UNIT 13 EVOLUTION OF MAN

Structure

13.1 INTRODUCTION

In the previous unit, we discussed how the first primitive organisms arose within a few hundred million years of the planet becoming cool enough to support life. In the present unit, we would discuss the theory of evolution. We would particularly lay emphasis on the evolution of man; many of whose characteristics, such as very high degree of intelligence, upright walking and marked sociability, distinguish him from other mammals like monkeys and apes.

Here, we have tried to reconstruct the origin of man by putting together the traditional study of fossils, the study of mankind, especially of its societies, customs and structure or what we call anthropology and the evolution of man as an animal through studies of cellular and biological macro-molecules.

Objectives

After you have studied this unit, you should be able to:

- describe Darwin's theory of evolution through natural selection,
- list various stages of human evolution,
- state evidences from different sources for the processes of human evolution like palaeontology, archaeology, anthropology and biochemistry,
- explain how the age of fossils of plants and animals etc. is determined.

13.2 THEORIES OF EVOLUTION

Towards the beginning of the nineteenth century, scientists had already started doubting the theory of special creation and various attempts were made to explain how different life forms could have evolved. Lamarck, a French naturalist (Fig. 13.1), for instance, believed that all living things adapted to their environment, by using and developing their organs and characteristics that suit their environment best. If environment changed, their organs too changed accordingly to suit the needs and these changes were passed on from one generation to another.

Accordingly, as the giraffe lived in an environment of high trees and had to stretch its neck to eat the leaves, its neck became long and this trait was inherited by its descendants. This theory has won little support with the scientists. As we can see, there is no evidence that a dog trained to do certain things would pass on the ability to the next generation, or a scientist's skill is passed on to his children.

Fig. 13.1: Lamarck was a French naturalist and predecessor (1744-1829) of Darwin. Lamarck believed in evolutionary change, but thought that such changes were brought on as an animal struggled to adapt to its environment, and then these changes were passed on by inheritance.

13.2.1 Darwin and Natural Selection

The English naturalist Charles Darwin (1809-1882, Fig. 13.2) explained how biological evolution took place, in his remarkable **"The Origin of Species"** in 1859. Darwin began his observations at the age of 22, as a naturalist on H.M.S. Beagle, which was a sail ship (Fig. 13.3) going round the world. He spent five adventurous years on the voyage. During this period, he visited may islands of the Atlantic Ocean, some parts of the coasts of South America, and some islands of the South Pacific, of which the Galapagos is the most important. This journey gave Darwin a prolonged exposure to an area of the world, radically different in its plant and animal life from his native place. He collected and preserved a lot of material and took extensive notes throughout the voyage.

Fig. 13.2: Charles Darwin: his active pursuit of varied scientific interests brought him fame in 1859 as the author of the "Origin of Species".

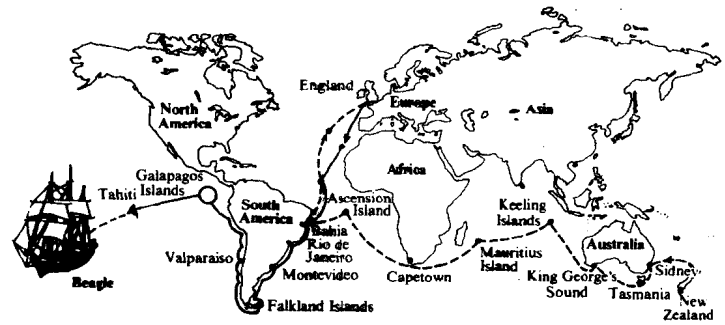


Fig. 13.3: Route of H.M.S. Beagle surveying trip around the world (1831-1836). Dashed lines indicate the return journey of Charles Darwin.

Once back in England, he spent nearly 22 years examining his collection and pondering over the question of how evolution of species could have taken place. He drew the evidence from three important areas: the record of the rocks, in which he discovered fossils and imprints of creatures of the past ages; the distribution of animals and plants in the world; and finally from the study of the breeding experiments that were going on in the nineteenth century to improve life stock or to breed dogs and pigeons.

Darwin's great innovative step was to introduce the theory of 'natural selection' as the mechanism for evolution. Though the credit for giving this theory is generally given to Darwin, another English naturalist—Alfred Russel Wallace had conceived the theory of evolution independently at the same time. The work of the two scientists was presented jointly at the meeting of the Linnean Society in London in 1858. The theory began with two observations. First, more organisms are born than can survive to reproduce themselves, because the environment has limited means of subsistence. This overproduction results in a struggle for existence and ultimate survival of the fittest. Plant and animal species compete within and among themselves for food, water, air, light—everything that enables organisms to survive and reproduce. The second observation is that offsprings, i.e. children differ slightly from their parents and from each other in characteristics which they inherit. This we now call genetic variation. Darwin held the view that these variations are a source of evolutionary change. According to him in any group, individuals with characteristics which enable them to adapt best to their environment survive and reproduce, while those who lack these characteristics have a poor chance of survival. Thus, Nature selects and preserves the useful variations in a changing environment, Darwin called this natural selection.

Darwin's theory of evolution through natural selection is a scientific theory. Darwin developed it taking into account his own observations as well as the other existing information. Through his analysis, he not only postulated the theory of evolution, but was able to give us a mechanism for evolutionary change. However, like all scientific theories, Darwin's theory of evolution through natural selection has been enriched and extended as more facts have been discovered about living beings.

In his own time, Darwin's Theory of biological evolution was unacceptable to most people, especially the Church; as it spoke against special creation. In fact, Darwin was very severely criticised for his views. However, he got support from scientific circles. The debate went on for quite a few years, and continues even today between the men of science and those of religion.

13.2.2 Human Evolution

Charles Darwin in the 'Origin of Species' gave a mechanism for the evolution of plants and animals in general, even though he had speculated about the origin of man. Four years later, he published the "Descent of Man", in which he speculated that like other animals, man too had evolved form pre-existing living forms.

Darwin was greatly impressed by the similarities in the bodily structure of man and the great African apes, the Chimpanzee and the Gorilla. From this, he speculated on the location of man's origins. In his own words, "In each great region of the world, the living mammals are closely related to the extinct species of the same region. It is, therefore, probable that Africa was formerly inhabited by extinct apes, closely allied to the gorilla and chimpanzee; and as these two species are now man's nearest allies, it is somewhat more than probable, that our early ancestors lived on the African continent than elsewhere".

Darwin had noted that embryos, i.e. early unborn young ones, of different organisms pass through very similar stages (Fig. 13.4). However, small alterations in the timings of events in early development might produce a substantial change in the mature organism; for example in many ways adult humans are like juvenile apes, their small faces and globular cranium bones enclosing the brain are indicative of this. A crucial step in human evolution, enlargement of the brain, can be seen as a result of the slowing down of development in the embryo of an ape-like ancestor. Instead of stopping at birth, brain growth continues well into childhood, eventually producing a much larger and more complicated piece of mental machinery.

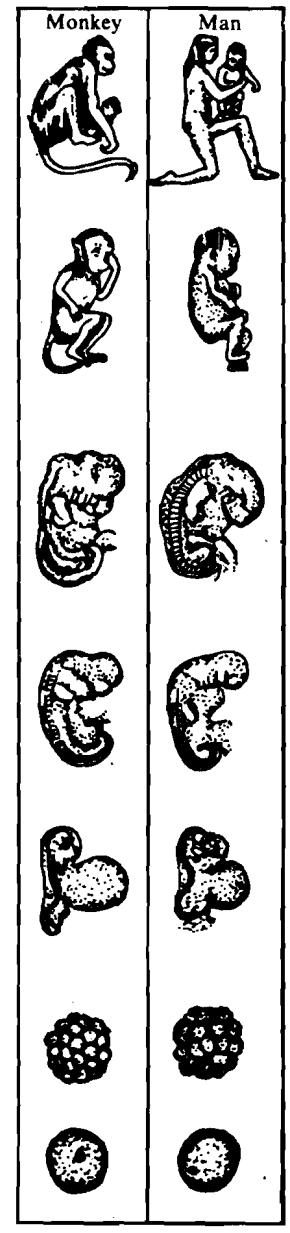


Fig. 13.4: Similarities between monkeys and man during embryonic development

13.2.3 Primate Heritage

Man belongs to a group of animals called mammals which are different from other animal groups in possessing hair, and milk producing mammary glands, among other things. Mammals can be further divided into smaller groups or 'orders' on the basis of differences within the group. 'Primates', the order to which man belongs, alongwith apes and monkeys, were active during the night, that is, they were nocturnal in the beginning of their evolution. These animals were insect-eaters and lived on trees (Fig. 13.5). This combination of feeding on insects, while being suspended on branches and

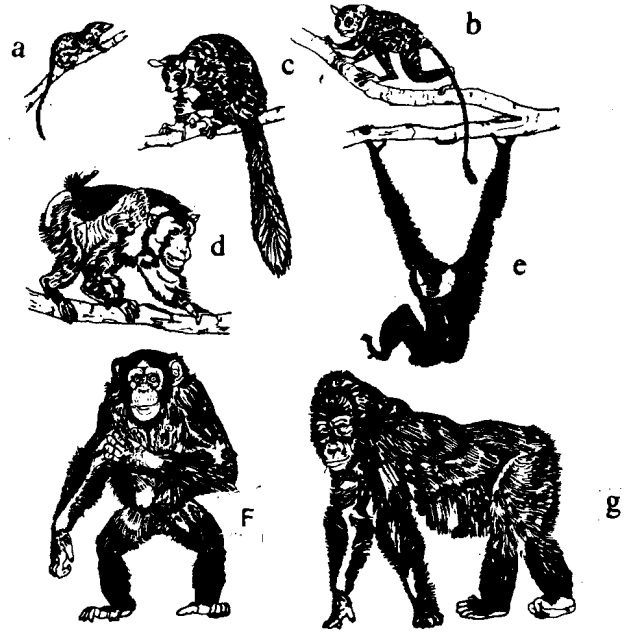
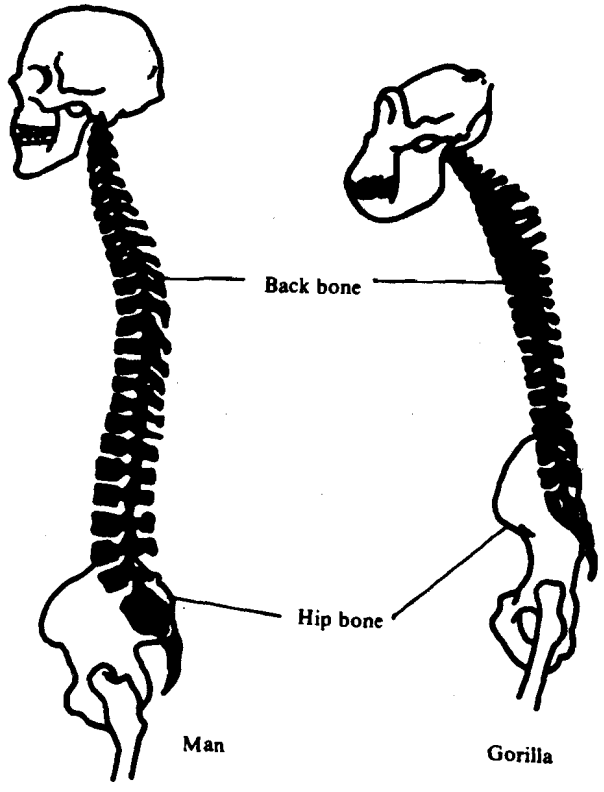


Fig. 13.5: A tree shrew (a) and some representatives of modern primates lemur (b) tarsier (c) macaque monkey (d) gibbon (e) chimpanzee (f) Gorilla (g)

twigs, led the primates to develop some important adaptations. The hand, underwent several changes. The thumb became opposable, that is, it closes to meet the finger tips which aided in holding the prey. Sensitive fingers developed, having nails rather than claws. Eye sockets were shifted to the front of the head, providing the primates a better vision and keen ability for judging distance.

These striking adaptations in the primates gave rise to large sized forms, which adopted a diurnal life style, i.e. they were active during the day. Their diet included plant food like leaves and fruits. The origin of monkeys and apes took these adaptations to even higher levels. Possession of sensitive finger tips became of even greater importance, as the ripeness of fruits could be judged better by touch than by sight.

Apes move beneath the branches, suspended by long agile arms rather than walking along them (Fig. 13.5 (e)). This involves a relatively upright posture, and their hips became a part of this kind of movement. Even when they move on the ground, apes occasionally walk as bipeds, i.e., on two feet. It may be an awkward walk with short steps and swaying motion, but it is two footed nonetheless. Changes in the skull and backbone help in the upright posture (Fig. 13.6). And the way the heart, lungs and other body organs are suspended in the abdomen differs from that of conventionally four footed animals.



Fig, 13.6: Comparison of skull, back bone and hip bone of man and gorilla.

SAQ 1

a) Indicate whether the following statements are true (T) or false (F).
   i) Lamarck noted that embryos of different organisms pass through very similar stages and as such seem to indicate that like other life forms, man too could have descended from the animals like monkeys and apes. ( )
   ii) The need for a keen ability for judging distance, produced relocation of the eye sockets in early primates to the front of the head. ( )

b) Give very brief answers to the following questions in the space provided.
   i) What sort of informations were collected by Darwin during his voyage on H.M.S. Beagle?

.....

ii) How can mammals be distinguished from other animals?

.....

iii) Which animals were insect eaters?

.....

iv) Name the mammals that move beneath the branches of trees.

.....

13.3 EVIDENCES OF HUMAN EVOLUTION

We have described above, the various adaptations associated with bipedal locomotion in the early primates. Many more changes were yet to take place before the first human forms were to emerge. You may like to know, what were these various changes, what evidences we have in support of the evolution of modern man—**'Homo sepiens'**. You would appreciate that, whenever a theory is postulated, we look for evidences which support that line of thinking. This is true for the general theory of evolution and also for the evolution of our own species. Let us try to reconstruct this theory from the evidences that are provided from different sources, such as the fossil records of animals which lived in the past, similarities found in the developing embryos of primates and of other animals about which we have talked above, the archaeological remains of the past and their dating and more recently from biochemical studies. Cave paintings and other artefacts left by the early human beings speak of their social and cultural life.

13.3.1 Palaeontological Evidence

Palaeontology is a branch of earth sciences, which is essentially a study of plant and animal life in the past geological periods, millions of years ago. It deals with the successive plants and animals which have inhabited the earth since the earliest times. Evidence of their existence is left in the form of skeletons and bones buried in the rocks. These are known as fossils. Crucial evidence of human evolution is provided by the study of these fossils.

Sometimes, the buried body and the skeleton of an animal disintegrate entirely. If the surrounding material is sufficiently firm, a cavity may remain, having the exact outlines of the structures that disappeared. Such a cavity is called **mold**, Similar to molds are the **impressions**. These are left by extinct objects or parts of the body upon the surrounding material. The impression is made while the surrounding material is soft, like footprints in clay or lava. Footprints of extinct animals are also impressions affording valuable information about the animals that made them.

It is important to mention here, that early human fossils that have been found are generally fragmentary and incomplete. This is because only during the last 50,000 years or so, man started burying his dead. These later fossils are better preserved and, therefore, give us more information. For the earlier period, parts of bones are often the basis of imagining the re-construction of the whole skeleton. The finding of fossils deposits is both a matter of chance and of deliberate excavation in certain regions of the earth.

The First Hominids: The First Human Fossil

The earliest human like or hominid (Fig. 13.7) remains come from two separate East African sites. Ethiopia has yielded several hundred fossil fragments of individuals that lived and died between 3.0 and 3.6 million years ago. The second site is in Tanzania where three hominids left a 20m trail of footprints some 3.75 million years ago. It is concluded that these earliest hominids were built with an ape's head on top of a man-like body. They show hominid characteristics to place them firmly within human ancestry. There is evidence that they walked on two feet. However, enough primitive features still remained, so as to put them close to an ape-like ancestor with tree climbing habits.

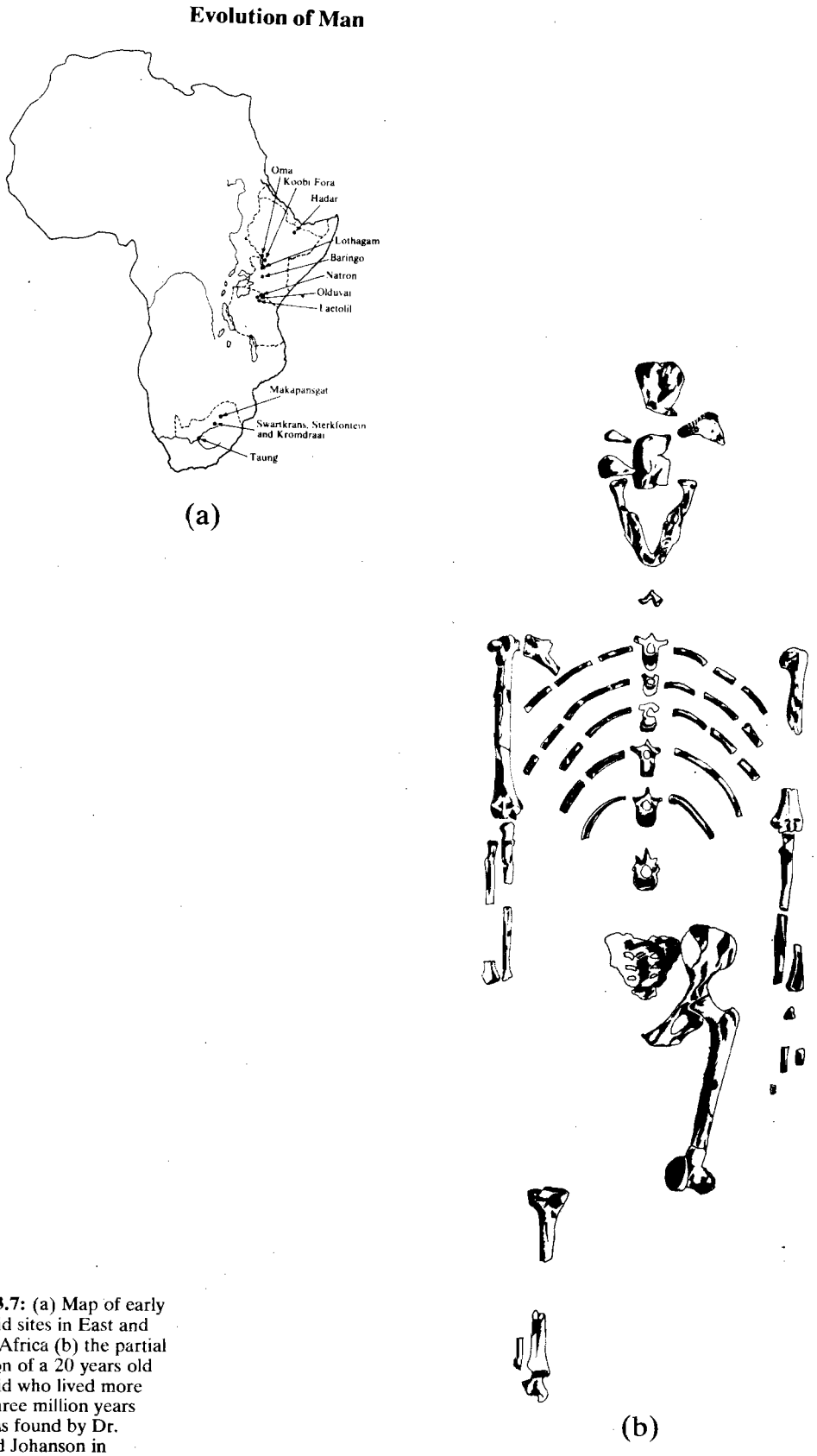


Fig. 13.7: (a) Map of early hominid sites in East and South Africa (b) the partial skeleton of a 20 years old hominid who lived more than three million years ago was found by Dr. Donald Johanson in Ethiopia. The fossil remains, are known as 'Lucy'.

Australopithecus—The Transitional Human Forms

By about two million years ago, there were several well established hominid ancestors in Africa. One of the earliest of these is Australopithecus (Fig. 13.8). Fossils of Australopithecus, which have been recovered from South and East Africa, show that their brains were relatively small, the bones enclosing the brain, therefore, were rather ape like, but the face was shorter than in apes. The enamel of the teeth indicated that Australopithecus ate essentially fruits. The evidence for two-footed posture in Australopithecus is strong as the back bone shows the typical hominid curvature. Also the hip bone, which is the skeletal frame to which the legs are attached is shorter than in apes, although it is not as short as in modern humans.

Homo Habilis—The First Tool Makers

One of the most important developments in human evolution was the dramatic expansion in brain size which, according to the fossil data available so far, began about two million years ago. Certain specimens recovered from deposits in East Africa apparently have brain capacities in excess of 650 cm^3 and close to 800 cm^3. These specimens were taken to represent the first appearance of our own kind and were termed **Homo habilis**. The species name **Homo habilis**, means, literally, handy man. **Homo habilis** walked upright. The bones of the hand, while displaying many characteristics of modern humans, are somewhat curved in places and more robust than in modern man, i.e. **Homo sapiens**. The leg and foot bones have characteristics that are both ape-like and human-like, but overall, they are much closer to those of modern humans than to apes. The leg and foot were those of a habitual two-footed animal. The simultaneous occurrence of **Homo habilis** fossils and crude flakes and stone tools indicate that they used tools. There is no evidence that this early form of homonids ate meat.

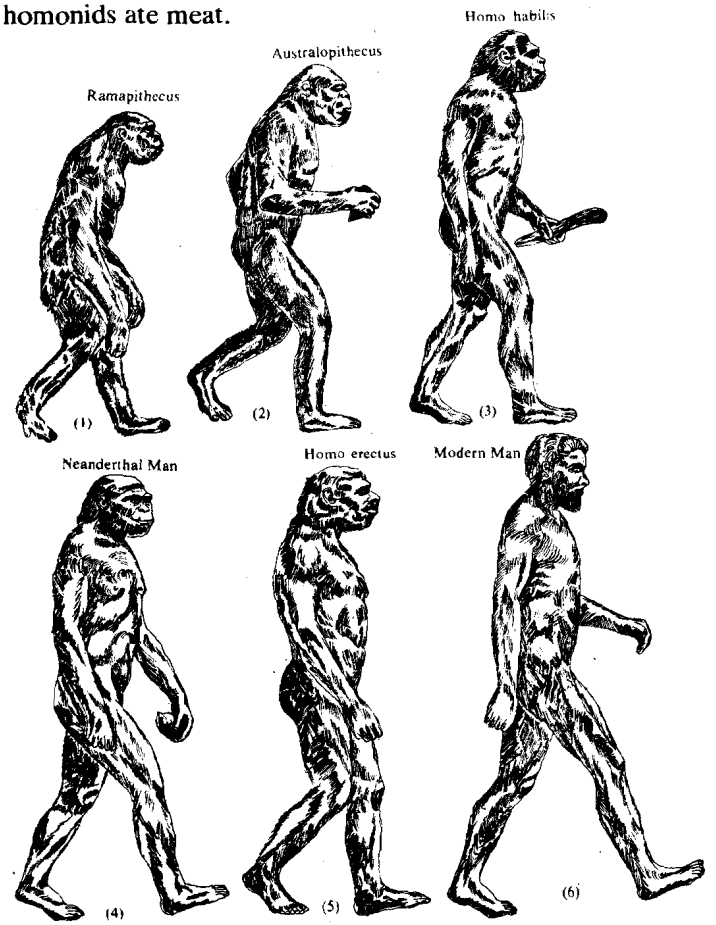


Fig. 13.8: Artist's reconstruction of the appearance of the Early Man.

Homo Erectus

Homo erectus or the erect man first arose at least 1.6 million years ago and continued to live for more than a million years before the transition to **Homo sapiens** occured. **Homo erectus** had a large brain (Fig. 13.9) measuring 800 to 900 cm^3. Fossils of **Homo erectus** have been discovered throughout Africa, Europe and Asia. Signs that **Homo erectus** hunted animals and ate meat, are available from the stone tools he used and the marks which these tools left on the bones of animals which have been recovered near their own dwelling areas.

There is evidence, that the life of **Homo erectus** must have been fairly complex; placing great demands on these individuals as intelligent, socially interacting beings. One can even imagine that a relatively complex spoken language may have evolved. The prehistoric record is, of course, silent on this point.

The Neanderthals

These were the first human like fossils found. The Neanderthals existed throughout western Europe and across into the near east and central Asia from about 100,000 years ago to 40,000 or 35,000 years ago, depending on the precise locality. There are, striking structural distinctions between Neanderthals and modern humans. Although, the posture, range of movements and manipulation skills were the same in Neanderthals as in modern humans, the skeleton was substantially more robust. Neanderthal's brain (Fig. 13.9) was on average slightly larger than normal for modern humans, measuring about 1400 cm^3. The large brain size could be corresponding to the more robust musculature. Neanderthals (Fig. 13.8) were proficient hunters, skilled tool makers and they used hides for protecting their bodies. For the first time in human history, ritual burial became common.

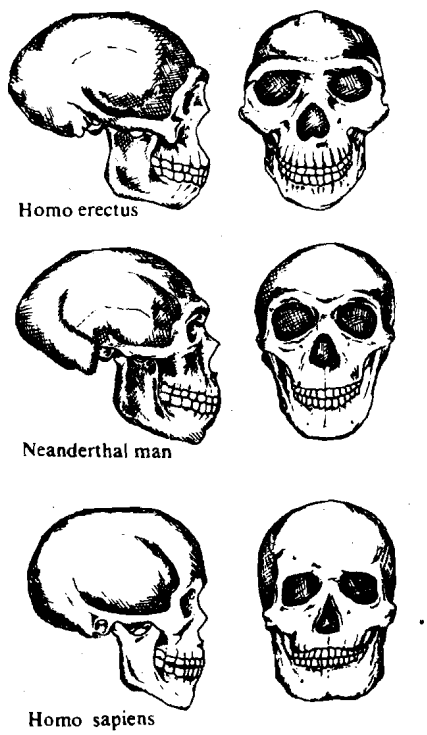


Fig. 13.9: Comparison of Neanderthal man with *Homo erectus* and *Homo sapiens* shows it to have some features of both. The very large brain of the Neanderthals, which slightly exceeds that of Homo sapiens is seen as a modern feature.

Homo Sapiens—Modern Human Beings

Discoveries of number of fossils of **Homo sapiens** suggest that modern humans (Figs. 13.8, 13.9) arose in Africa and migrated to the rest of the old world via the Middle East. It should be noted that these modern humans of the early upper stone age, 40,000 years ago, were distinctly more robust or sturdy as compared with the population today.

13.3.2 Archaeological Evidence

The study of human antiquities, especially of prehistoric period is known as archaeology. The biological and cultural evolution of man proceeded side by side and the two influenced each other. Like the physical remains of man, his cultural remains also lie buried in the ancient deposits. Often, the two categories of evidence are found together in the same layers of the rock. With the passage of time, and the increasing capacity of his brain and development in other bodily organs, man's culture became more and more varied and complex. He learnt the use of new materials for making tools and developed new techniques for improving them. The use of tools had a

tremendous impact on increased access to food and therefore on cooperative living in colonies. In many areas, archaeological remains show reindeer to be the principal source of meat they ate.

13.3.3 Anthropological Evidence

Modern humans arose at a time when the Earth was going through a very cold and icy period called the Ice Age, which began about 75,000 years ago and ended about 10,000 years ago. The Ice Age was at its most severe about 18,000 years ago, a point which coincides with the development of prehistoric art, represented by colourful images painted on cave walls and rock shelters, Many thousands of carved and engraved pieces of bone and ivory have been discovered from the same period. A great majority of images are, indeed, of animals we can recognize, especially images of reindeer and bisons are plentiful; while paintings of people are strangely absent.

The general view about agriculture is that, at the end of the last Ice Age, i.e. about 10,000 years ago, there was a dramatic global shift in the human pattern of living from nomadic hunting and food gathering to settlements producing food. The discovery that sprinkling of grain could lead to crops and hence to lot of food, must have had a big impact on social living. Settled living probably led to increase of population, as also to development of music and dance to occupy the leisure. Language and communication must have developed, as also a capacity to wonder and to reflect about nature.

13.3.4 Biochemical Evidence

As we had said earlier in section 13.2, Darwin had recognized that humans and the great apes shared many physical characteristics. This led him to conclude, that humans and apes descended from a common stock. Darwin's conclusions were based on the study of fossils and the physical similarities that he had observed. Now, a century later biochemical studies of proteins and the genetic material—DNA show how good his guess was.

Biochemical studies show us that, as evolution proceeds and the species get differentiated, they accumulate changes in the structure of their proteins and DNA. Longer the separation time, greater the changes. These changes are expressed in terms of percent genetic distance which indicates the proportional difference between the DNA of the two species. Comparative studies of the proteins of the African apes and humans showed that chimpanzees, gorillas and humans are closely related to one another, while the Asian apes, i.e. the gibbon and orangutan were the more distant cousins of this trio (Fig. 13.10).

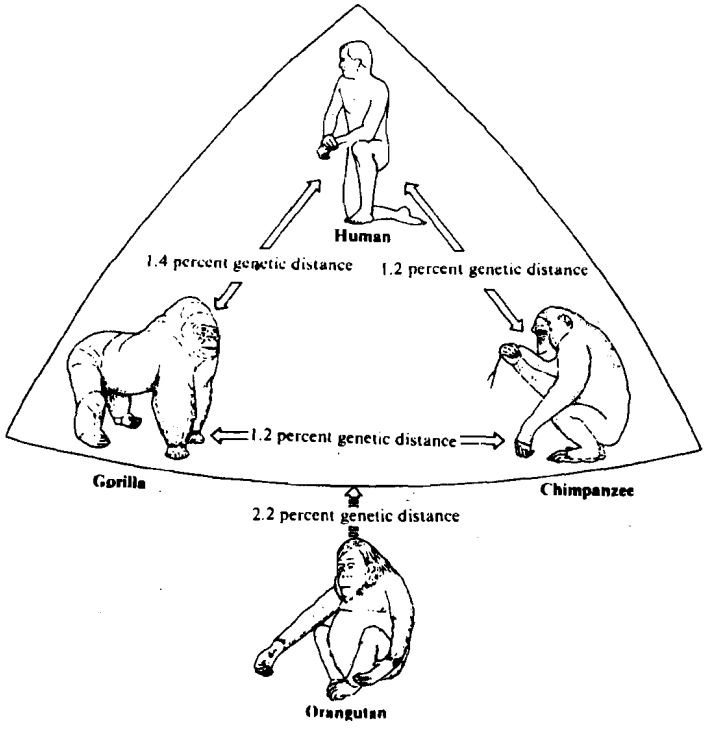


Fig. 13.10: A chart to show hereditary distance between humans and the apes.

Once the Asian and African apes were considered to be closely related and it was thought that the hominids developed from apes prior to 15 million years ago. Biochemical evidence, however, indicates that the ape-human divergence may have been much closer to five million years and that the gorilla split off first, leaving the chimpanzees and the human-like creatures to share a common ancestor briefly before separating. **Ramapithecus** (Fig. 13.8)—a fossil specimen found in Asia, Europe and Africa was at one time thought to be closely related to the species of modern man. However, on the basis of biochemical evidence, it has now been shown that it cannot be considered a homonid, because it lived before the Asian apes diverged from hominids. Same is true for **Sivapithecus indicus,** a fine fossil specimen of which was discovered in 1980 from the foothills of the western Himalayas in Pakistan.

SAQ 2

Match the type of evidence given in favour of evolution in column 1 with the statement given in column 2.

1		2
Biochemical	i)	With the passage of time and the increasing capacity of man's brain and development in other bodily organs, his culture became more and more varied and complex.
Palaeontological	ii)	The earlier assumption regarding human evolution is supported by chemical studies on the nature of proteins and DNA, which show chimpanzees, gorillas and humans to be closely related to each other.
Anthropological	iii)	'Lucy', a partial fossil skeleton, recovered from a site in Ethiopia showed that bipedal locomotion had already developed to an advanced stage, even though the brain size was modest.
Archaeological	iv)	Thousands of carved and engraved pieces of bone and ivory have been discovered from the prehistoric period.

13.3.5 Dating the Past

You would be wondering how we can tell, today, that a particular rock is a million years old, or a fossil is 50 thousand years old. For instance, how do we estimate the duration of various geological periods on a time scale of billions of years? Initially, such estimates were based on the rate at which geological processes such as depositions of stones and rocks occur. Many layers of rock originated as deposits in the sea and at the mouths of rivers. Therefore, one way to get an idea of the length of time required to produce a deposit of a given thickness, is to measure the rate at which rivers are depositing sediments in the sea today.

With the developing knowledge of radioactivity, more accurate dating of fossils and certain types of rocks has become possible. Radioactive substances can be easily detected using certain instruments. They have built-in "clocks" in the form of 'radioactive isotopes' that change or decay at a constant rate into non-radioactive form. If this rate is known, the length of time since the fossil or the rock was formed can be estimated by measuring the quantities in the rock, of the radioactive isotopes and the non-radioactive ones into which they have changed. For example, Uranium is transformed into certain isotopes of lead which are not radioactive. So, the age of uranium-containing rocks can be determined by comparison of the proportions of undecayed Uranium and that of the corresponding lead isotopes present in the rock, see Fig. 13.11.

The method most commonly used, now, for estimating the age of fossils is radio-carbon dating. Radioactive isotope of carbon is commonly known as carbon-14. Since carbon-14 is chemically the same as ordinary carbon, both are absorbed by plant and animal tissues in the same proportion as they are present in the atmosphere as carbon dioxide. Plants use this carbon dioxide in making their food. Animals eat the plants. Hence, the proportion of carbon-14 in the tissues of plants and animals is the same as in the atmosphere, as long as the plant or the animal is living. But as soon as it dies, no

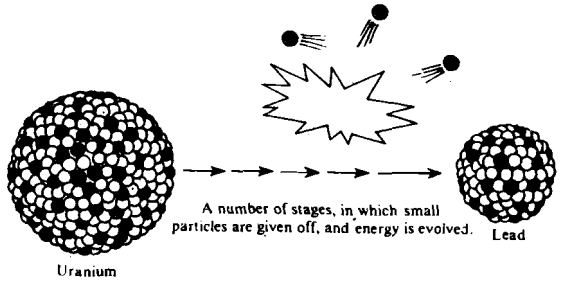


Fig. 13.11: Radioactive atoms have unstable atomic nuclei. When these nuclei break down or decay, they emit characteristic particles or rays. The end result of this radioactive decay is that another kind of atom is formed.

more carbon can enter its body as photosynthesis or food intake stops. Following death, the carbon-14, already present in the body, decays steadily into ordinary carbon. So the smaller the number of carbon-14 atoms remaining, the older is the fossil. Thus, if we take a piece of ancient wood or bone and measure the amount of carbon-14 present in it, we can estimate the age of the material. This technique has been applied to materials of known age, and thus its accuracy was tested giving confidence in the age determinations of unknown samples.

The carbon-14 method is applicable only to organic materials which still contain carbon. It cannot be used for fossils in which all organic matter has decayed. In that case the age of the fossil can be estimated by determining the presence of other radioactive elements like flourine, or phosphorus.

SAQ 3

Complete the following statements.

i) Accurate dating of fossils and certain types of rock is possible with the development of the knowledge of .....

ii) The rate of decay of radioactive isotopes into non-radioactive forms helps in estimating the age of .....

iii) Radio-carbon dating is used for organic materials that still possess .....

iv) Age of the fossil in which all organic matter has decayed is estimated with the help of radioactive isotopes of .....

13.4 SUMMARY

In the present unit you have studied:

- That Darwin's theory of natural selection postulates the survival of the best adapted forms with the inheritance of the distinctive characters in which their fitness lies.
- The evidences from palaeontology, archaeology, anthropology as well as the study of proteins and genetic material of present day apes and human beings indicate a common ancestry till about five million years ago.
- That the age of rocks, fossils and archaeological remains is estimated by measuring the quantities of radioactive and non-radioactive isotopes of different elements.

13.5 TERMINAL QUESTIONS

1 What does Darwin's theory speak about?

.....

.....

2 State the difference between palaeontology and archaeology.

.....

.....

3 How is the age of a fossil determined?

.....

.....

4 How is the age of the remains of ancient plants, animals, men, and their belongings known?

.....

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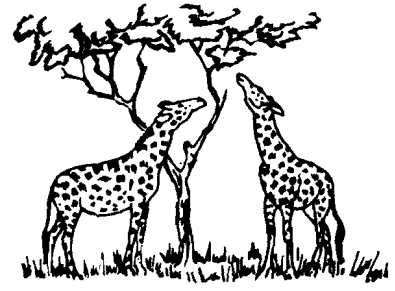
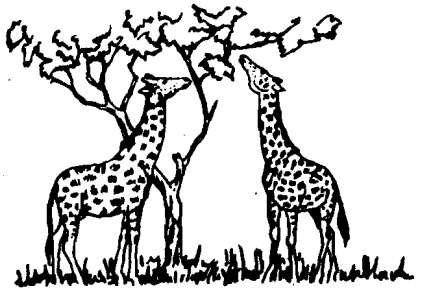
5 Study the diagrams in part (a) and (b) of Fig. 13.12 showing two theories about evolution and give short answers to the following questions.

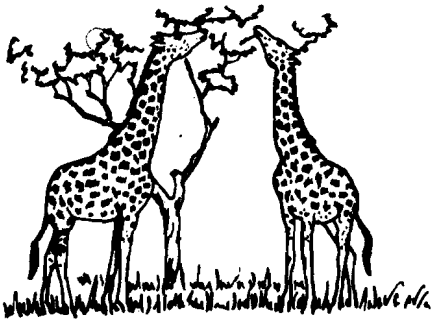
(a)



Early giraffes probably had short necks which they stretched to reach food.

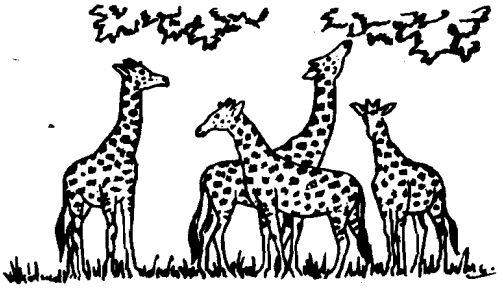


Their offspring had longer necks which they stretched to reach food.

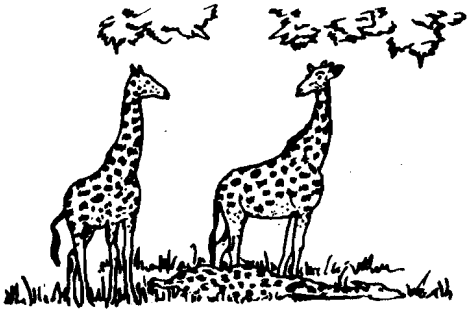


Eventually the continued stretching of the neck resulted in today's giraffe.

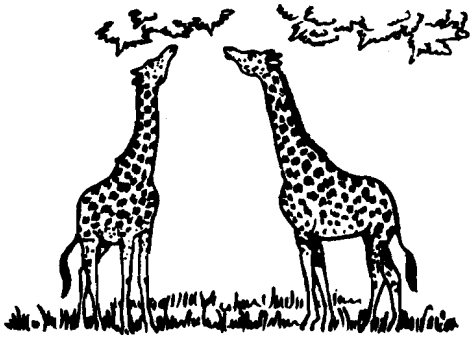
(b)



Early giraffes probably had necks of various lengths.



Competition and natural selection led to survival of the longer-necked giraffes and their offspring.



Eventually only long necked giraffes survived the competition.

i) Name the two scientists who proposed these two theories.
ii) Which of two theories is supported by the current data and evidence about evolution?

13.6 ANSWERS

Self Assessment Questions

1) a) i) False ii) True
   b) i) During his voyage Darwin collected and preserved a variety of plants and animals and took extensive notes on them.
      ii) Mammals have mammary glands and hair on the body while other animals do not possess these characters.
      iii) early primates
      iv) apes
2) i) Archaeological ii) Biochemical iii) Palaeontological iv) Anthropological
3) i) radioactivity ii) fossil iii) carbon iv) flourine or phosphorus

Terminal Questions

1) The survival of the forms best adapted to environment with the inheritance of those distinctive characteristics in which their fitness lies.
2) Palaeontology deals with the fossil remains of prehistoric animals or plants whereas archaeology is the study of human antiquities especially of prehistoric period.
3) The carbon-14 method is applicable to organic materials still containing carbon, it can not be used for fossils in which all organic matter has decayed. Therefore, in case of these fossils, the rate at which flourine becomes incorporated into bones during fossilization is utilized for estimating the age.
4) Age of ancient wood, bone antiques etc. can be determined by using carbon-14.
5) i) a) Lamarck
      b) Darwin
   ii) Only Darwin's theory of natural selection is supported by existing data.

GLOSSARY

asteroid: a small body orbiting the Sun; a minor planet
astrology: a study of the supposed influence of the positions of the Sun, Moon, planets and stars upon human affairs
astronomy: the science which describes objects in space according to their location, motion, size, composition, and appearance
astrophysics: the branch of astronomy that applies the methods and tools of physics to the study of heavenly objects
atom: the smallest particle of an element, which retains its properties
aurora: the display of lights in nature, usually in the polar regions
binary star: a double-star system in which the two stars revolve around each other
biochemistry: chemistry of living organisms
biomolecule: molecules of substances like sugar, fats & proteins present in living organisms.
biped: two-footed animal e.g. man or a bird
black dwarf: thought to be the final stage in the evolution of a white dwarf
black hole: thought to be the final stage in the evolution of a massive star
cell: microscopic unit of living matter enclosing self-producing genes
compound: a substance made up of two or more elements
constellation: a definite region of the sky defined by a group of stars
core: the central portion of a planet or any heavenly body
cosmology: the study of the organisation and structure of the universe and its evolution
cranium: bony part of the head enclosing the brain
crater: a depression in the surface of the Earth, Moon, or other such bodies
crescent: that phase of the Moon, which shows it less than half full
crust: the outer layer of the Earth, Moon, or other such bodies
cybernetics: the science of communication and control in machines and animals
density: the mass of an object divided by its volume
deoxyribo nucleic acid (DNA): complex biomolecules responsible for storing and transfer of genetic material

electromagnetic radiation: a special kind of energy that can propagate through vacuum, like light
electromagnetic spectrum: the full range of electromagnetic radiation
element: simplest substance like oxygen, carbon etc. which cannot be broken down into simpler forms by chemical processes
environment: collective term for the conditions in which an organism lives e.g. temperature, light, water, other organisms
evolution: development of more complicated forms of life (plants and animals) from earlier and simpler forms
focus: the point at which the converging rays of light meet after passing through a lens or a mirror
fossils: recognisable part, trace, or imprint of a prehistoric animal or plant once buried in earth, now hardened like rock
galaxy: a collection of millions to hundreds of billions of stars, and clouds of gas and dust
genetic: the ways in which characteristics are passed on from parents to offspring
gibbous: that phase of the Moon or a planet during which it appears more than half full but less than full
hormone: internal secretion that passes into the blood and stimulates the body organs or endocrine glands
intergalactic: space between the galaxies
interstellar: space between the stars
isotope: atom of an element e.g. heavy hydrogen, having a nuclear mass different from that of other atoms of the same element, although chemically identical
light year: the distance light travels in one year
mass: a measure of the amount of material in an object
molecule: a combination of two or more atoms
nebulae: a cloud of dust in space
nova: a star that suddenly brightens and then fades again
nucleus (of an atom): the central part of the atom, containing protons and neutrons
nucleus (of a cell): body containing the chromosomes present in nearly all cells of plants and animals. It is essential for continued life of most cells
nucleic acids: two complex compounds (DNA, RNA) which occur in all living cells
orbit: a closed path along which a body moves as it revolves around a point in space
organic molecules: molecules which have carbon and hydrogen atoms as their constituents or molecules derived from these.
parallax (stellar): the apparent shift of a star against the background of more distant stars due to the motion of the Earth around the Sun
period (of rotation or revolution): the time taken to complete one rotation or one revolution, respectively
phase (of the Moon or a planet): changes in the portion of their illuminated 'face' is visible from the Earth
photosynthesis: process in which energy of sunlight is used by green plants to build up complex substances, like carbohydrates from carbon dioxide and water
primate: one of the highest order of mammals including men, apes, monkeys and lemurs
primordial: existing at or from the beginning
prism: a solid of glass or other transparent material shaped like a wedge and used to disperse light into its spectrum of seven colours
proteins: body building substances essential to good health, present in such food as milk, egg, meat etc.
protostar: the mass of material in the process of forming a star
pulsar: an object that emits brief pulses of radiowaves; possibly a very rapidly spinning neutron star
quasar: a star-like object at a great distance; it emits huge amounts of energy
radiation: the sending out of energy, heat etc. as waves
radio active substance: atoms of some elements such as radium and uranium break up spontaneously with the emission of radiations or electrically charged particles capable of penetrating even opaque bodies and producing electrical effects
red giant: a very large, cool star
red shift: the shifting of spectral lines towards the red end of the spectrum due to the source moving away from the observer
spores: germ, single celled or many celled body by which plants specially moss, ferns, fungi etc. reproduce themselves

stellar evolution: the life cycle of a star
terrestrial: living on the earth or land
UV-rays (ultra-violet rays): invisible rays having wave lengths shorter than that of violet colour (in sun light, light from mercury vapour lamp, etc.)
wavelength: the distance between two successive crests or two successive troughs of a wave
white dwarf: a very hot, dense, small star
zodiac: a band in the sky containing the twelve constellations usually associated with astrology

FURTHER READING

1 *Cosmos,* Carl Sagan, Ballantine Books, New York, 1985.
2 *Physics, Part I & II, A text book for class X,* NCERT, 1985, Chapter 1.
3 *Essays about the Universe,* Boris A. Vorontsov-Vel'yaminov, Mir Publishers, Moscow, 1985.
4 *Basic Biology, Part II, A Text book for class X* (ed.) by R.N. Kapil, NCERT, 1986.
5 *The Ascent of Man,* J. Bronowski, BBC, London, 1976.
6 *New Guide to Science,* Isaac Asimov, Penguin, 1987.

COURSE CONTENTS

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Unit 30 Modern Development in Science and Technology – II

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