goods in large quantities.	....
iii) Use of bricks for building houses; planning the layout of cities.	....
iv)	Astronomy
v)	Medicine
vi) The art of making jewellery, the crafts of pottery, metal-work, etc.	....

So far, we have not talked much about the level of scientific and technical achievements of the early civilisations in the Indian subcontinent. With the help of archaeological and other evidence from the Indus Valley Civilisation, we will now try to visualise the growth of science in India in those times.

2.3.3 Indus Valley Civilisation

The great cities of Harappa and Mohenjo-daro, now in Pakistan, were discovered in the 1920s. They were the first evidence of a fairly advanced civilisation in the Indus Valley. Subsequent excavations at other sites such as Kalibangan, Ropar and Lothal have shown that this civilisation spread as far as the present Haryana to the east and as far as Gujarat to the south. You can see all these sites in the accompanying map (Fig. 2.22).

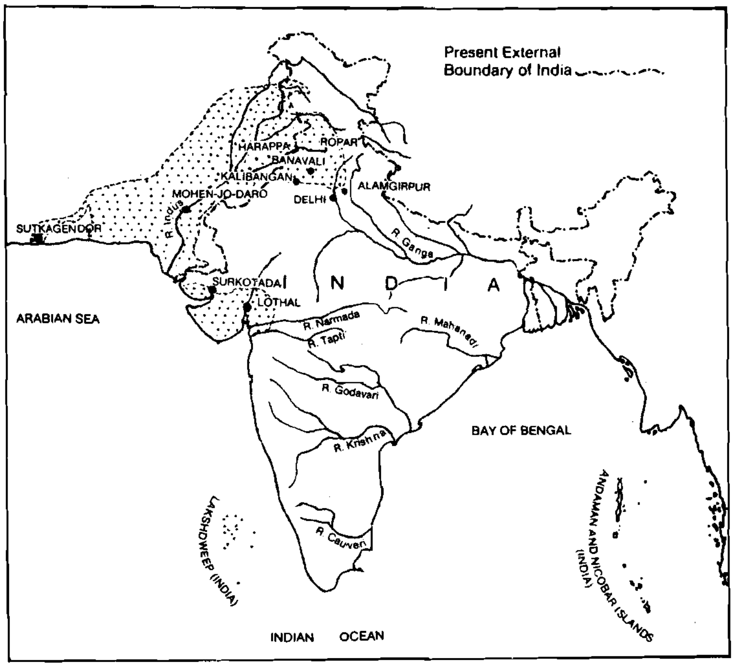
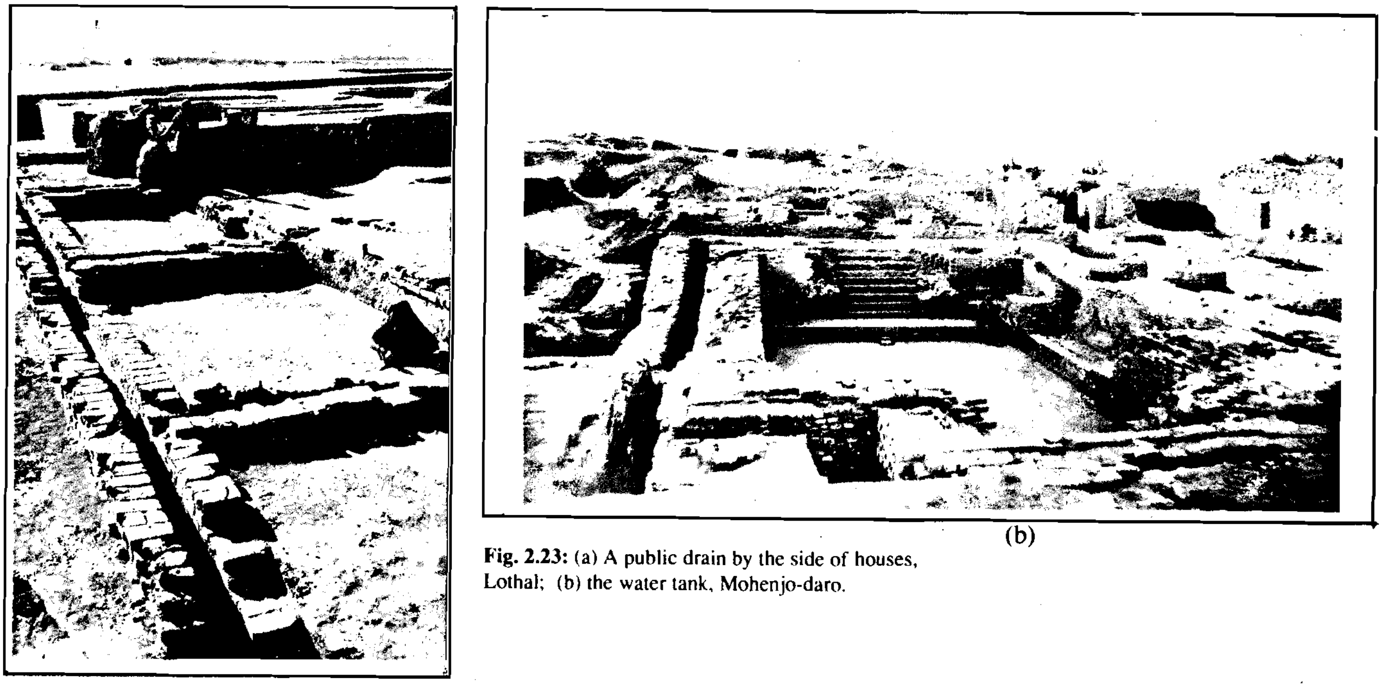


Fig. 2.22: Extent of Indus Valley Civilisation, showing some major cities.

The ancient cities in the Indus Valley show town planning of a truly amazing nature. Some of the city houses are multi-storeyed and palatial. They are built of well baked burnt bricks and supplied with such amenities as excellent bathrooms and lavatories. These obviously belonged to the rich. The town layout was in rectangular blocks of about 200 yards × 400 yards, with wide main streets and good minor lanes. The straight streets met at perfect right angles. There was a superb drainage system for carrying out rain water, and cesspools for clearing the sewage. There were enormous well constructed granaries. The small tenement houses in rectangular blocks obviously accommodated workers or slaves. Public baths were an important feature of the Indus Valley cities. Many rooms and multi-storeyed buildings were found around an open courtyard, which contained a rectangular tank of about 23 ft × 30 ft and 8 ft deep. The bricks were well laid in the tank wall, with waterproof intermediate layer of pitch. A finely built drain allowed water to be emptied for cleaning the tank, while filling was done by drawing water from a nearby well (Fig. 2.23).

The high quality of construction and layout found in the Indus Valley implies that the people of these cities were good technologists. They had mastered the techniques of construction using a profound knowledge of space utilisation and geometry. Historians conjecture that the making of bricks with perfect geometrical precision, fitting them together in different shapes and sizes, and maintaining straightness and angles, in roads as well as in big buildings, required considerable knowledge of geometry.

It is interesting to find detailed description of the geometrical theorems and axioms in a text called *Sulvasutra* which dates around 600-300 B.C. These *sutras* were used for making intricate devotional fire altars in Vedic times. Fire altars have also been found in some cities of Indus Valley Civilisation like Kalibangan. This leads the historians to conjecture that Sulva geometry is the product of the earlier age of Indus Valley Civilisation, transmitted through tradition to a later age.



(a)

(b)

Fig. 2.23: (a) A public drain by the side of houses, Lothal; (b) the water tank, Mohenjo-daro.

We are all familiar with the famous Pythagoras theorem which says that "the square on the hypotenuse of a right angled triangle is equal to the sum of the squares on the other two sides" (Fig. 2.24). Its discovery is generally attributed to the Greek thinker Pythagoras (582-500 B.C.). The *Sulvasutra* also contains an alternate version of this theorem which says that "the diagonal of a rectangle produces areas, which its length and breadth produce separately". Apart from this, *Sulvasutra* deals with construction of geometrical figures, combination and transformation of areas, measurements of areas and volumes, squaring the circles and vice versa, making of similar figures with different areas, and a variety of other related problems. The value of square root of 2 (i.e. $\sqrt{2}$) is given in *Sulvasutra* as 1.4142156.

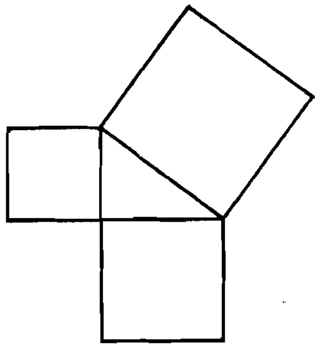


Fig. 2.24: Illustration of the Pythagorean theorem.

All this leads us to surmise that the inhabitants of Indus Valley may have possessed considerable knowledge of geometry.

Bronze tools, containers, seals, ornaments, toys etc. found in the excavations at Mohenjo-daro, Harappa and the other sites indicate that the Indus Valley Civilisation had attained a high level of scientific and technical know-how (Fig. 2.25). We also have evidence of trade with Mesopotamia in the artefacts found in archaeological surveys. Richness of slit deposited by the Indus on its banks made it possible to cultivate without deep ploughing. Hence, the available evidence does not reveal bronze ploughs but only tools to bury the seeds very near the surface of the soil.

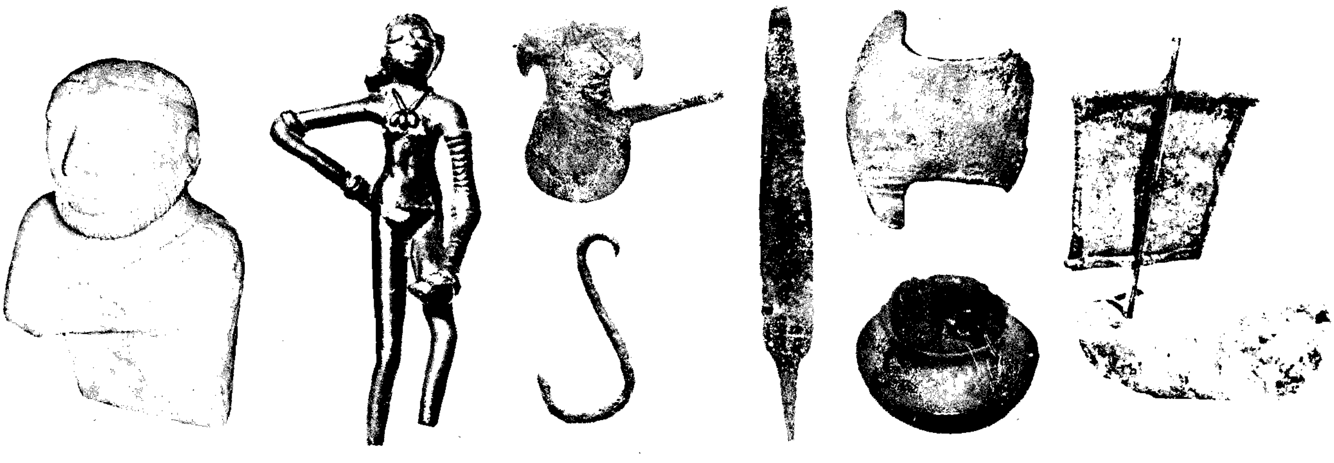


Fig. 2.25: Some tools and artefacts found in the excavations at various sites of the Indus Valley Civilisation.

A peculiar feature of the Indus Valley Civilisation was that bronze was used only for making tools, such as sturdy knives, chisels and saws, but almost never for instruments of violence. The spears used were thin without a rib and totally ineffective in combat. There were no bronze arrowheads either. The early Indus Valley culture was particularly non-violent.

All these inferences about the Indus Valley Civilisation arise from the physical evidence, such as tools, artefacts like pottery and textiles, architecture and the total plan of the cities including water works and sewage disposal, gathered from these sites. We could have known a lot more about those times, if only we were able to decipher the writings on the seals found at these sites. So far, we haven't been able to make out what the various symbols and writings carved on stone seals, indicate. Thus, in future, new facts may emerge which could shed more light on the Indus Valley culture.

To sum up, we have seen above how the changes in the methods of production led to the rise of villages and cities. The growth of cities created further demands which led to great scientific and technical advances. In turn, these advances improved the methods of production. Much of the equipment that evolved at that time has not changed appreciably in the 5000 years that have gone by. Most of us still use the same kind of tables and chairs; live in rooms with walls and ceilings of stone, brick and plaster, eat from the same kind of dishes and wear clothes made of the same kind of cloth such as cotton, wool or silk. Even the staple cereals that we eat were more or less known at that time. However, the glorious era which gave us so many things, came to an end, by about 1500 B.C. We will now outline the factors that led to the decline of the Bronze Age Civilisation.

2.3.4 Decline of the Bronze Age Civilisation

We find that the great developments in production methods that came with the rise of early cities lasted only for a few centuries. The initial burst of technical advance was followed by a long period of stagnation. Cities arose and fell; one dynasty of priest-kings overthrew another. But there was no change in the pattern of production. It remained based on irrigation agriculture, supplemented by trade with other cultures.

City state is a city that is also an independent state. For example, Babylon in Mesopotamia, Athens in Greece.

This, probably, happened because in this process the social organisation had also changed. In the primitive human society no special groups existed, whereas there now came into being different strata in the society. As we have seen earlier in Sec. 2.3.1, there arose a division between those who produced and those who appropriated the produce. This also meant a division between the thinkers and the doers, between theory and practice. We have also seen how this led to stagnation in science. Eventually, the social structure became exploitative. Peasants and urban craftsmen became poorer, many of them ending up as slaves later on. The emergence of two distinct classes, the haves and the havenots, in the society, led to conflicts between them. This weakened the city states and ultimately put a stop to their intellectual and technical progress.

Increasing population and continuous barbarian invasions also brought tremendous pressure on these city cultures. They had to expand territorially to occupy more available land, in order to feed the population. They also had to raise armies and fortifications to defend themselves. Even in the Indus Valley, which was a non-violent culture, fortifications were raised in the later days. Fortifications, walls and other instruments of violence such as catapults and moving towers required the application of mechanics. As wars became a part of life, a new group of professionals came into being. They were the persons who invented and made new war machines and built defensive and offensive structures. They may have been the forerunners of the engineers of today.

To end the story of Bronze Age, while civilisation stagnated at the centre near the rivers, its influence was spreading wider and wider. An impressive and valuable stock of knowledge was handed on to the succeeding generations. The science and techniques of the next major historical epoch, the Iron Age, are largely derived from those of the ancient world. The people of Iron Age themselves did not doubt the greatness of the empires that they had destroyed. We find an echo of those times in the famous Greek classics, the Iliad and the Odyssey, written by Homer. We will read about the people of Iron Age in the next unit.

SAQ 6

Tick mark, in the boxes provided, the three factors among the following, that led to the decline of Bronze Age Civilisation.

a) The emergence of two distinct groups of the producers and the appropriators. ☐

b) Rise and fall of several cities. ☐

c) Invasions by nomadic barbarians. ☐
d) Overthrow of one dynasty of priest-kings by another. ☐
e) Increase in population, leading to a pressure on cities. ☐

2.4 SUMMARY

You have just finished studying the history of science in two major epochs, the Stone Age and the Bronze Age. In this unit, we have tried to trace the origins of science in the primitive human society, and the birth and growth of science in the early human civilisations. These two epochs span a period of more than 100,000 years of human history. We will now summarise what we have learnt in this unit.

- The origins of science can be found in the attempts of the early human beings to meet their basic needs of food, shelter and clothing, which led to the development of primitive tools and techniques.
- Language arose basically from their need to communicate better. Several rituals and magic rites also came into being in the primitive society.
- Increasing population and certain climatic changes forced the primitive human beings to look for other methods of production.
- Agriculture enabled them to control and manipulate nature to satisfy their needs. Cities came into being. The needs of growing cities led to a spurt in scientific and technical activity adding to their fund of knowledge. The new techniques, in turn, led to better means of production.
- The unequal distribution of the produce resulted in the rise of a dominant group of priest-kings, 'the thinkers' who isolated themselves from farmers and urban craftsmen, 'the doers'. In the attempt of the priest-kings to consolidate their power, the gulf between the two increased, leading to stagnation in society and in science. Barbarian invasions further weakened the city states.

2.5 TERMINAL QUESTIONS

1) Give short answers in about four or five lines.

   a) Which primitive practice reflects the features of designing and planning that characterise modern science?

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   b) How did the use of clothing and domestication of animals affect the primitive society?

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2) Fill in the blanks to indicate, which among the following factors gave rise to the ideas of 'spirits', religion and magic rites/rituals.

   a) The primitive human beings were unable to control natural calamities such as floods, fires etc. They also could not understand why people died. They attributed this to ....

b) Techniques were not sufficiently developed to provide enough food for all. It was thought that animals and plants would yield more food if the tribals danced around them or offered sacrifices. This, among other things, resulted in ....

c) When man felt helpless in controlling nature for his needs and tried to come to terms with nature, he took recourse to ....

3) Give short answers, in three or four lines, to the questions given below :

i) The transition from the primitive society to an agriculture based society was brought about by a change in the methods of production. Cities came into existence and the socio-economic needs of those times led to advances in science and techniques.

a) What were the different methods of production used by the primitive society and the Bronze Age Civilisation?

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b) List the socio-economic needs that led to the advances in techniques in the early phase of the growth of cities.

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c) In what ways were these needs fulfilled by the technical advances of those times?

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ii) The growth of cities and the technical advances eventually led to the formation of two distinct groups—the producers and the appropriators.

d) What was the difference between the two groups?

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e) From the list given in the margin, select the people who were producers and those who were appropriators, and put them in the table given below :

	Producers	Appropriators
agriculturists priests masons carpenters administrators		

	Producers	Appropriators
wheel wrights makers of agricultural tools kings		

f) List the aspects of science discussed in Unit 1, that the above statements (i) and (ii), and your answers to the questions (a) to (e) illustrate.

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2.6 ANSWERS

Self Assessment Questions

1) (i) Physics, Technology (ii) Chemistry (iii) Physics (iv) Chemistry (v) Chemistry (vi) Technology.

2) (i) √ (ii) √ (iii) × (iv) √ (v) ×

3) (i) a, b, e, h (ii) b, c, f, i, j (iii) d, g.

4) Stone Age, food, nature, dependent, calamities, cold, different, primitive.

5) ii) Standardisation of numbers, measures and weights; use of balance; arithmetic; writing.

   iii) Ideas of right angle, straight line, rectangle, areas of figures, volumes of solids, laid the basis for the birth of geometry.

   iv) Need for navigation on high seas, making of calendars, planning agriculture on a large scale, preparing for floods etc.

   v) Treatment of wounds, fractures, dislocations etc.; diagnosis of diseases.

   vi) Chemistry.

6) (a), (c), (e).

Terminal Questions

1) a) The tool maker first thought of what tool he was going to make (design) and how he was going to do it (plan). Then he took a large chunk of stone and shaped it accordingly.

   b) The use of clothing enabled primitive human beings to withstand cold weather. The domestication of animals increased their mobility and also the availability of food. Thus, the primitive society could hope to survive even in adverse conditions.

2) (a) spirits (b) magic rites/rituals (c) religion

3) a) Food gathering and hunting in the primitive society; agriculture, masonry, carpentry and other crafts in the Bronze Age Civilisation.

   b) The needs for having better tools for agriculture, houses for shelter, pottery for storage, carts and boats for transport and trade, planned layout etc. in growing cities, led to the advances in techniques.

   c) By the technical advances in pottery, metal-working, masonry, carpentry, brick-working, boat-making, stone-working etc.

d) The producers like farmers, masons, wheel wrights, carpenters etc. were themselves involved in the production of goods; the appropriators did not produce goods themselves, they cornered other people's produce.

e) Producers : agriculturists, masons, carpenters, wheel wrights, makers of agricultural tools.

   Appropriators : priests, administrators, kings.

f) We are listing the aspects from Unit 1 alongwith reference to the pages where these occur, against each statement.

   i) When methods of production evolve societies transform (p. 16). In a society at a given time, the social and economic needs give rise to scientific and technical advances (p. 10).

   a) The major historical epochs correspond to different methods of production (p.15).

   b) Same as the second half of answer at (i).

   c) The development of science and techniques leads to an increase in production of goods and creates a degree of satisfaction among its members (p. 16).

   ii) (d), (e) The innovations in science and technique are gradually used by dominant social forces to strengthen their domination (p. 10).